计算机网络实验

实验3：基于UDP服务设计可靠传输协议并编程实现

实验3-1

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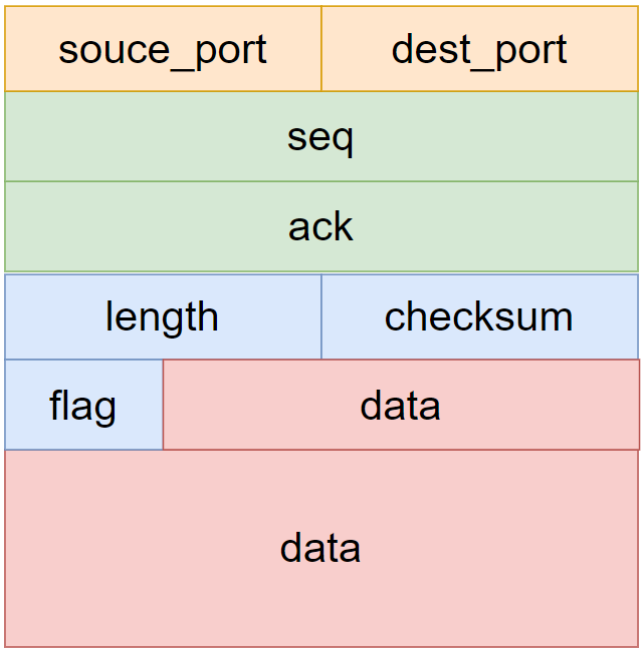
一、实验要求

- 利用数据报套接字在用户空间实现面向连接的可靠数据传输，功能包括：建立连接、差错检测、确认重传等。流量控制采用停等机制，完成给定测试文件的传输
- 数据报套接字：UDP；
- 建立连接：实现类似TCP的握手、挥手功能；
- 差错检测：计算校验和；
- 确认重传：rdt2.0、rdt2.1、rdt2.2、rdt3.0等，亦可自行设计协议；
- 单向传输：发送端、接收端；
- 有必要日志输出

二、协议设计

（一）报文结构



1. 对于报文的设计，含有2字节的源端口，2字节的目标端口，4字节的seq，4字节的ack，2字节的长度，2字节的校验和，1字节的标志，若干字节数据。

长度为传输报文时，记录当前报文所传输数据的有效字节数。

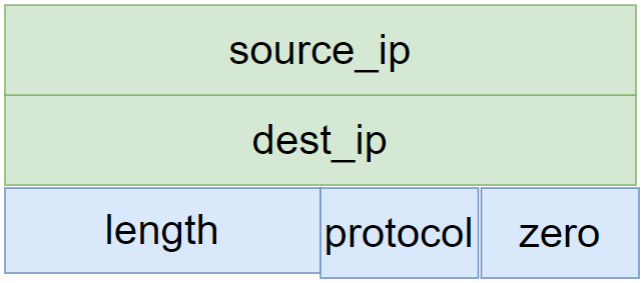
2. 对于标志位：

从低到高分别为ACK，SYN，FIN和END。其中END为在传输文件结束后发送报文的标志位。

（二）校验和计算和验证

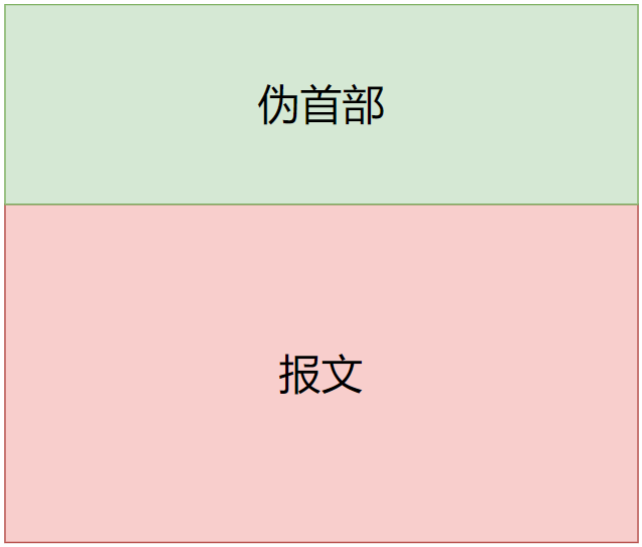
(1)伪首部

首先生成伪首部，伪首部结构如下：



分别为源ip，目标ip，长度，版本号和填充0。

(2)计算校验和




```
void setChecksum(msg* message, pseudoHead* ph) {
    //设为0
    message->checksum = 0;
    int sum = 0;
    int len_pseudo = sizeof(pseudoHead);
    int len_msg = sizeof(msg);
    for (int i = 0; i < len_pseudo / 2; i++) {
        sum += ((WORD*)ph)[i];
    }
    for (int i = 0; i < len_msg / 2; i++) {
        sum += ((WORD*)message)[i];
    }
    while (sum >> 16) {
        sum = (sum & 0xffff) + (sum >> 16);
    }
    message->checksum = ~sum;

};
```

设置校验和的时候，计算伪首部和报文的16位和，取反。

(3)验证校验和

```
bool verfiyChecksum(msg* message, pseudoHead* ph) {

    int sum = 0;
    int len_pseudo = sizeof(pseudoHead);
    int len_msg = sizeof(msg);
    for (int i = 0; i < len_pseudo / 2; i++) {
        sum += ((WORD*)ph)[i];
    }
    for (int i = 0; i < len_msg / 2; i++) {
        sum += ((WORD*)message)[i];
    }
    while (sum >> 16) {
        sum = (sum & 0xffff) + (sum >> 16);
    }
    return sum == 0xffff;
};
```

验证校验和，将生成伪首部，计算伪首部和接收到的报文的16位和，如结果为0xffff，则验证正确。

（三） 三次握手

对于三次握手

(1) 客户端:

1. 发送同步报文，标记位为SYN,seq=0,ack=0;
2. 开始计时，接收服务器报文，若超时则重传同步报文。
3. 判断接收的报文是否为：标志位（SYN，ACK），seq=0，ack=1。若是发送报文：标志位（ACK），seq=1，ack=1。否则返回退出。

(2) 服务器:

