



哈尔滨工业大学  
Harbin Institute of Technology

# 计算机网络 课程实验报告

实验名称	可靠数据传输协议-GBN 协议的设计与实现					
姓名	袁野		院系	计算学部计算机科学与技术专业		
班级	1903102		学号	1190200122		
任课教师	刘亚维		指导教师	刘亚维		
实验地点	格物 207		实验时间	2021.11.7		
实验课表现	出勤、表现得分(10)		实验报告 得分(40)		实验总分	
	操作结果得分(50)					
教师评语						



### 实验目的:

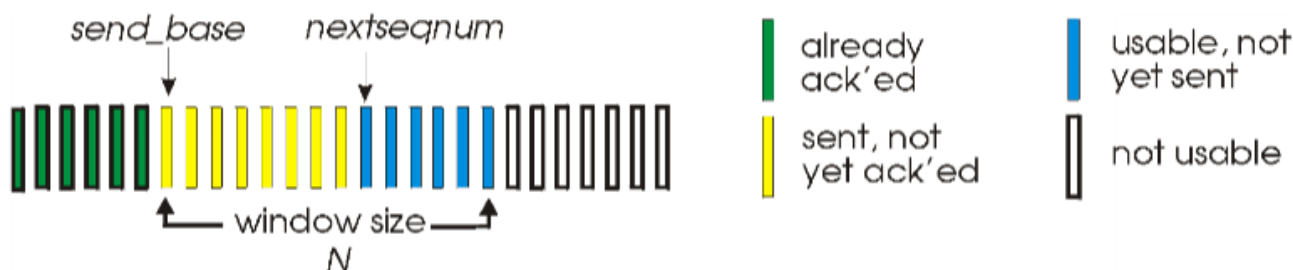
理解可靠数据传输的基本原理; 掌握停等协议的工作原理; 掌握基于 UDP 设计并实现一个停等协议的过程与技术。  
理解滑动窗口协议的基本原理; 掌握 GBN 的工作原理; 掌握基于 UDP 设计并实现一个 GBN 协议的过程与技术。

### 实验内容:

- 1) 基于 UDP 设计一个简单的停等协议, 实现单向可靠数据传输 (服务器到客户的数据传输)。
  - 2) 模拟引入数据包的丢失, 验证所设计协议的有效性。
  - 3) 改进所设计的停等协议, 支持双向数据传输; (选作内容, 加分项目, 可以当堂完成或课下完成)
  - 4) 基于所设计的停等协议, 实现一个 C/S 结构的文件传输应用。(选作内容, 加分项目, 可以当堂完成或课下完成)
- 
- 1) 基于 UDP 设计一个简单的 GBN 协议, 实现单向可靠数据传输 (服务器到客户的数据传输)。
  - 2) 模拟引入数据包的丢失, 验证所设计协议的有效性。
  - 3) 改进所设计的 GBN 协议, 支持双向数据传输; (选作内容, 加分项目, 可以当堂完成或课下完成)
  - 4) 将所设计的 GBN 协议改进为 SR 协议。(选作内容, 加分项目, 可以当堂完成或课下完成)

### 实验过程:

## 1. 基于UDP的GBN协议



### 1.1 GBN (SR) 协议数据分组格式

Seq	Data	0
-----	------	---

1. Seq为数据包的序号, 大小为一个字节, 取值为0~255。
2. Data为数据包内容, 大小不超过1024字节。
3. 最后一个字符为 '\0', 表示数据包的结尾。
4. 缓冲区大小共1026字节。

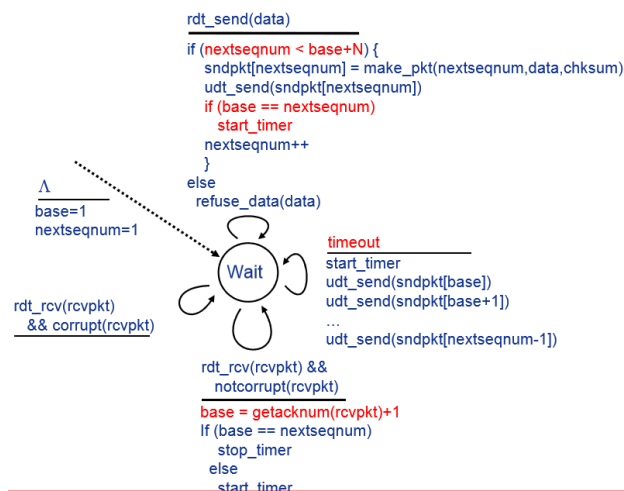
### 1.2 确认分组格式与各个域作用

ACK	0
-----	---

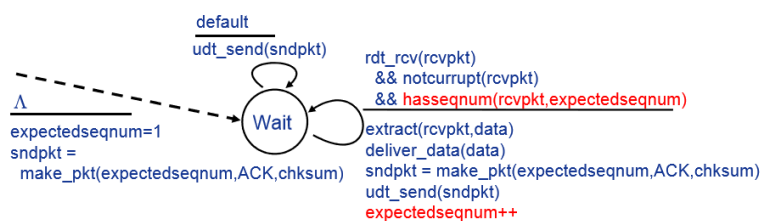
该分组包含两个字节, 第一个字节表示序列号, 第二个字节为 '\0'。

### 1.3 协议两端程序流程图

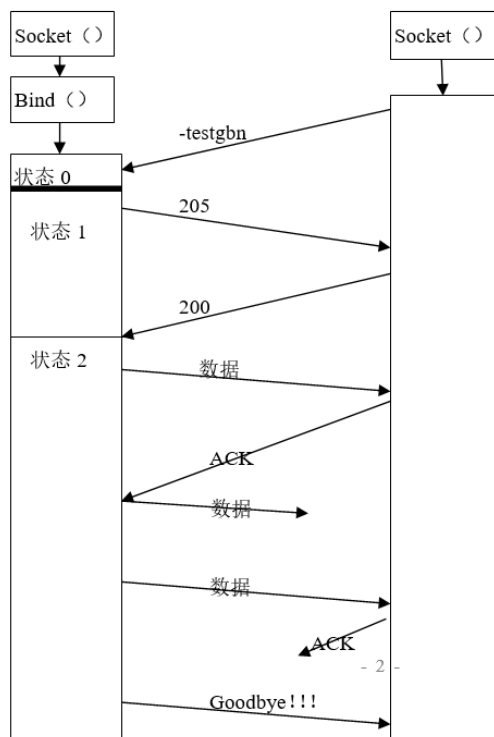
以自动机形式给出:



服务器端（发送端）

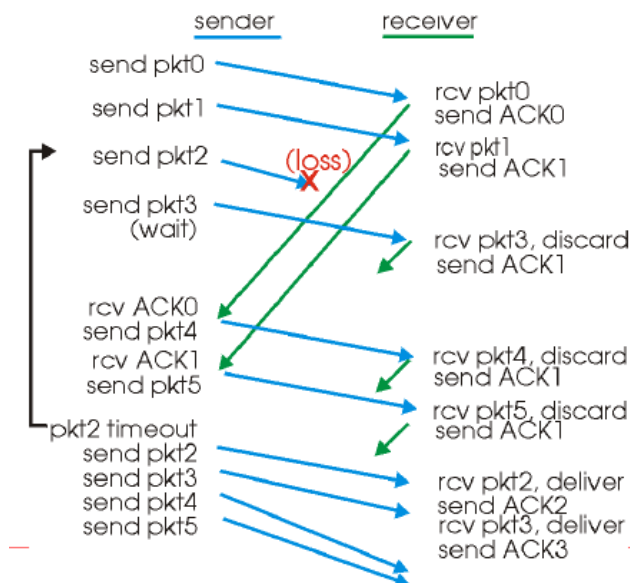


客户端（接收端）

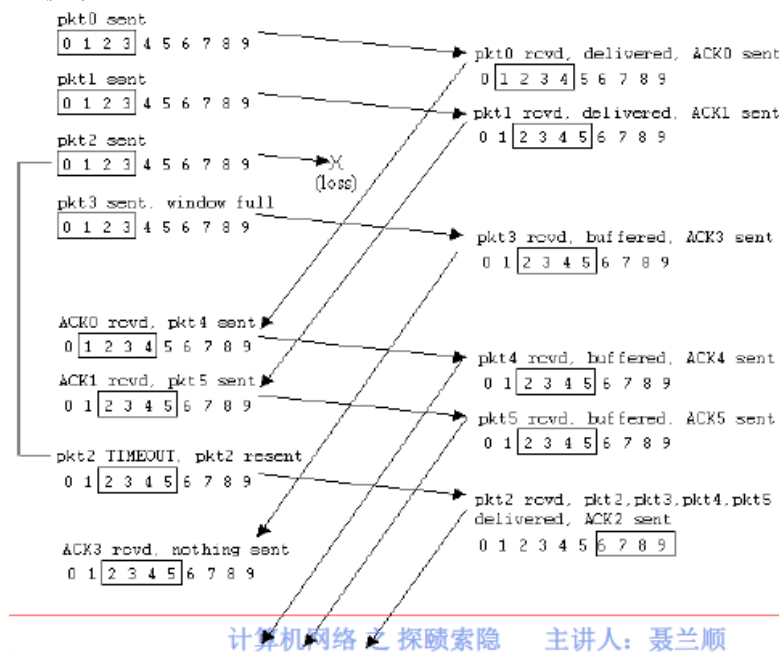


## 1.4 协议典型交互过程

### 1.4.1 GBN协议



### 1.4.2 SR协议



计算机网络之探索索隐 主讲人：聂兰顺

## 1.5 数据分组丢失验证模拟方法

丢失模拟方式在客户端实现，如果数据包丢失，则客户端认为没有接受到；如果ACK丢失，则客户端不向服务器发送ACK数据包。

在lossInLossRatio函数，将填写的X或者Y丢失率作为参数，在该函数中在0-100中随机生成一个数，如果该数小于丢失率\*100则认为丢失。

在服务器端有测试文件serverfile.txt, 将其与客户端的接收文件进行比较，如果相同则认为其可靠。

## 2. 程序实现的主要类（或函数）及其主要作用

### 2.1 服务器端GBN\_Server

#### 2.1.1 ackHandler(char c)

```
void ackHandler(char c) {
    unsigned char index = (unsigned char)c - 1; //序号减一
    printf("Recv a ack of %d\n", index);
    if (curAck <= index) {
        for (int i = curAck; i <= index; ++i) {
            ack[i] = TRUE;
            totalAck++;
        }
        curAck = (index + 1) % SEQ_SIZE;
    }
    else {
        //这种情况可能有两种原因导致，一种是发生丢包，另一种是用于序号循环使用
        //但考虑到发生连续好几个ack都丢了的概率较低，根据两者差值判断是哪种情况
        //ack 超过了最大值，回到了 curAck 的左边
        if (curAck - index > SEND_WIND_SIZE) {
            for (int i = curAck; i < SEQ_SIZE; ++i) {
                ack[i] = TRUE;
                totalAck++;
            }
            for (int i = 0; i <= index; ++i) {
                ack[i] = TRUE;
                totalAck++;
            }
            curAck = index + 1;
        }
    }
}
```

处理收到的ACK确认信息，并修改窗口内的信息状态。

#### 2.1.2 getCurTime(char \*ptime)

```
void getCurTime(char* ptime) {
    char buffer[128];
    memset(buffer, 0, sizeof(buffer));
    time_t c_time;
    struct tm* p;
    time(&c_time);
    p = localtime(&c_time);
    sprintf_s(buffer, "%d/%d/%d %d:%d:%d", p->tm_year + 1900,
        p->tm_mon, p->tm_mday, p->tm_hour, p->tm_min, p->tm_sec);
    strcpy_s(ptime, sizeof(buffer), buffer);
}
```

获取当前时间并将其储存在ptime中。

#### 2.1.3 lossInLossRatio()

```
BOOL lossInLossRatio(float lossRatio) {
    int lossBound = (int)(lossRatio * 100);
    int r = rand() % 100;
    if (r < lossBound) {
        return TRUE;
    }
    return FALSE;
}
```

等概率随机生成一个[0, 99]的数字，并判断其是否在[0, 100\*LossRatio-1]以内。

### 2.1.4 seqIsAvailable()

```
bool seqIsAvailable() {
    int step;
    step = curSeq - curAck;
    step = step >= 0 ? step : step + SEQ_SIZE; //序列号是循环使用的
    //序列号是否在当前发送窗口之内
    if (step >= SEND_WIND_SIZE) {
        return false;
    }
    if (ack[curSeq]) {
        return true;
    }
    return false;
}
```

判断当前序列号是否可用。

### 2.1.5 timeoutHandler()

```
void timeoutHandler() {
    printf("Timer out error.\n");
    int index;
    int res = 0;
    for (int i = 0; i < SEND_WIND_SIZE; ++i) {
        //将已经发出去的, 还没收到ack的, 重新置为还没发
        index = (i + curAck) % SEQ_SIZE;
        if (ack[index] == FALSE) res++;
        ack[index] = TRUE;
    }
    totalSeq -= res;
    curSeq = curAck;
}
```

将还未收到ACK确认信号且超时的数据包重新设置为未发送。

## 2.2 客户端GBN\_Client

### 2.2.1 lossInLossRatio()

与服务器中的同名函数同理。

## 3. 支持双向数据传输

将服务器端文件内支持发动数据包的相关代码复制到客户端代码中, 再将客户端代码中支持接收数据包的代码复制到服务器端即可。

## 4. SR协议

### 4.1 客户端修改

增加函数seqRecvAvailable()

```
bool seqRecvAvailable(int seq) {
    int step;
    step = seq - curAck;
    step = step >= 0 ? step : step + SEQ_SIZE;
    //序列号是否在当前接收窗口之内
    if (step >= RECV_WIND_SIZE) {
        return false;
    }
    return true;
}
```

判断接收的包是否在接收窗口内, 如果在则接收, 否则丢弃。

## 4.2 服务器端修改

改进累计确认机制，允许收到乱序的ack，超时后只重传已发送但未收到ack的分组。如果当前接收的ack序号为窗口第一个序号，则右移窗口直到窗口第一个序号为接收的ack序号，否则直接打上标记为已接受的ack即可。

```
void ackHandler(char c) {
    unsigned char index = (unsigned char)c - 1; //序列号减一
    printf("Recv a ack of %d\n", index);
    totalAck++;
    //如果ack的是窗口的第一个，右移窗口
    if (curAck == index) {
        ack[index] = TRUE;
        curAck = (index + 1) % SEQ_SIZE;
        //看可以右移几位
        for (int i = 1; i < SEND_WIND_SIZE; ++i) {
            int nxt = (i + index) % SEQ_SIZE;
            if (ack[nxt] == FALSE) {
                ack[nxt] = TRUE;
                curAck = (nxt + 1) % SEQ_SIZE;
                totalSeq++;
            }
            else break;
        }
        curSeq = curAck;
    }
    else {
        ack[index] = FALSE;
    }
}
```