1. 阻塞，接收客户端报文，如果是SYN,seq=0,ack=0。发送报文:标志位（SYN，ACK），seq=0，ack=1；否则循环继续等待接收报文。
2. 非阻塞，开始计时，接收客户端报文，若超时则重传同步报文。
3. 判断接收的报文是否为：标志位（ACK），seq=1，ack=1。若是，建联成功。否则返回退出。

（四）四次挥手

对于四次挥手

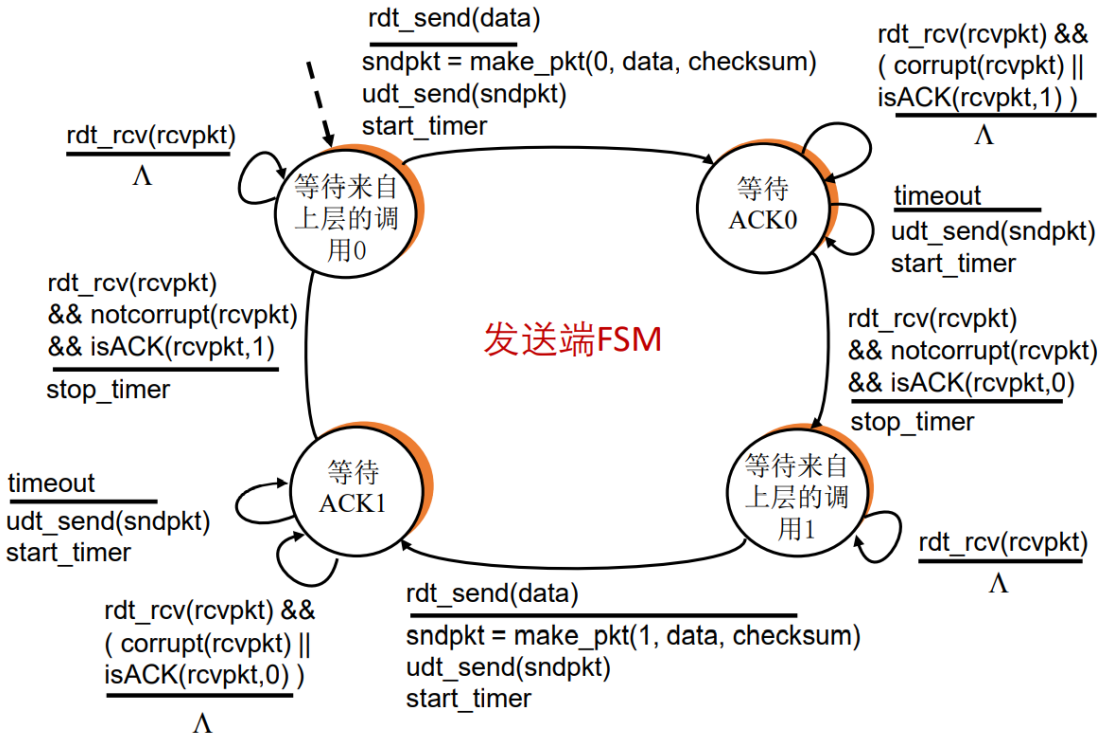
(1) 客户端:

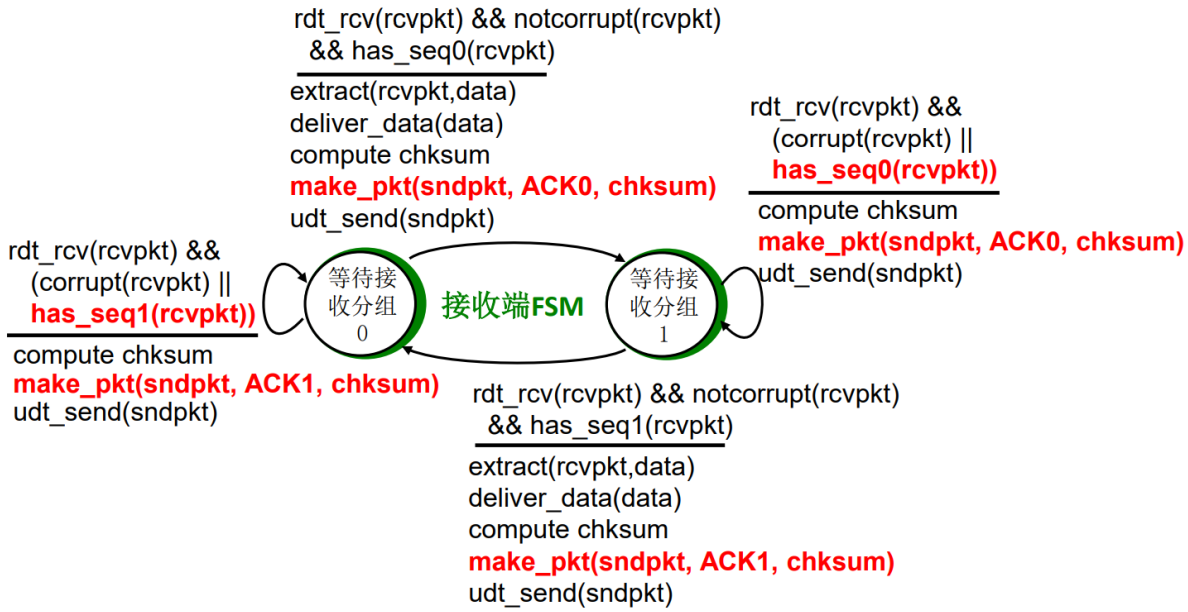
1. 发送结束报文，标记位为FIN。
2. 开始计时，接收服务器报文，若超时则重传报文。
3. 判断接收的报文是否为：标志位（FIN，ACK）。否则继续接收。
4. 阻塞，接收报文，判断是否为：标志位（FIN）。若是，发送报文，标志位（FIN，ACK）。否则继续接收。
5. 等待2msl，如果收到服务器的FIN报文，重传确定报文。
6. 返回退出。

(2) 服务器:

1. 阻塞，接收客户端报文，如果是FIN。发送报文:标志位（FIN，ACK）；否则循环继续等待接收报文。
2. 无要传输的数据，发送FIN报文。
3. 非阻塞，超时重传FIn报文。判断接收的报文是否为(FIN,ACK)，如是断开连接。