## 验证过程以及实验结果：

采用演示截图、文字说明等方式，给出本次实验的实验结果。

### 1. GBN传输协议

```

D:\Codefield\Workplace\reliabledatatrans\GBN_Client\Release\GBN_Client.exe
The Winsock 2.2 dll was found okay
*****
-time to get current time
-quit to exit client
-testgbn [X] [Y] to test the gbn
-testgbn_send [X] [Y] to test the gbn
*****
-testgbn 0.02 0.02
Begin to test GBN protocol, please don't abort the process
The loss ratio of packet is 0.02, the loss ratio of ack is 0.02
Ready for file transmission
recv a packet with a seq of 1
This article is about the group of creative disciplines. For the concept of art, see Art. For
other uses, see Art (disambiguation).
"Arts" redirects here. For the acronym, see ARTS.

Clockwise, from left to right:
A tambourine player at a traditional debaa dance festival in Mayotte
Still Life with Profile of Laval by Paul Gauguin
The title page of Shakespeare's sonnets in a 1609 edition by Thomas Thorpe
Las Lajas Shrine, Nariño Department, Colombia
A Bian Lian performer.
The arts are a very wide range of human practices of creative expression, storytelling and cu
ltural participation. They encompass multiple diverse and plural modes of thinking, doing and
being, in an extremely broad range of media. Both highly dynamic and a characteristically co
nstant feature of human life, they have developed into innovative, stylized and sometimes int
ricate forms. This is often achieved through sustained and deliberate study, training and/or
theorizing within a particular tradition, across generations and even between
send a ack of 1
recv a packet with a seq of 2
civilizations. The arts are a vehicle through which human beings cultivate distinct social, c
ultural and individual identities, while transmitting values, impressions, judgments, ideas,
visions, spiritual meanings, patterns of life and experiences across time and space.

Prominent examples of the arts include architecture, visual arts (including ceramics, drawing
, filmmaking, painting, photography, and sculpting), literary arts (including fiction, drama,
poetry, and prose), performing arts (including dance, music, and theatre), textiles and fash
ion, folk art and handicraft, oral storytelling, conceptual and installation art, criticism,
and culinary arts (including cooking, chocolate making and winemaking). They can employ skill
and imagination to produce objects, performances, convey insights and experiences, and const
ruct new environments and spaces.

The arts can refer to common, popular or everyday practices as well as more sophisticated and
systematic, or institutionalized ones. They can be discrete and s
send a ack of 2
recv a packet with a seq of 3

```

客户端发出指令并进行接收



```

D:\Codefield\Workplace\reliabledatrans\GBN_Server\Debug\GBN_Server.exe
The Winsock 2.2 dll was found okay
recv from client: -testgbn
Begin to test GBN protocol, please don't abort the process
Shake hands stage
Begin a file transfer
File size is 25600B, each packet is 1024B and packet total num is 25
send a packet with a seq of 0
Recv a ack of 0
send a packet with a seq of 1
Recv a ack of 1
send a packet with a seq of 2
Recv a ack of 2
send a packet with a seq of 3
Recv a ack of 3
send a packet with a seq of 4
Recv a ack of 4
send a packet with a seq of 5
Recv a ack of 5
send a packet with a seq of 6
Recv a ack of 6
send a packet with a seq of 7
Recv a ack of 7
send a packet with a seq of 8
Recv a ack of 8
send a packet with a seq of 9
Recv a ack of 9
send a packet with a seq of 10
Recv a ack of 10
send a packet with a seq of 11
Recv a ack of 11
send a packet with a seq of 12
send a packet with a seq of 13
Recv a ack of 11
send a packet with a seq of 14
Recv a ack of 11
send a packet with a seq of 15
send a packet with a seq of 16
Recv a ack of 11
send a packet with a seq of 17
Recv a ack of 11
send a packet with a seq of 18
Recv a ack of 11
send a packet with a seq of 19
Recv a ack of 11
send a packet with a seq of 0
Recv a ack of 11
send a packet with a seq of 1
Recv a ack of 11
Timer out error.
send a packet with a seq of 12

```

服务器端界面，其中数据包12未收到ack信息

```

Within social sciences, cultural economists show how video games playing is conducive to the
involvement in more traditional art forms and cultural practices, which suggests the compleme
ntarity between video games and the arts. [32]

In May 2011, the National Endowment of the Arts included video games in its redefinition of w
hat is considered a "work of art"
send a ack of 4
recv a packet with a seq of 5
when applying for a grant. [33] In 2012, the Smithsonian American Art Museum presented an exh
ibit, The Art of the Video Game. [34] Reviews of the exhibit were mixed, including questioning
whether video games belong in an art museum.
send a ack of 5
All Finished!

*****
-time to get current time
-quit to exit client
-testgbn [X] [Y] to test the gbn
-testgbn_send [X] [Y] to test the gbn
*****

```

客户端接收完毕

```
send a packet with a seq of 2
Recv a ack of 2
send a packet with a seq of 3
Recv a ack of 3
send a packet with a seq of 4
Recv a ack of 4
recv from client: All Finished!
```

收完毕

服务器端发送完毕

```
选择D:\Codefield\Workplace\reliabledatatrans\GBN_Client\Release\GBN_Client.exe
Recv a ack of 1
send a packet with a seq of 2
Recv a ack of 2
send a packet with a seq of 3
Recv a ack of 3
send a packet with a seq of 4
Recv a ack of 4
send a packet with a seq of 5
Recv a ack of 5
send a packet with a seq of 6
Recv a ack of 6
send a packet with a seq of 7
Recv a ack of 7
send a packet with a seq of 8
Recv a ack of 8
send a packet with a seq of 9
Recv a ack of 9
send a packet with a seq of 10
Recv a ack of 10
send a packet with a seq of 11
Recv a ack of 11
send a packet with a seq of 12
Recv a ack of 12
send a packet with a seq of 13
Recv a ack of 13
send a packet with a seq of 14
Recv a ack of 14
send a packet with a seq of 15
Recv a ack of 15
send a packet with a seq of 16
Recv a ack of 16
send a packet with a seq of 17
Recv a ack of 17
send a packet with a seq of 18
Recv a ack of 18
send a packet with a seq of 19
Recv a ack of 19
send a packet with a seq of 0
Recv a ack of 0
send a packet with a seq of 1
Recv a ack of 1
send a packet with a seq of 2
Recv a ack of 2
send a packet with a seq of 3
Recv a ack of 3
send a packet with a seq of 4
Recv a ack of 4
All Finished!
*****
```

双向通信中的客户端



```

D:\Codefield\Workplace\reliabledatatrans\GBN_Server\Debug\GBN_Server.exe
considered as arts.[28]
Applied arts
Main article: Applied arts
The applied arts are the application of design and decoration to everyday, functional, object
s to make them aesthetically pleasing.[29] The applied arts includes fields such as industria
l design, illustration, and commercial art.[30] The term "applied art" is used in distinction
to the fine arts, where the latter is defined as arts that aims to produce objects which are
beautiful or provide intellectual stimulation but have no primary everyday function. In prac
tice, the two often overlap.
Video games
See also: Video games as an art form
A debate exists in the fine arts and video game cultures ov
send a ack of 3
recv a packet with a seq of 4
er whether video games can be counted as an art form.[31] Game designer Hideo Kojima professe
s that video games are a type of service, not an art form, because they are meant to entertai
n and attempt to entertain as many people as possible, rather than being a single artistic vo
ice (despite Kojima himself being considered a gaming auteur, and the mixed opinions his game
s typically receive). However, he acknowledged that since video games are made up of artistic
elements (for example, the visuals), game designers could be considered museum curators 欽?n
ot creating artistic pieces, but arranging them in a way that displays their artistry and sel
ls tickets.
Within social sciences, cultural economists show how video games playing is conducive to the
involvement in more traditional art forms and cultural practices, which suggests the compleme
ntarity between video games and the arts.[32]
In May 2011, the National Endowment of the Arts included video games in its redefinition of w
hat is considered a "work of art"
send a ack of 4
recv a packet with a seq of 5
when applying for a grant.[33] In 2012, the Smithsonian American Art Museum presented an exh
ibit, The Art of the Video Game.[34] Reviews of the exhibit were mixed, including questioning
whether video games belong in an art museum.
send a ack of 5

```

双向通信中的服务器端，所有信息接收完毕

## 2. SR传输协议

```

D:\Codefield\Workplace\reliabledatrans\SR_Client\Debug\SR_Client.exe
-quit to exit client
-testsr [X] [Y] to test the gbn
*****
-testsr 0.1 0.1 Times New Roman 小四 A A Aa A
Begin to test GBN protocol, please don't abort the process
The loss ratio of packet is 0.10, the loss ratio of ack is 0.10
Ready for file transmission
recv a packet with a seq of 1
This article is about the group of creative disciplines. For the concept of art, see Art. For
other uses, see Art (disambiguation).
"Arts" redirects here. For the acronym, see ARTS.

问题讨论:
1. 问题: 添加If-Modified并发送之后总是反馈
原因: 报文最后有两个空行, 即两个 "\r\n"
2. 在发送If-Modified之后报文中会出现两个
原因: 浏览器本身的cache储存报文之后会在
添加一个If-Modified请求, 就会有两个相同
时浏览器缓存会对我们的代理产生许多其他

Clockwise, from left to right:
A tambourine player at a traditional debaa dance festival in Mayotte
Still Life with Profile of Laval by Paul Gauguin
The title page of Shakespeare's sonnets in a 1609 edition by Thomas Thorpe
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A Bian Lian performer.
The arts are a very wide range of human practices of creative expression, storytelling and cu
ltural participation. They encompass multiple diverse and plural modes of thinking, doing and
being, in an extremely broad range of media. Both highly dynamic and a characteristically co
nstant feature of human life, they have developed into innovative, stylized and sometimes int
ricate forms. This is often achieved through sustained and deliberate study, training and/or
theorizing within a particular tradition, across generations and even between
send a ack of 1
The packet with a seq of 2 loss
recv a packet with a seq of 3
self-contained, or combine and interweave with other art forms, such as the combination of art
work with the written word in comics. They can also develop or contribute to some particular
aspect of a more complex art form, as in cinematography.

By definition, the arts themselves are open to being continually re-defined. The practice of
modern art, for example, is a testament to the shifting boundaries, improvisation and experim
entation, reflexive nature, and self-criticism or questioning that art and its conditions of
production, reception, and possibility can undergo.

As both a means of developing capacities of attention and sensitivity, and as ends in themsel
ves, the arts can simultaneously be a form of response to the world, and a way that our respo
nses, and what we deem worthwhile goals or pursuits, are transformed. From prehistoric cave p
aintings, to ancient and contemporary forms of ritual, to modern-day films, art has served to
register, embody and preserve our ever shifting relationships to each other
send a ack of 3
recv a packet with a seq of 4
and to the world.

```

SR协议中的客户端

```

选择D:\Codefield\Workplace\reliabledatrans\SR_Server\Debug\SR_Server.exe
send a packet with a seq of 0
Recv a ack of 0
send a packet with a seq of 1
send a packet with a seq of 2
Recv a ack of 2
send a packet with a seq of 3
Recv a ack of 3
send a packet with a seq of 4
Recv a ack of 4
send a packet with a seq of 5
send a packet with a seq of 6
Recv a ack of 6
send a packet with a seq of 7
Recv a ack of 7
send a packet with a seq of 8
Recv a ack of 8
send a packet with a seq of 9
send a packet with a seq of 10
Recv a ack of 10
Timer out error.
send a packet with a seq of 1
Recv a ack of 1
send a packet with a seq of 5
send a packet with a seq of 6
send a packet with a seq of 7
Recv a ack of 7
send a packet with a seq of 8
Recv a ack of 8
send a packet with a seq of 9
Recv a ack of 9
send a packet with a seq of 10
Recv a ack of 10
send a packet with a seq of 11
send a packet with a seq of 12
Recv a ack of 12
send a packet with a seq of 13
send a packet with a seq of 14
Recv a ack of 14
Timer out error.
send a packet with a seq of 5
Recv a ack of 5
send a packet with a seq of 6
Recv a ack of 6
send a packet with a seq of 11
Recv a ack of 11
send a packet with a seq of 13
send a packet with a seq of 14
send a packet with a seq of 15
Recv a ack of 15
send a packet with a seq of 16

```

SR协议中的服务器端

可见其中多次发生未收到ACK的情况，分别进行了重新发送

#### 问题讨论：

1. 问题：返回数据错乱  
原因：数据包序列号需要减一才能和窗口的位置相对应。
2. 问题：窗口总是被覆盖  
原因：忘记保证发送端滑动窗口的序号数目 + 接受端滑动窗口的序号数目  $\leq$  分组编号数目

#### 心得体会：

经过此次实验，熟悉了停等协议、GBN协议和SR协议的工作原理以及区别，了解了滑动窗口这一巧妙的设计思想，通过停等协议到GBN协议，再到SR协议的演变，数据传输的效率不停增加，工作原理也越来越复杂。