（五）可靠数据传输 rdt3.0





单向传输的rdt3.0。维持两个seq号。

由于三次握手的时候使用了0和1.所以将此处的两个seq号设为2和3。

总体来说，客户端在发送完一个seq号的数据后进入该seq号的确定状态。如果超时则重发数据包。或者收到另一个seq的确定后维持状态不变。

而服务器端在收到当前状态的正确seq号的时候会发送该seq号的ack，转换状态。若收到的seq号为另一状态或损坏，则发送其状态的ack。以希望让客户端进入发送下一seq的状态。

三、代码实现

（一）初始化

以下分别为客户端和服务器的初始化。

客户端：

```
void init() {

    //Startup
    WSADATA wsadata;
    WORD version;
    version = MAKEWORD(2, 2);
    int result_start;
    result_start = WSAStartup(version, &wsadata);

    if (result_start != 0) {
        cout << "Startup failed" << endl;
        return;
    }

    //client and server  addr

    addr_client.sin_port = htons(port_client);                  //port
    addr_client.sin_addr.S_un.S_addr = inet_addr(ip_client); //ip addr
    addr_client.sin_family = AF_INET;

    addr_server.sin_port = htons(port_route);
    addr_server.sin_addr.S_un.S_addr = inet_addr(ip_route);
    addr_server.sin_family = AF_INET;
    //creat socket
    sockClient = socket(AF_INET, SOCK_DGRAM, 0);
    if (sockClient == INVALID_SOCKET) {
        cout << "socket creat failed" << endl;
        return;
    }

    u_long imode = 1;
    ioctlsocket(sockClient, FIONBIO, &imode);//非阻塞

    //bind
    int result_bind;
    result_bind = bind(sockClient, (SOCKADDR*)&addr_client,
sizeof(SOCKADDR_IN));
    if (result_bind == SOCKET_ERROR) {
        cout << "bind failed" << endl;
        return;
    }

    //初始化伪头部
    memset(&ph, 0, sizeof(pseudoHead));
    ph.source_ip = inet_addr(ip_client);
    ph.dest_ip = inet_addr(ip_server);

    cout << "初始化成功，客户端开始建接"<<endl;
```

```
};
```

服务器:

```
void init() {

    //Startup
    WSADATA wsadata;
    WORD version;
    version = MAKEWORD(2, 2);
    int result_start;
    result_start = WSAStartup(version, &wsadata);

    if (result_start != 0) {
        cout << "Startup failed" << endl;
        return;
    }

    //client and server  addr

    addr_client.sin_port = htons(port_route);                    //port
    addr_client.sin_addr.S_un.S_addr = inet_addr(ip_route); //ip addr
    addr_client.sin_family = AF_INET;

    addr_server.sin_port = htons(port_server);
    addr_server.sin_addr.S_un.S_addr = inet_addr(ip_server);
    addr_server.sin_family = AF_INET;

    //creat socket
    sockServer = socket(AF_INET, SOCK_DGRAM, 0);
    if (sockServer == INVALID_SOCKET) {
        cout << "socket creat failed" << endl;
        return;
    }

    //bind
    int result_bind;
    result_bind = bind(sockServer, (SOCKADDR*)&addr_server,
sizeof(SOCKADDR_IN));
    if (result_bind == SOCKET_ERROR) {
        cout << "bind failed" << endl;
        return;
    }

    //初始化伪首部
    memset(&ph, 0, sizeof(pseudoHead));
    ph.source_ip = inet_addr(ip_client);
    ph.dest_ip = inet_addr(ip_server);

    cout << "初始化成功，服务器端开始建接" << endl;

}
```

（二）建立连接

客户端：

```
bool establishConnect() {

    int len = sizeof(SOCKADDR_IN);
    char recBuffer[sizeof(msg)];    //接收缓冲区
    char sendBuffer[sizeof(msg)];   //发送缓冲区
    memset(recBuffer, 0, sizeof(msg));
    memset(sendBuffer, 0, sizeof(msg));
    msg* sed = (msg*)sendBuffer;
    msg* rec = (msg*)recBuffer;

    setSyn(sed);        //设置SYN
    sed->seq_num = 0;   //设置seq=0
    sed->ack_num = 0;   //设置ack=0
    sed->source_port = port_client;
    sed->dest_port = port_server;
    setChecksum(sed, &ph);  //设置校验和

    //发送
    sendto(sockClient, sendBuffer, sizeof(msg), 0, (sockaddr*)&addr_server,
len);

    clock_t start = clock(); //开始计时

    while (recvfrom(sockClient, recBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, &len) <= 0) {

        if (clock() - start >= MAX_TIME) {
            //超时重传
            sendto(sockClient, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, len);
            start = clock();
        }
    }
    cout << "客户端:接收到报文（SYN，ACK）" << endl;

    if (isAck(rec) && isSyn(rec) && verfiyChecksum(rec, &ph)) {

            cout << "客户端:接收报文（SYN，ACK）验证正确" << endl;
            memset(sendBuffer, 0, sizeof(msg));
            setAck(sed);    //设置ack
            sed->seq_num = 1;
            sed->ack_num = 1;
            sed->source_port = port_client;
            sed->dest_port = port_server;
            setChecksum(sed, &ph);
            sendto(sockClient, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, len);

        }
    else {
            cout << "客户端:接收报文（SYN，ACK）验证错误" << endl;
```

```
            return 0;

        }

    cout << "客户端： 建立连接成功" << endl;
        return true;

};
```

服务器：

```
bool establishConnect() {

    int len = sizeof(SOCKADDR_IN);
    char recBuffer[sizeof(msg)];    //接收缓冲区
    char sendBuffer[sizeof(msg)];   //发送缓冲区
    msg* sed = (msg*)sendBuffer;
    msg* rec = (msg*)recBuffer;
    memset(recBuffer, 0, sizeof(msg));
    memset(sendBuffer, 0, sizeof(msg));

    while (1) {

        //阻塞，接收SYN
        recvfrom(sockServer, recBuffer, sizeof(msg), 0, (sockaddr*)&addr_client,
&len);

        if (isSyn(rec) && verfiyChecksum(rec, &ph) && rec->seq_num==0) {
            cout << "服务器端： 接收到客户端SYN报文，验证成功" << endl;

            //设置SYN，ACK报文
            setAck(sed);
            setSyn(sed);
            sed->seq_num = 0;
            sed->ack_num = 1;
            sed->source_port = port_server;
            sed->dest_port = port_client;
            setChecksum(sed, &ph);
            //发送SYN，ACK
            sendto(sockServer, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_client, len);
            break;
        }
        else {
            cout << "服务器端： 接收到客户端SYN报文，验证失败" << endl;
            continue;
        }
    }
    //设为非阻塞
    u_long imode = 1;
    ioctlsocket(sockServer, FIONBIO, &imode);//非阻塞


    clock_t start = clock(); //开始计时
```

```
    while (recvfrom(sockServer, recBuffer, sizeof(msg), 0,
(sockaddr*)&addr_client, &len) <= 0) {

        // over time
        if (clock() - start >= MAX_TIME) {

            //超时重传
            sendto(sockServer, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_client, len);
            cout << "服务器端： 重传报文（SYN，ACK）" << endl;
            start = clock();
        }
    }
    if (isAck(rec) && verfiyChecksum(rec, &ph)) {

        cout << "服务器端：接收到客户端报文（SYN，ACK）验证正确" << endl;
    }
    else {

        return false;
    }

    imode = 0;
    ioctlsocket(sockServer, FIONBIO, &imode);//阻塞
    return true;

}
```

（三）确认重传，rdt3.0

客户端：

打包函数：根据要打包的长度，设置seq，将传输数据打包进报文，返回报文。

```
msg make_pkt( int seq, char * data , unsigned short len  ) {
    msg message;
    memset(&message, 0, sizeof(msg));
    message.source_port = port_client;
    message.dest_port = port_server;
    message.length = len;
    message.seq_num = seq;
    memcpy(message.msg, data, len);
    pseudoHead ph;      //伪首部
    memset(&ph, 0, sizeof(pseudoHead));
    ph.source_ip = inet_addr(ip_client);
    ph.dest_ip = inet_addr(ip_server);
    setChecksum(&message, &ph); //设置校验和
    return message;
}
```

有限状态机：

- 根据数据的总长度和最大报文数据长度，可以计算需要发送多少包，每个包的数据段长度，将该长度写入报文的length中。

- 在状态机的循环开始处，判断是否已经将所有的包发完并且得到确认。如果是，则发送标志位为（END）的报文，该报文的数据部分为所要传输的文件的名。并设置超时重传，以保证服务器得到。
- 接收到报文（END，ACK），退出。
- 四个状态按照rdt3.0的状态转移。

```
void rdt3_send_FSM(unsigned long length_file ,char * file,char * filename) {

    int packetNUM = int(length_file / Max_Size) + (length_file % Max_Size ? 1 :
0);
    cout << "packetNUM: " << packetNUM << endl;
    int index = 0;
    int stage = 0;
    int len = sizeof(SOCKADDR_IN);
    int packetDataLen = min(Max_Size, length_file - index * Max_Size);
    char *dataBuffer=new char[Max_Size];
    char *pktBuffer = new char[sizeof(msg)];
    char* recpktBuffer = new char[sizeof(msg)];
    msg sndpkt;
    clock_t start_timer;


    msg* rec = (msg*)recpktBuffer;
    cout << "本次文件数据长度为    " << length_file << "Bytes,    需要传输" <<
packetNUM << "个数据包" << endl;

    while (1) {


        //发送传输结束报文
        if (index == packetNUM) {

            u_long imode = 1;
            ioctlsocket(sockClient, FIONBIO, &imode);//非阻塞


            char* sendBuffer = new char[sizeof(msg)];
            memset(sendBuffer, 0, sizeof(msg));
            msg *sed = (msg*)sendBuffer;
            setEnd(sed);
            sed->source_port = port_client;
            sed->dest_port = port_server;
            string fn = filename;
            int filename_len = sizeof(fn);

            memcpy(sed->msg, filename, filename_len);
            sed->length = filename_len;
            setChecksum(sed, &ph);  //设置校验和

            //发送
            sendto(sockClient, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, len);
            cout << "客户端：  发送报文（END）" << endl;

            clock_t start_timer = clock(); //开始计时
```

```
            while (recvfrom(sockClient, recpktBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, &len) <= 0||!(isEnd(rec)&&isAck(rec))) {
                // over time
                if (clock() - start_timer >= MAX_TIME) {

                    //超时重传
                    sendto(sockClient, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, len);
                    cout << "客户端:  发送报文（END）,重传" << endl;
                    start_timer = clock();
                }
            }


            if (isEnd(rec)&&isAck(rec) && verfiyChecksum(rec, &ph) ) {
                cout << "客户端：接收服务器报文（END，ACK），文件传输完成" << endl;
                return ;
            }
            else
                continue;
        }

        //传输数据长度
        packetDataLen=min(Max_Size, length_file - index * Max_Size);

        switch (stage) {
            case 0:
                memcpy(dataBuffer, file+index* Max_Size, packetDataLen);
                sndpkt = make_pkt(2, dataBuffer, packetDataLen);
                memcpy(pktBuffer, &sndpkt, sizeof(msg));
                sendto(sockClient, pktBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, len);
                start_timer = clock();
                stage = 1;
                cout << "状态0\t发送\tseq:\t2\tindex:\t" << index <<"\tlength:\t"
<< packetDataLen << "\tchecksum:\t"<<sndpkt.checksum << endl;
                break;

            case 1:

                //超时重传
                if (clock() - start_timer >= MAX_TIME) {
                    sendto(sockClient, pktBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, len);
                    cout << "状态1\t发送\tseq:\t2\tindex:\t" << index <<
"\tlength:\t" << packetDataLen << "\tchecksum:\t" << sndpkt.checksum << "  (重
传)" << endl;
                    start_timer = clock();
                }


                if (recvfrom(sockClient, recpktBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, &len)) {
```

```
                    if (isAck(rec) && verfiyChecksum(rec, &ph) && rec->ack_num
== 2) {
                        cout << "状态1\t接收\tack:\t2\tAck:\t" << isAck(rec) <<
"\tlength:\t" << rec->length << "\tchecksum:\t" << rec->checksum  << endl;
                        stage = 2;
                        index++;
                        break;
                    }
                }
                break;

            case 2:
                memcpy(dataBuffer, file + index * Max_Size, packetDataLen);
                sndpkt = make_pkt(3, dataBuffer, packetDataLen);
                memcpy(pktBuffer, &sndpkt, sizeof(msg));
                sendto(sockClient, pktBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, len);
                cout << "状态2\t发送\tseq:\t3\tindex:\t" << index << "
\tlength:\t" << packetDataLen << " \tchecksum:\t" << sndpkt.checksum << endl;
                start_timer = clock();
                stage = 3;
                break;


            case 3:

                //超时重传
                if (clock() - start_timer >= MAX_TIME) {
                    sendto(sockClient, pktBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, len);
                    cout << "状态3\t发送\tseq:\t3\tindex:\t" << index <<
"\tlength:\t" << packetDataLen << " \tchecksum:\t" << sndpkt.checksum << "  (重
传)" << endl;

                    start_timer = clock();
                }


                if (recvfrom(sockClient, recpktBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, &len)) {
                    if (isAck(rec) && verfiyChecksum(rec, &ph) && rec->ack_num
== 3) {
                        cout << "状态3\t接收\tack:\t3\tAck:\t" << isAck(rec) <<
"\tlength:\t" << rec->length << "\tchecksum:\t" << rec->checksum << endl;
                        stage = 0;
                        index++;
                        break;
                    }
                }
                break;
        }
    }
}
```