## GBN\_Server.cpp

```
#include <stdlib.h>
#include <time.h>
#include <WinSock2.h>
#include <fstream>
#pragma comment(lib,"ws2_32.lib")
#define SERVER_PORT 12340 //端口号
#define SERVER_IP "0.0.0.0" //IP 地址
const int PACKET_NUM = 25;
const int BUFFER_LENGTH = 1026; //缓冲区大小, (以太网中 UDP 的数据帧中包长度应小于 1480 字节)
const int SEND_WIND_SIZE = 10; //发送窗口大小为 10, GBN 中应满足  $W + 1 \leq N$  (W 为发送窗口大小, N 为序列号个数)
//本例取序列号 0...19 共 20 个
//如果将窗口大小设为 1, 则为停-等协议
const int SEQ_SIZE = 20; //序列号的个数, 从 0~19 共计 20 个
//由于发送数据第一个字节如果值为 0, 则数据会发送失败, 因为 0 直接代表字符串的结尾了
//因此接收端序列号为 1~20, 与发送端一一对应
BOOL ack[SEQ_SIZE]; //收到 ack 情况, 对应 0~19 的 ack
int curSeq; //当前数据包的 seq
int curAck; //当前等待确认的 ack
int totalSeq; //收到的包的总数
int totalPacket; //需要发送的包总数
int totalAck; //已经确认的总数, 用于判断是否可以停止传输
//*****

// Method: lossInLossRatio
// FullName: lossInLossRatio
// Access: public
// Returns: BOOL
// Qualifier: 根据丢失率随机生成一个数字, 判断是否丢失, 丢失则返回 TRUE, 否则返回 FALSE
// Parameter: float lossRatio [0,1]
//*****

BOOL lossInLossRatio(float lossRatio) {
    int lossBound = (int)(lossRatio * 100);
    int r = rand() % 100;
    if (r < lossBound) {
        return TRUE;
    }
}
```

```
        return FALSE;
    }
//*****
// Method: getCurTime
// FullName: getCurTime
// Access: public
// Returns: void
// Qualifier: 获取当前系统时间, 结果存入 ptime 中
// Parameter: char * ptime
//*****
void getCurTime(char* ptime) {
    char buffer[128];
    memset(buffer, 0, sizeof(buffer));
    time_t c_time;
    struct tm* p;
    time(&c_time);
    p = localtime(&c_time);
    sprintf_s(buffer, "%d/%d/%d %d:%d:%d", p->tm_year + 1900,
        p->tm_mon, p->tm_mday, p->tm_hour, p->tm_min, p->tm_sec);
    strcpy_s(ptime, sizeof(buffer), buffer);
}
//*****
// Method: seqIsAvailable
// FullName: seqIsAvailable
// Access: public
// Returns: bool
// Qualifier: 当前序列号 curSeq 是否可用
//*****
bool seqIsAvailable() {
    int step;
    step = curSeq - curAck;
    step = step >= 0 ? step : step + SEQ_SIZE; //序列号是循环使用的
    //序列号是否在当前发送窗口之内
    if (step >= SEND_WIND_SIZE) {
        return false;
    }
    if (ack[curSeq]) {
        return true;
    }
    return false;
}
//*****
// Method: timeoutHandler
// FullName: timeoutHandler
```

```
// Access: public
// Returns: void
// Qualifier: 超时重传处理函数，滑动窗口内的数据帧都要重传
//*****

void timeoutHandler() {
    printf("Timer out error.\n");
    int index;
    int res = 0;
    for (int i = 0; i < SEND_WIND_SIZE; ++i) {
        //将已经发出去的，还没收到 ack 的，重新置为还没发
        index = (i + curAck) % SEQ_SIZE;
        if (ack[index] == FALSE)res++;
        ack[index] = TRUE;
    }
    totalSeq -= res;
    curSeq = curAck;
}
//*****

// Method: ackHandler
// FullName: ackHandler
// Access: public
// Returns: void
// Qualifier: 收到 ack，累积确认，取数据帧的第一个字节
//由于发送数据时，第一个字节（序列号）为 0（ASCII）时发送失败，因此加一了，此处
需要减一还原
// Parameter: char c
//*****

void ackHandler(char c) {
    unsigned char index = (unsigned char)c - 1; //序列号减一
    printf("Recv a ack of %d\n", index);
    if (curAck <= index) {
        for (int i = curAck; i <= index; ++i) {
            ack[i] = TRUE;
            totalAck++;
        }
        curAck = (index + 1) % SEQ_SIZE;
    }
    else {
        //这种情况可能有两种原因导致，一种是发生丢包，另一种是用于序列号循环使用
        //但考虑到发生连续好几个 ack 都丢了的概率较低，根据两者差值判断是哪种情况
        //ack 超过了最大值，回到了 curAck 的左边
        if (curAck - index > SEND_WIND_SIZE) {
```



```
        for (int i = curAck; i < SEQ_SIZE; ++i) {
            ack[i] = TRUE;
            totalAck++;
        }
        for (int i = 0; i <= index; ++i) {
            ack[i] = TRUE;
            totalAck++;
        }
    }
    curAck = index + 1;
}
}

//主函数
int main(int argc, char* argv[]) {
    //加载套接字库（必须）
    WORD wVersionRequested;
    WSADATA wsaData;
    //套接字加载时错误提示
    int err;
    //版本 2.2
    wVersionRequested = MAKEWORD(2, 2);
    //加载 dll 文件 Scket 库
    err = WSAStartup(wVersionRequested, &wsaData);
    if (err != 0) {
        //找不到 winsock.dll
        printf("WSAStartup failed with error: %d\n", err);
        return -1;
    }
    if (LOBYTE(wsaData.wVersion) != 2 || HIBYTE(wsaData.wVersion) != 2)
    {
        printf("Could not find a usable version of Winsock.dll\n");
        WSACleanup();
    }
    else {
        printf("The Winsock 2.2 dll was found okay\n");
    }

    //双向传输，所以服务器端也要设置丢包率
    float packetLossRatio = 0;
    float ackLossRatio = 0;
    srand((unsigned)time(NULL));

    SOCKET sockServer = socket(AF_INET, SOCK_DGRAM, IPPROTO_UDP);
    //设置套接字为非阻塞模式
```

```
int iMode = 1; //1: 非阻塞, 0: 阻塞
ioctlsocket(sockServer, FIONBIO, (u_long FAR*) & iMode); //非阻塞设置
SOCKADDR_IN addrServer; //服务器地址
//addrServer.sin_addr.S_un.S_addr = inet_addr(SERVER_IP);
addrServer.sin_addr.S_un.S_addr = htonl(INADDR_ANY); //两者均可
addrServer.sin_family = AF_INET;
addrServer.sin_port = htons(SERVER_PORT);
err = bind(sockServer, (SOCKADDR*)&addrServer, sizeof(SOCKADDR));
if (err) {
    err = GetLastError();
    printf("Could not bind the port %d for socket. Error code is %d\n", SERVER_PORT,
err);
    WSACleanup();
    return -1;
}
SOCKADDR_IN addrClient; //客户端地址
int length = sizeof(SOCKADDR);
char buffer[BUFFER_LENGTH]; //数据发送接收缓冲区
ZeroMemory(buffer, sizeof(buffer));
//将测试数据读入内存
std::ifstream icin;
icin.open("../test.txt");
char data[1024 * PACKET_NUM];
ZeroMemory(data, sizeof(data));
icin.read(data, 1024 * PACKET_NUM);
icin.close();
totalPacket = sizeof(data) / 1024;
//printf("%d\n", totalPacket);
int recvSize;
for (int i = 0; i < SEQ_SIZE; ++i) {
    ack[i] = TRUE;
}
while (true) {
    //非阻塞接收, 若没有收到数据, 返回值为-1
    recvSize = recvfrom(sockServer, buffer, BUFFER_LENGTH, 0,
((SOCKADDR*)&addrClient), &length);
    if (recvSize < 0) {
        Sleep(200);
        continue;
    }
    printf("recv from client: %s\n", buffer);
    if (strcmp(buffer, "-time") == 0) {
        getCurTime(buffer);
    }
}
```

```

else if (strcmp(buffer, "-quit") == 0) {
    strcpy_s(buffer, strlen("Good bye!") + 1, "Good bye!");
}
else if (strcmp(buffer, "-testgbn") == 0) {
    //进入 gbn 测试阶段
    //首先 server (server 处于 0 状态) 向 client 发送 205 状态码 (server 进入 1 状态)
    //server 等待 client 回复 200 状态码, 如果收到 (server 进入 2 状态), 则开始传输文件, 否则延时等待直至超时
    //在文件传输阶段, server 发送窗口大小设为
    for (int i = 0; i < SEQ_SIZE; ++i) {
        ack[i] = TRUE;
    }
    ZeroMemory(buffer, sizeof(buffer));
    int recvSize;
    int waitCount = 0;
    printf("Begin to test GBN protocol, please don't abort the process\n");
    //加入了一个握手阶段
    //首先服务器向客户端发送一个 205 的状态码 (我自己定义的) 表示服务器准备好了, 可以发送数据
    //客户端收到 205 之后回复一个 200 的状态码, 表示客户端准备好了, 可以接收数据了
    //服务器收到 200 状态码之后, 就开始使用 GBN 发送数据了
    printf("Shake hands stage\n");
    int stage = 0;
    bool runningFlag = true;
    int isFinished = 0;
    while (runningFlag) {
        if (isFinished) {
            break;
        }
        switch (stage) {
            case 0://发送 205 阶段
                buffer[0] = 205;
                sendto(sockServer, buffer, strlen(buffer) + 1, 0, (SOCKADDR*)&addrClient, sizeof(SOCKADDR));
                Sleep(100);
                stage = 1;
                break;
            case 1://等待接收 200 阶段, 没有收到则计数器+1, 超时则放弃此次“连接”, 等待从第一步开始
                recvSize = recvfrom(sockServer, buffer, BUFFER_LENGTH, 0, (SOCKADDR*)&addrClient, &length);
                if (recvSize < 0) {

```

```

        ++waitCount;
        if (waitCount > 20) {
            runningFlag = false;
            printf("Timeout error\n");
            break;
        }
        Sleep(500);
        continue;
    }
    else {
        if ((unsigned char)buffer[0] == 200) {
            printf("Begin a file transfer\n");
            printf("File size is %dB, each packet is 1024B and packet total
num is % d\n", sizeof(data), totalPacket);
            curSeq = 0;
            curAck = 0;
            totalSeq = 0;
            totalAck = 0;
            waitCount = 0;
            stage = 2;
        }
    }
    break;
case 2://数据传输阶段
    if (seqIsAvailable() && totalSeq < totalPacket) { //第二个判断是处理已
经发出但因为部分 ack 丢失，还未确认的情况。这时是暂时不需要传的
        //发送给客户端的序列号从 1 开始
        buffer[0] = curSeq + 1;
        ack[curSeq] = FALSE;
        //数据发送的过程中应该判断是否传输完成
        //为简化过程此处并未实现
        memcpy(&buffer[1], data + 1024 * totalSeq, 1024);
        printf("send a packet with a seq of %d\n", curSeq);
        sendto(sockServer, buffer, BUFFER_LENGTH, 0,
(SOCKADDR*)&addrClient, sizeof(SOCKADDR));
        ++curSeq;
        curSeq %= SEQ_SIZE;
        ++totalSeq;
        Sleep(500);
    }
    //等待 Ack，若没有收到，则返回值为-1，计数器+1
    recvSize = recvfrom(sockServer, buffer, BUFFER_LENGTH, 0,
((SOCKADDR*)&addrClient), &length);
    if (recvSize < 0) {

```

```

        waitCount++;
        //20 次等待 ack 则超时重传
        if (waitCount > 20)
        {
            timeoutHandler();
            waitCount = 0;
        }
    }
    else {
        //收到 ack
        ackHandler(buffer[0]);
        waitCount = 0;
        //printf("%d\n", totalAck);
        if (totalAck == totalPacket) {
            isFinished = 1;
            strcpy(buffer, "All Finished!\n");
        }
    }
    Sleep(500);
    break;
}
}
}

else if (strcmp(buffer, "-testgbn_send") == 0) { //双向传输的情况，服务器传的情况
已经测试过了，所以这里测试服务器收
    FILE* fser = fopen("serverfile.txt", "w+");
    int iMode = 0; //1: 非阻塞，0: 阻塞
    ioctlsocket(sockServer, FIONBIO, (u_long FAR*)& iMode); //阻塞设置
    printf("%s\n", "Begin to test GBN protocol, please don't abort the process");
    printf("The loss ratio of packet is %.2f,the loss ratio of ack is %.2f\n",
packetLossRatio, ackLossRatio);
    int waitCount = 0;
    int stage = 0;
    BOOL b;
    unsigned char u_code; //状态码
    unsigned short seq; //包的序列号
    unsigned short recvSeq; //接收窗口大小为 1，已确认的序列号
    unsigned short waitSeq; //等待的序列号
    int len = sizeof(SOCKADDR);
    while (true)
    {
        //等待 server 回复设置 UDP 为阻塞模式
        recvfrom(sockServer, buffer, BUFFER_LENGTH, 0,
(SOCKADDR*)&addrClient, &len);

```

```
if (strcmp(buffer, "All Finished!\n") == 0) {
    fclose(fser); //写完之后关闭文件
    break;
}
switch (stage) {
case 0: //等待握手阶段
    u_code = (unsigned char)buffer[0];
    if ((unsigned char)buffer[0] == 205)
    {
        printf("Ready for file transmission\n");
        buffer[0] = 200;
        buffer[1] = '\0';
        sendto(sockServer, buffer, 2, 0, (SOCKADDR*)&addrClient,
sizeof(SOCKADDR));

        stage = 1;
        recvSeq = 0;
        waitSeq = 1;
    }
    break;
case 1: //等待接收数据阶段
    seq = (unsigned short)buffer[0];
    //随机法模拟包是否丢失
    b = lossInLossRatio(packetLossRatio);
    if (b) {
        printf("The packet with a seq of %d loss\n", seq);
        continue;
    }
    printf("recv a packet with a seq of %d\n", seq);
    //如果是期待的包，正确接收，正常确认即可
    if (!(waitSeq - seq)) {
        ++waitSeq;
        fwrite(&buffer[1], sizeof(char), strlen(buffer) - 1, fser);
        if (waitSeq == 21) {
            waitSeq = 1;
        }
        //输出数据
        printf("%s\n", &buffer[1]);
        buffer[0] = seq;
        recvSeq = seq;
        buffer[1] = '\0';
    }
    else {
        //如果当前一个包都没有收到，则等待 Seq 为 1 的数据包，
        不是则不返回 ACK（因为并没有上一个正确的 ACK）
    }
}
```

```
        if (!recvSeq) {
            continue;
        }
        buffer[0] = recvSeq;
        buffer[1] = '\0';
    }
    b = lossInLossRatio(ackLossRatio);
    if (b) {
        printf("The ack of %d loss\n", (unsigned char)buffer[0]);
        continue;
    }
    sendto(sockServer, buffer, 2, 0, (SOCKADDR*)&addrClient,
sizeof(SOCKADDR));
    printf("send a ack of %d\n", (unsigned char)buffer[0]);
    break;
}
Sleep(500);
}
}
//printf("%s\n", buffer);
sendto(sockServer, buffer, strlen(buffer) + 1, 0, (SOCKADDR*)&addrClient,
sizeof(SOCKADDR));
Sleep(500);
}
//关闭套接字，卸载库
closesocket(sockServer);
WSACleanup();
return 0;
}
```

## GBN\_Client.cpp

```
// GBN_client.cpp : 定义控制台应用程序的入口点。
//
#include <stdlib.h>
#include <WinSock2.h>
#include <time.h>
#include <stdio.h>
#include <fstream>
#pragma comment(lib, "ws2_32.lib")
#define SERVER_PORT 12340 //接收数据的端口号
#define SERVER_IP "127.0.0.1" // 服务器的 IP 地址
const int BUFFER_LENGTH = 1026;
const int PACKET_NUM = 25;
```

```
const int SEQ_SIZE = 20; //接收端序列号个数, 为 1~20
const int SEND_WIND_SIZE = 10; //发送窗口大小为 10, GBN 中应满足  $W + 1 \leq N$  (W 为发送窗口大小, N 为序列号个数)

BOOL ack[SEQ_SIZE]; //收到 ack 情况, 对应 0~19 的 ack
int curSeq; //当前数据包的 seq
int curAck; //当前等待确认的 ack
int totalPacket; //需要发送的包总数

int totalSeq; //已发送的包的总数
int totalAck; //确认收到 (ack) 的包的总数
/*****
/* -time 从服务器端获取当前时间
-quit 退出客户端
-testgbn [X][Y] 测试 GBN 协议实现可靠数据传输
[X] [0,1] 模拟数据包丢失的概率
[Y] [0,1] 模拟 ACK 丢失的概率
*/
*****/

void printTips() {
    printf("*****\n");
    printf("| -time to get current time | \n");
    printf("| -quit to exit client | \n");
    printf("| -testgbn [X] [Y] to test the gbn | \n");
    printf("| -testgbn_send [X] [Y] to test the gbn | \n");
    printf("*****\n");
}

/*****
// Method: lossInLossRatio
// FullName: lossInLossRatio
// Access: public
// Returns: BOOL
// Qualifier: 根据丢失率随机生成一个数字, 判断是否丢失, 丢失则返回 TRUE, 否则返回 FALSE
// Parameter: float lossRatio [0,1]
*****/

BOOL lossInLossRatio(float lossRatio) {
    int lossBound = (int)(lossRatio * 100);
    int r = rand() % 100;
    if (r < lossBound) {
        return TRUE;
    }
    return FALSE;
}
```



```

/*****
// Method: seqIsAvailable
// FullName: seqIsAvailable
// Access: public
// Returns: bool
// Qualifier: 当前序列号 curSeq 是否可用
*****/
bool seqIsAvailable() {
    int step;
    step = curSeq - curAck;
    step = step >= 0 ? step : step + SEQ_SIZE;
    //序列号是否在当前发送窗口之内
    if (step >= SEND_WIND_SIZE) {
        return false;
    }
    if (ack[curSeq]) {
        return true;
    }
    return false;
}

/*****
// Method: timeoutHandler
// FullName: timeoutHandler
// Access: public
// Returns: void
// Qualifier: 超时重传处理函数，滑动窗口内的数据帧都要重传
*****/
void timeoutHandler() {
    printf("Timer out error.\n");
    int index;
    int res = 0;
    for (int i = 0; i < SEND_WIND_SIZE; ++i) { //将已经发出去的，还没收到 ack 的，重新置为还没发
        index = (i + curAck) % SEQ_SIZE;
        if (ack[index] == FALSE) res++;
        ack[index] = TRUE;
    }
    totalSeq -= res; // 重置数量
    curSeq = curAck;
}

/*****
// Method: ackHandler
// FullName: ackHandler
// Access: public