服务器：

打包函数：，设置ack，返回报文。

```
msg make_pkt(int ack) {

    msg message;
    memset(&message, 0, sizeof(msg));
    message.source_port = port_client;
    message.dest_port = port_server;
    setAck(&message);
    message.ack_num = ack;
    pseudoHead ph;      //伪首部
    memset(&ph, 0, sizeof(pseudoHead));
    ph.source_ip = inet_addr(ip_client);
    ph.dest_ip = inet_addr(ip_server);
    setChecksum(&message, &ph); //设置校验和

    return message;
}
```

有限状态机：

- 两个状态，在rdt3.0的基础之上，每个状态增加判断接受的包是否为（END）。在该报文中得到所传输文件的文件名。
- 发送确定报文（END，ACK）。

```
DWORD rdt3_receive_FSM(char* file,char *filename) {



    int index = 0;
    int stage = 0;

    int len = sizeof(SOCKADDR_IN);

    char* pktBuffer = new char[sizeof(msg)];
    char* recpktBuffer = new char[sizeof(msg)];
    char* sendBuffer = new char[sizeof(msg)];

    DWORD rec_data_len = 0;
    msg* rec = (msg*)recpktBuffer;

    //传输请求
    u_long imode = 0;
    if(ioctlsocket(sockServer, FIONBIO, &imode)==SOCKET_ERROR)
    cout << "error" << endl;

    bool start_tran = 0;

    while (1) {
        memset(recpktBuffer, 0, sizeof(msg));

        switch (stage) {
```

```
        case 0:

            if (recvfrom(sockServer, recpktBuffer, sizeof(msg), 0,
(sockaddr*)&addr_client, &len) > 0 &&  rec->length!=0) {
            }
            else {

                break;
            }

            if (isEnd(rec)&& start_tran) {
                memcpy(filename, rec->msg, rec->length);
                cout << "传输完毕" << endl;
                memset(sendBuffer, 0, sizeof(msg));
                msg sed = make_pkt(0);
                setEnd(&sed);
                sed.checksum = 0;
                setChecksum(&sed, &ph);

                memcpy(sendBuffer, &sed, sizeof(msg));

                sendto(sockServer, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_client, len);
                cout << "服务器: 发送报文（END，ACK）" << endl;
                return rec_data_len;
            }


            if (rec->seq_num == 3 || !(verfiyChecksum(rec, &ph))) {

                msg sedpkt = make_pkt(3);
                memcpy(sendBuffer, &sedpkt, sizeof(msg));
                sendto(sockServer, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_client, len);
                cout << "状态0\t接收\tseq:\t3\t" << endl;
                cout << "状态0\t发送\tack:\t3\ACK:\t" << isAck(&sedpkt) <<
"\tlength:\t" << sedpkt.length << "\tchecksum:\t" << sedpkt.checksum << endl;

                stage = 0;
                cout << "在状态0时收到seq1" << endl;
                break;

            }

            //正确接收
            if (rec->seq_num == 2 && (verfiyChecksum(rec, &ph))) {

                msg sedpkt = make_pkt(2);
                memcpy(sendBuffer, &sedpkt, sizeof(msg));
                sendto(sockServer, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_client, len);
                cout << "状态0\t接收\tseq:\t2\tindex:\t" << index << "\tlength:\t"
<< rec->length << "\tchecksum:\t" << rec->checksum << endl;
                cout << "状态0\t发送\tack:\t2\ACK:\t" << isAck(&sedpkt) <<
"\tlength:\t" << sedpkt.length << "\tchecksum:\t" << sedpkt.checksum << endl;
```

```
                memcpy(file + rec_data_len, rec->msg, rec->length);
                rec_data_len += rec->length;
                stage = 1;
                start_tran = 1;
                index++;
                break;

            }
            break;


        case 1:

            recvfrom(sockServer, recpktBuffer, sizeof(msg), 0,
(sockaddr*)&addr_client, &len);

            if (isEnd(rec)&& start_tran) {

                memcpy(filename, rec->msg, rec->length);
                cout << "传输完毕" << endl;
                memset(sendBuffer, 0, sizeof(msg));
                msg sed = make_pkt(0);
                setEnd(&sed);
                sed.checksum = 0;
                setChecksum(&sed, &ph);
                memcpy(sendBuffer, &sed, sizeof(msg));
                sendto(sockServer, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_client, len);

                return rec_data_len;
            }


            if (rec->seq_num == 2 || !(verfiyChecksum(rec, &ph))) {

                msg sedpkt = make_pkt(2);
                memcpy(sendBuffer, &sedpkt, sizeof(msg));
                sendto(sockServer, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_client, len);
                cout << "状态1\t接收\tseq:\t2\t" << endl;
                cout << "状态1\t发送\tack:\t2\ACK:\t" << isAck(&sedpkt) <<
"\tlength:\t" << sedpkt.length << "\tchecksum:\t" << sedpkt.checksum << endl;

                stage = 1;

                break;

            }

            if (rec->seq_num == 3 && (verfiyChecksum(rec, &ph))) {

                msg sedpkt = make_pkt(3);
                memcpy(sendBuffer, &sedpkt, sizeof(msg));
                sendto(sockServer, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_client, len);
```

```
                cout << "状态1\t接收\tseq:\t3\tindex:\t" << index << "\tlength:\t"
<< rec->length << "\tchecksum:\t" << rec->checksum << endl;
                cout << "状态1\t发送\tack:\t3\ACK:\t" << isAck(&sedpkt) <<
"\tlength:\t" << sedpkt.length << "\tchecksum:\t" << sedpkt.checksum << endl;
                memcpy(file + rec_data_len, rec->msg, rec->length);
                rec_data_len += rec->length;
                start_tran = 1;
                stage = 0;
                index++;
                break;
            }
            break;
        }
    }

}
```

（四）四次挥手

客户端：

```
bool closeConnect() {

    int len = sizeof(SOCKADDR_IN);
    char recBuffer[sizeof(msg)];    //接收缓冲区
    char sendBuffer[sizeof(msg)];   //发送缓冲区

    memset(recBuffer, 0, sizeof(msg));
    memset(sendBuffer, 0, sizeof(msg));

    msg* sed = (msg*)sendBuffer;
    msg* rec = (msg*)recBuffer;

    //（1）客户端发送FIN报文
    setFin(sed);        //设置Fin
    sed->seq_num = 0;   //设置seq=0
    sed->ack_num = 0;   //设置ack=0
    sed->source_port = port_client;
    sed->dest_port = port_server;

    setChecksum(sed, &ph);  //设置校验和

    //发送
    sendto(sockClient, sendBuffer, sizeof(msg), 0, (sockaddr*)&addr_server,
len);
    cout << "客户端：发送报文（FIN）" << endl;

    clock_t start = clock(); //开始计时

    //（2）接收确定服务器端的FIN，ACK报文
    while (recvfrom(sockClient, recBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, &len) <= 0) {

        if (clock() - start >= MAX_TIME) {
            //超时重传
```

```
            sendto(sockClient, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, len);
            cout << "客户端：发送报文（FIN），重传" << endl;
            start = clock();
        }
    }

    if (isAck(rec) && isFin(rec) && verfiyChecksum(rec, &ph)) {
        cout << "客户端：接收报文（FIN，ACK）验证正确" << endl;
    }
    else {

        return false;
    }
    u_long imode = 0;
    ioctlsocket(sockClient, FIONBIO, &imode);//阻塞

    //（3）接收确定服务器端的FIN报文

    while (1) {
        recvfrom(sockClient, recBuffer, sizeof(msg), 0, (sockaddr*)&addr_server,
&len);

        if (isFin(rec) && verfiyChecksum(rec, &ph)) {

            cout << "客户端：接收到服务器报文（FIN），验证正确" << endl;
            break;
        }
    }

    imode = 1;
    ioctlsocket(sockClient, FIONBIO, &imode);//非阻塞

    //（4）发送FIN，ACK报文
    cleanflag(sed);
    setFin(sed);
    setAck(sed);
    setChecksum(sed, &ph);  //设置校验和
    sendto(sockClient, sendBuffer, sizeof(msg), 0, (sockaddr*)&addr_server,
len);
    cout << "客户端：发送报文（FIN，ACK）" << endl;

    //等待2MSL
    start = clock(); //开始计时

    while (clock() - start <= 2 * MAX_TIME) {
        if (recvfrom(sockClient, recBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, &len) > 0&& isFin(rec) && verfiyChecksum(rec, &ph)) {
            sendto(sockClient, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, len);
            cout << "客户端：发送报文（FIN，ACK）,重传" << endl;
        }
    }

    cout << "客户端：连接关闭" << endl;
```

```
    closesocket(sockClient);
    return true;

};
```

服务器端：

```
bool closeConnect() {

    int len = sizeof(SOCKADDR_IN);
    char recBuffer[sizeof(msg)];    //接收缓冲区
    char sendBuffer[sizeof(msg)];   //发送缓冲区
    memset(recBuffer, 0, sizeof(msg));
    memset(sendBuffer, 0, sizeof(msg));

    msg* sed = (msg*)sendBuffer;
    msg* rec = (msg*)recBuffer;

    u_long imode = 0;
    ioctlsocket(sockServer, FIONBIO, &imode);//阻塞

    //（1）接收验证客户端的FIN报文。
    while (1) {
        recvfrom(sockServer, recBuffer, sizeof(msg), 0, (sockaddr*)&addr_server,
&len);

        if (isFin(rec) && verfiyChecksum(rec, &ph)) {

            cout << "服务器：  收到客户端Fin请求，验证正确" << endl;
            break;
        }
    }
    //（2）服务器：设置发送ACK，FIN报文

    setFin(sed);        //设置Fin
    setAck(sed);        //设置Ack
    sed->seq_num = 0;   //设置seq=0
    sed->ack_num = 0;   //设置ack=0
    sed->source_port = port_client;
    sed->dest_port = port_server;
    setChecksum(sed, &ph);  //设置校验和

    //发送
    sendto(sockServer, sendBuffer, sizeof(msg), 0, (sockaddr*)&addr_client,
len);

    //剩余数据

    //发送FIN
    cleanflag(sed);
    setFin(sed);        //设置Fin
    setChecksum(sed, &ph);
    sendto(sockServer, sendBuffer, sizeof(msg), 0, (sockaddr*)&addr_client,
len);
```

```
    imode = 1;
    ioctlsocket(sockServer, FIONBIO, &imode);//非阻塞

    //接收
    clock_t  start = clock(); //开始计时
    while (recvfrom(sockServer, recBuffer, sizeof(msg), 0,
(sockaddr*)&addr_server, &len) <= 0 ||!(isAck(rec) && isFin(rec) &&
verfiyChecksum(rec, &ph)) ) {

        // over time
        if (clock() - start >= MAX_TIME) {

            //超时重传
            sendto(sockServer, sendBuffer, sizeof(msg), 0,
(sockaddr*)&addr_client, len);
            cout << "服务器:  发送报文（FIN），重传" << endl;
            start = clock();
        }
    }

    if (isAck(rec) && isFin(rec) && verfiyChecksum(rec, &ph)) {
        cout << "服务器:  接收到报文（FIN，ACK），验证正确" << endl;
    }
    else {
        return false;
    }

    cout << "连接关闭" << endl;
    closesocket(sockServer);
    return true;
};
```