```

```

// Returns: void
// Qualifier: 收到 ack, 累积确认, 取数据帧的第一个字节
//由于发送数据时, 第一个字节(序列号)为 0 (ASCII) 时发送失败, 因此加一了, 此处
需要减一还原
// Parameter: char c
//*****
void ackHandler(char c) {
    unsigned char index = (unsigned char)c - 1; //序列号减一
    printf("Recv a ack of %d\n", index);
    if (curAck <= index) {
        for (int i = curAck; i <= index; ++i) { //对当前的 ack 进行标记
            ack[i] = TRUE;
            totalAck++;
        }
        curAck = (index + 1) % SEQ_SIZE;
    }
    else {
        //这种情况可能有两种原因导致, 一种是发生丢包, 另一种是用于序列号循环使
        //但考虑到发生连续好几个 ack 都丢了的概率较低, 根据两者差值判断是哪种情
        //ack 超过了最大值, 回到了 curAck 的左边
        if (curAck - index > SEND_WIND_SIZE) {
            for (int i = curAck; i < SEQ_SIZE; ++i) {
                ack[i] = TRUE;
                totalAck++;
            }
            for (int i = 0; i <= index; ++i) {
                ack[i] = TRUE;
                totalAck++;
            }
        }
        curAck = index + 1;
    }
}

int main(int argc, char* argv[]) {
    //加载套接字库(必须)
    WORD wVersionRequested;
    WSADATA wsaData;
    //套接字加载时错误提示
    int err;
    //版本 2.2
    wVersionRequested = MAKEWORD(2, 2);
    //加载 dll 文件 Scket 库

```

```
err = WSASStartup(wVersionRequested, &wsaData);
if (err != 0) {
    //找不到 winsock.dll
    printf("WSASStartup failed with error: %d\n", err);
    return 1;
}
if (LOBYTE(wsaData.wVersion) != 2 || HIBYTE(wsaData.wVersion) != 2) {
    printf("Could not find a usable version of Winsock.dll\n");
    WSACleanup();
}
else {
    printf("The Winsock 2.2 dll was found okay\n");
}
SOCKET socketClient = socket(AF_INET, SOCK_DGRAM, 0);
SOCKADDR_IN addrServer;
addrServer.sin_addr.S_un.S_addr = inet_addr(SERVER_IP);
addrServer.sin_family = AF_INET;
addrServer.sin_port = htons(SERVER_PORT);
//接收缓冲区
char buffer[BUFFER_LENGTH];
ZeroMemory(buffer, sizeof(buffer));
int len = sizeof(SOCKADDR);
//为了测试与服务器的连接，可以使用 -time 命令从服务器端获得当前时间
//使用 -testgbn [X] [Y] 测试 GBN 其中[X]表示数据包丢失概率
// [Y]表示 ACK 丢包概率
printTips();
int ret;
int interval = 1;//收到数据包之后返回 ack 的间隔，默认为 1 表示每个都返回 ack，
0 或者负数均表示所有的都不返回 ack
char cmd[128];
float packetLossRatio = 0; //默认包丢失率 0.2
float ackLossRatio = 0; //默认 ACK 丢失率 0.2
//用时间作为随机种子，放在循环的最外面
srand((unsigned)time(NULL));

//将测试数据读入内存
std::ifstream icin;
icin.open("../test.txt");
char data[1024 * PACKET_NUM];
ZeroMemory(data, sizeof(data));
icin.read(data, 1024 * PACKET_NUM);
icin.close();
totalPacket = sizeof(data) / 1024;
int recvSize;
```

```

for (int i = 0; i < SEQ_SIZE; ++i) ack[i] = TRUE;
while (true) {
    gets_s(buffer);
    ret = sscanf(buffer, "%s%f%f", &cmd, &packetLossRatio, &ackLossRatio);
    //开始 GBN 测试, 使用 GBN 协议实现 UDP 可靠文件传输
    if (!strcmp(cmd, "-testgbn")) {
        FILE* fcli = fopen("clientfile.txt", "w+");
        printf("%s\n", "Begin to test GBN protocol, please don't abort the process");
        printf("The loss ratio of packet is %.2f,the loss ratio of ack
is %.2f\n", packetLossRatio, ackLossRatio);
        int waitCount = 0;
        int stage = 0;
        BOOL b;
        unsigned char u_code; //状态码
        unsigned short seq; //包的序列号
        unsigned short recvSeq; //接收窗口大小为 1, 已确认的序列号
        unsigned short waitSeq; //等待的序列号
        sendto(socketClient, "-testgbn", strlen("-testgbn") + 1, 0,
(SOCKADDR*)&addrServer, sizeof(SOCKADDR));
        while (true) {
            //等待 server 回复设置 UDP 为阻塞模式
            recvfrom(socketClient, buffer, BUFFER_LENGTH, 0,
(SOCKADDR*)&addrServer, &len);
            if (strcmp(buffer, "All Finished!\n") == 0) {
                fclose(fcli);
                break;
            }
            switch (stage) {
            case 0: //等待握手阶段
                u_code = (unsigned char)buffer[0];
                if ((unsigned char)buffer[0] == 205)
                {
                    printf("Ready for file transmission\n");
                    buffer[0] = 200;
                    buffer[1] = '\0';
                    sendto(socketClient, buffer, 2, 0, (SOCKADDR*)&addrServer,
sizeof(SOCKADDR));

                    stage = 1;
                    recvSeq = 0;
                    waitSeq = 1;
                }
                break;
            case 1: //等待接收数据阶段
                seq = (unsigned short)buffer[0];

```

```
//随机法模拟包是否丢失
b = lossInLossRatio(packetLossRatio);
if (b) {
    printf("The packet with a seq of %d loss\n", seq);
    continue;
}
printf("recv a packet with a seq of %d\n", seq);
//如果是期待的包，正确接收，正常确认即可
if (!(waitSeq - seq)) {
    ++waitSeq;
    // 将接收的文件写入输出文件中
    fwrite(&buffer[1], sizeof(char), strlen(buffer) - 1, fcli);
    if (waitSeq == 21) {
        waitSeq = 1;
    }
    //输出数据
    printf("%s\n", &buffer[1]);
    buffer[0] = seq;
    recvSeq = seq;
    buffer[1] = '\0';
}
else {
    //如果当前一个包都没有收到，则等待 Seq 为 1 的数据包，
    //不是则不返回 ACK（因为并没有上一个正确的 ACK）
    if (!recvSeq) {
        continue;
    }
    buffer[0] = recvSeq;
    buffer[1] = '\0';
}
b = lossInLossRatio(ackLossRatio);
if (b) {
    printf("The ack of %d loss\n", (unsigned char)buffer[0]);
    continue;
}
sendto(socketClient, buffer, 2, 0, (SOCKADDR*)&addrServer,
sizeof(SOCKADDR));
printf("send a ack of %d\n", (unsigned char)buffer[0]);
break;
}
Sleep(500);
}
}
else if (strcmp(cmd, "-testgbn_send") == 0) {
```

```

//进入 gbn 测试阶段
//首先 server (server 处于 0 状态) 向 client 发送 205 状态码 (server 进入 1 状态)
//server 等待 client 回复 200 状态码, 如果收到 (server 进入 2 状态), 则开始传输文件, 否则延时等待直至超时
//在文件传输阶段, server 发送窗口大小设为 20
for (int i = 0; i < SEQ_SIZE; ++i) {
    ack[i] = TRUE;
}
ZeroMemory(buffer, sizeof(buffer));
int recvSize;
int waitCount = 0;
printf("Begin to test GBN protocol, please don't abort the process\n");
//加入了一个握手阶段
//首先服务器向客户端发送一个 205 的状态码 (我自己定义的) 表示服务器准备好了, 可以发送数据
//客户端收到 205 之后回复一个 200 的状态码, 表示客户端准备好了, 可以接收数据了
//服务器收到 200 状态码之后, 就开始使用 GBN 发送数据了
printf("Shake hands stage\n");
int stage = 0;
bool runningFlag = true;
int flag = 0;
sendto(socketClient, "-testgbn_send", strlen("-testgbn_send") + 1, 0, (SOCKADDR*)&addrServer, sizeof(SOCKADDR));
int iMode = 1; //1: 非阻塞, 0: 阻塞
ioctlsocket(socketClient, FIONBIO, (u_long FAR*)&iMode); //非阻塞设置
while (runningFlag) {
    if (flag) {
        break;
    }
    switch (stage) {
        case 0: //发送 205 阶段
            buffer[0] = 205;
            sendto(socketClient, buffer, strlen(buffer) + 1, 0, (SOCKADDR*)&addrServer, sizeof(SOCKADDR));
            Sleep(100);
            stage = 1;
            break;
        case 1: //等待接收 200 阶段, 没有收到则计数器+1, 超时则放弃此次“连接”, 等待从第一步开始
            recvSize = recvfrom(socketClient, buffer, BUFFER_LENGTH, 0, (SOCKADDR*)&addrServer, &len);
            if (recvSize < 0) {