（五）文件读和写

客户端：

- 选择要读文件，文件内容读入缓冲区，获得文件名。

```
    while (1) {

        char* filename = new char[100];
        memset(filename, 0, 100);
        string filedir;

        cout << endl;
        cout << "/*****************************************************/" <<
endl;
        cout << "默认: 1.jpg" << endl;
        cout << "1: 1.jpg" << endl;
        cout << "2: 2.jpg" << endl;
        cout << "3: 3.jpg" << endl;
        cout << "4: helloworld.txt" << endl;
        cout << "5: 退出" << endl;
```

```
        cout << "请输入要传输的文件：  " << endl;
        int i;
        cin >> i;

        cout << endl;
        cout << "/********************************************************/" <<
endl;

        if (i == 5) {
            cout << "传输结束 " << endl;
            break;
        }
        switch (i) {
        case 1:
            //filedir = "C:/Users/nan/Desktop/lab3/lab3_1/test file/1.jpg";
            filedir = "test file/1.jpg";
            memcpy(filename, "1.jpg", sizeof("1.jpg"));
            break;
        case 2:
            //filedir = "C:/Users/nan/Desktop/lab3/lab3_1/test file/2.jpg";
            filedir = "test file/2.jpg";
            memcpy(filename, "2.jpg", sizeof("2.jpg"));
            break;
        case 3:

            //filedir = "C:/Users/nan/Desktop/lab3/lab3_1/test file/3.jpg";
            filedir = "test file/3.jpg";
            memcpy(filename, "3.jpg", sizeof("3.jpg"));
            break;
        case 4:

            //filedir = "C:/Users/nan/Desktop/lab3/lab3_1/test
file/helloworld.txt";
            filedir = "test file/helloworld.txt";
            memcpy(filename, "helloworld.txt", sizeof("helloworld.txt"));
            break;
        default:
            //filedir = "C:/Users/nan/Desktop/lab3/lab3_1/test file/1.jpg";
            filedir = "test file/1.jpg";
            memcpy(filename, "1.jpg", sizeof("1.jpg"));
            break;
        }

        ifstream infile(filedir, ifstream::binary);
        if (!infile.is_open()) {
            cout << "无法打开文件" << endl;
            return 0;
        }

        infile.seekg(0, infile.end);
        DWORD fileLen = infile.tellg();
        infile.seekg(0, infile.beg);
        cout<<"传输文件长度: " << fileLen << endl;
        char* fileBuffer = new char[fileLen];
        infile.read(fileBuffer, fileLen);
```

```
        infile.close();
        cout << "开始传输文件: "<< i << endl;
        clock_t start_timer = clock();
        rdt3_send_FSM(fileLen, fileBuffer,filename);
        clock_t end_timer = clock();
        double endtime = (double)(end_timer - start_timer) / CLOCKS_PER_SEC;
        cout << "Total time:" << endtime <<" s" << endl;
        cout << "吞吐率: " << fileLen * 8 / endtime / 1024 / 1024 << "Mbps" <<
endl;

    }
```

服务器:

- 获得文件内容和文件名。
- 写入

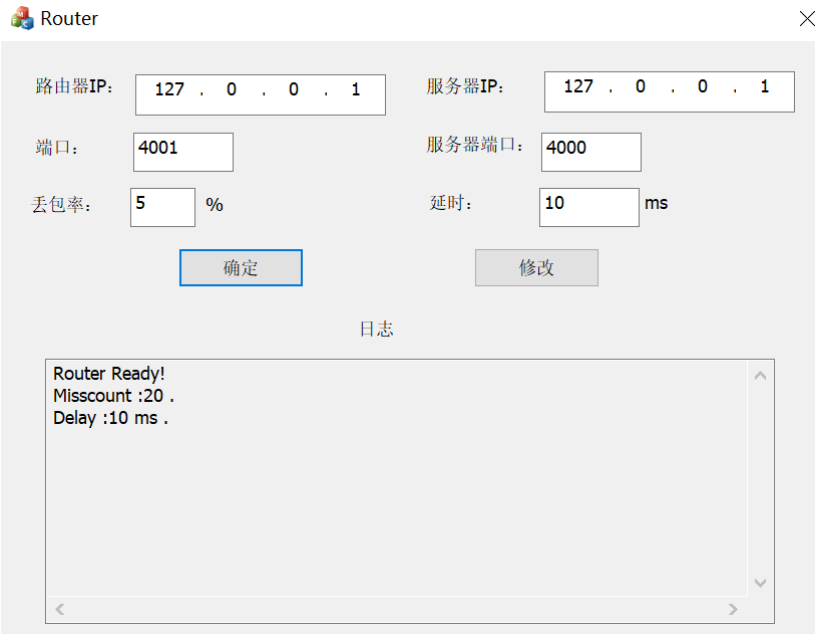
```
    bool tran = 1;

    while (tran) {
        char* fileBuffer = new char[90000000];
        DWORD fileLength = 0;
        char* filename = new char[100];
        memset(filename, 0, 100);
        fileLength = rdt3_receive_FSM(fileBuffer, filename);
        cout << "/*******************************************************/" <<
endl;
        cout << endl;
        //string dir = "C:/Users/nan/Desktop/lab3/lab3_1/rec file/";
        string dir = "rec file/";
        string  fn = filename;
        string filenm = dir + fn;
        //写入文件
        ofstream outfile(filenm, ios::binary);
        outfile.write(fileBuffer, fileLength);
        outfile.close();
        cout << "是否继续接受传输（Y/N）:  ";
        char i;
        cin >> i;
        cout << "/*******************************************************/" <<
endl;
        cout << endl;
        switch (i)
        {
        case 'y':
            tran = 1;
            break;
        case 'n':
            tran = 0;
            break;
        default:
            break;
        }
```

```
    }
```

四、程序演示

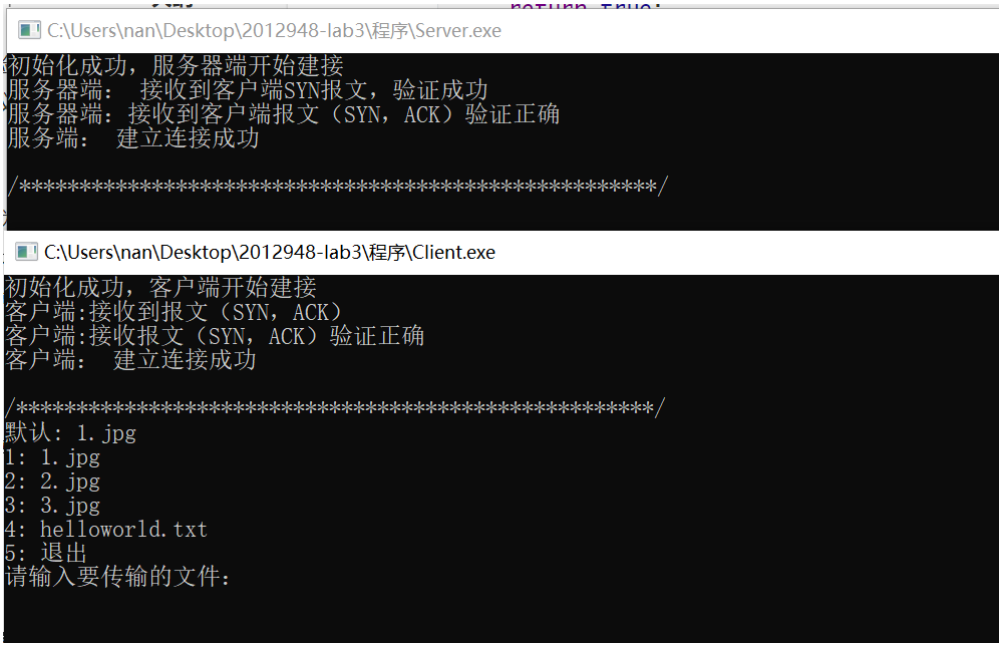
- (1)



路由器:
ip：127.0.0.1 端口: 4001;

server:
ip：127.0.0.1 端口: 4000;

- (2)建立连接



- （3）传输

客户端:

C:\Users\nan\Desktop\2012948-lab3\程序\Client.exe

```
状态2   发送    seq:    3       index:  195     length: 8192    checksum:       64742
状态3   接收    ack:    3       Ack:    1       length: 0       checksum:       56766
状态0   发送    seq:    2       index:  196     length: 8192    checksum:       64743
状态1   接收    ack:    2       Ack:    1       length: 0       checksum:       56767
状态2   发送    seq:    3       index:  197     length: 8192    checksum:       64742
状态3   接收    ack:    3       Ack:    1       length: 0       checksum:       56766
状态0   发送    seq:    2       index:  198     length: 8192    checksum:       64743
状态1   接收    ack:    2       Ack:    1       length: 0       checksum:       56767
状态2   发送    seq:    3       index:  199     length: 8192    checksum:       64742
状态3   接收    ack:    3       Ack:    1       length: 0       checksum:       56766
状态0   发送    seq:    2       index:  200     length: 8192    checksum:       64743
状态1   接收    ack:    2       Ack:    1       length: 0       checksum:       56767
状态2   发送    seq:    3       index:  201     length: 8192    checksum:       64742
状态3   接收    ack:    3       Ack:    1       length: 0       checksum:       56766
状态0   发送    seq:    2       index:  202     length: 1024    checksum:       49573
状态1   接收    ack:    2       Ack:    1       length: 0       checksum:       56767
客户端:  发送报文（END）
客户端: 接收服务器报文（END，ACK），文件传输完成
Total time:7.229 s
吞吐率：1.74752Mbps

/*******************************************************/
默认: 1.jpg
1: 1.jpg
2: 2.jpg
3: 3.jpg
4: helloworld.txt
5: 退出
请输入要传输的文件：
```

服务器：

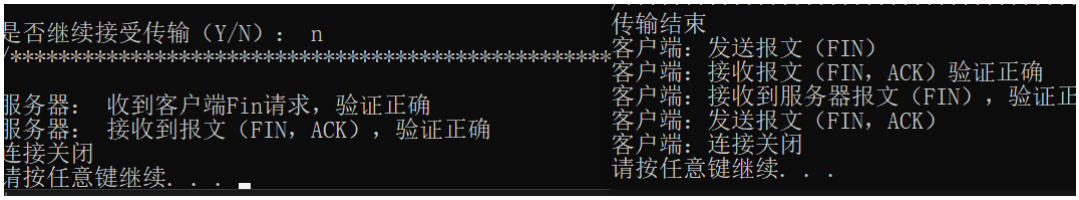
C:\Users\nan\Desktop\2012948-lab3\程序\Server.exe

```
状态0   接收    seq:    2       index:  190     length: 8192    checksum:       64743
状态0   发送    ack:    2ACK:   1       length: 0       checksum:       56767
状态1   接收    seq:    3       index:  191     length: 8192    checksum:       64742
状态1   发送    ack:    3ACK:   1       length: 0       checksum:       56766
状态0   接收    seq:    2       index:  192     length: 8192    checksum:       64743
状态0   发送    ack:    2ACK:   1       length: 0       checksum:       56767
状态1   接收    seq:    3       index:  193     length: 8192    checksum:       64742
状态1   发送    ack:    3ACK:   1       length: 0       checksum:       56766
状态0   接收    seq:    2       index:  194     length: 8192    checksum:       64743
状态0   发送    ack:    2ACK:   1       length: 0       checksum:       56767
状态1   接收    seq:    3       index:  195     length: 8192    checksum:       64742
状态1   发送    ack:    3ACK:   1       length: 0       checksum:       56766
状态0   接收    seq:    2       index:  196     length: 8192    checksum:       64743
状态0   发送    ack:    2ACK:   1       length: 0       checksum:       56767
状态1   接收    seq:    3       index:  197     length: 8192    checksum:       64742
状态1   发送    ack:    3ACK:   1       length: 0       checksum:       56766
状态0   接收    seq:    2       index:  198     length: 8192    checksum:       64743
状态0   发送    ack:    2ACK:   1       length: 0       checksum:       56767
状态1   接收    seq:    3       index:  199     length: 8192    checksum:       64742
状态1   发送    ack:    3ACK:   1       length: 0       checksum:       56766
状态0   接收    seq:    2       index:  200     length: 8192    checksum:       64743
状态0   发送    ack:    2ACK:   1       length: 0       checksum:       56767
状态1   接收    seq:    3       index:  201     length: 8192    checksum:       64742
状态1   发送    ack:    3ACK:   1       length: 0       checksum:       56766
状态0   接收    seq:    2       index:  202     length: 1024    checksum:       49573
状态0   发送    ack:    2ACK:   1       length: 0       checksum:       56767
传输完毕
/*******************************************************/

是否继续接受传输（Y/N）：
```

传输结果：

- (4)断开连接



五、代码库

lab3_1 · nan/computer_network