```

```

        ++waitCount;
        if (waitCount > 20) {
            runningFlag = false;
            printf("Timeout error\n");
            break;
        }
        Sleep(500);
        continue;
    }
    else {
        if ((unsigned char)buffer[0] == 200) {
            printf("Begin a file transfer\n");
            printf("File size is %dB, each packet is 1024B and packet total
num is %d\n", sizeof(data), totalPacket);
            curSeq = 0;
            curAck = 0;
            totalSeq = 0;
            totalAck = 0;
            waitCount = 0;
            stage = 2;
        }
    }
    break;
case 2://数据传输阶段
    if (seqIsAvailable() && totalSeq < totalPacket) { //第二个判断是处理
已经发出但因为部分 ack 丢失，还未确认的情况。这时是暂时不需要传的
        //发送给客户端的序列号从 1 开始
        buffer[0] = curSeq + 1;
        ack[curSeq] = FALSE;
        //数据发送的过程中应该判断是否传输完成
        //为简化过程此处并未实现
        memcpy(&buffer[1], data + 1024 * totalSeq, 1024);
        printf("send a packet with a seq of %d\n", curSeq);
        sendto(socketClient,    buffer,    BUFFER_LENGTH,    0,
(SOCKADDR*)&addrServer, sizeof(SOCKADDR));
        ++curSeq;
        curSeq %= SEQ_SIZE;
        ++totalSeq;
        Sleep(500);
    }
    //等待 Ack，若没有收到，则返回值为-1，计数器+1
    recvSize = recvfrom(socketClient, buffer, BUFFER_LENGTH, 0,
((SOCKADDR*)&addrServer), &len);
    if (recvSize < 0) {

```

```
        waitCount++;
        //20 次等待 ack 则超时重传
        if (waitCount > 20)
        {
            timeoutHandler();
            waitCount = 0;
        }
    }
    else {
        //收到 ack
        ackHandler(buffer[0]);
        waitCount = 0;
        // printf("%d\n", totalAck);
        if (totalAck == totalPacket) {
            flag = 1;
            strcpy(buffer, "All Finished!\n");
        }
    }
    Sleep(500);
    break;
}

}

}

//printf("%s\n", buffer);
sendto(socketClient, buffer, strlen(buffer) + 1, 0, (SOCKADDR*)&addrServer,
sizeof(SOCKADDR));
ret = recvfrom(socketClient, buffer, BUFFER_LENGTH, 0,
(SOCKADDR*)&addrServer, &len);
printf("%s\n", buffer);
if (!strcmp(buffer, "Good bye!")) {
    break;
}
printTips();
}
//关闭套接字
closesocket(socketClient);
WSACleanup();
return 0;
}
```

## SR\_Server.cpp

```
#include <stdlib.h>
#include <time.h>
```



```
#include <WinSock2.h>
#include <fstream>
#pragma comment(lib,"ws2_32.lib")
#define SERVER_PORT 12340 //端口号
#define SERVER_IP "127.0.0.1" //IP 地址
const int PACKET_NUM = 25;
const int BUFFER_LENGTH = 1026; //缓冲区大小, (以太网中 UDP 的数据帧中包长度应
小于 1480 字节)
const int SEND_WIND_SIZE = 10; //发送窗口大小为 10, GBN 中应满足  $W + 1 \leq N$  (W
为发送窗口大小, N 为序列号个数)
//本例取序列号 0...19 共 20 个
//如果将窗口大小设为 1, 则为停-等协议
const int SEQ_SIZE = 20; //序列号的个数, 从 0~19 共计 20 个
//由于发送数据第一个字节如果值为 0, 则数据会发送失败, 因为 0 直接代表字符串的结
尾了
//因此接收端序列号为 1~20, 与发送端一一对应
BOOL ack[SEQ_SIZE]; //收到 ack 情况, 对应 0~19 的 ack, 值为 false 不能用 (已经被接
受但还在窗口里)
int curSeq; //当前数据包的 seq
int curAck; //当前等待确认的 ack, 同时也代表了当前窗口位置
int totalPacket; //需要发送的包总数
int totalSeq; //已经发的总数
int totalAck; //已经确认的总数, 用于判断是否可以停止传输
//*****

// Method: getCurTime
// FullName: getCurTime
// Access: public
// Returns: void
// Qualifier: 获取当前系统时间, 结果存入 ptime 中
// Parameter: char * ptime
//*****

void getCurTime(char* ptime) {
    char buffer[128];
    memset(buffer, 0, sizeof(buffer));
    time_t c_time;
    struct tm* p;
    time(&c_time);
    p = localtime(&c_time);
    sprintf_s(buffer, "%d/%d/%d %d:%d:%d", p->tm_year + 1900, p->tm_mon, p->tm_mday,
p->tm_hour, p->tm_min, p->tm_sec);
    strcpy_s(ptime, sizeof(buffer), buffer);
}
//*****

// Method: seqIsAvailable
```

```
// FullName: seqIsAvailable
// Access: public
// Returns: bool
// Qualifier: 当前序列号 curSeq 是否可用
//*****

bool seqIsAvailable() {
    int step;
    step = curSeq - curAck;
    step = step >= 0 ? step : step + SEQ_SIZE; //序列号是循环使用的
    //序列号是否在当前发送窗口之内
    if (step >= SEND_WIND_SIZE) {
        return false;
    }
    //与 gbn 不同的是，只要在窗口内就发送
    return true;
}
//*****

// Method: timeoutHandler
// FullName: timeoutHandler
// Access: public
// Returns: void
// Qualifier: 超时重传处理函数
//*****

void timeoutHandler() {
    printf("Timer out error.\n");
    totalSeq -= SEND_WIND_SIZE;
    curSeq = curAck;
}
//*****

// Method: ackHandler
// FullName: ackHandler
// Access: public
// Returns: void
// Qualifier: 收到 ack
//由于发送数据时，第一个字节（序列号）为 0（ASCII）时发送失败，因此加一了，此处
//需要减一还原
// Parameter: char c
//*****

void ackHandler(char c) {
    unsigned char index = (unsigned char)c - 1; //序列号减一
    printf("Recv a ack of %d\n", index);
    totalAck++;
    //如果 ack 的是窗口的第一个，右移窗口
    if (curAck == index) {
```

```
    ack[index] = TRUE;
    curAck = (index + 1) % SEQ_SIZE;
    //看可以右移几位
    for (int i = 1; i < SEND_WIND_SIZE; ++i) {
        int nxt = (i + index) % SEQ_SIZE;
        if (ack[nxt] == FALSE) {
            ack[nxt] == TRUE;
            curAck = (nxt + 1) % SEQ_SIZE;
            totalSeq++;
        }
        else break;
    }
    curSeq = curAck;
}
else {
    ack[index] = FALSE;
}
}
//主函数
int main(int argc, char* argv[])
{
    //加载套接字库（必须）
    WORD wVersionRequested;
    WSADATA wsaData;
    //套接字加载时错误提示
    int err;
    //版本 2.2
    wVersionRequested = MAKEWORD(2, 2);
    //加载 dll 文件 Sckket 库
    err = WSAStartup(wVersionRequested, &wsaData);
    if (err != 0) {
        //找不到 winsock.dll
        printf("WSAStartup failed with error: %d\n", err);
        return -1;
    }
    if (LOBYTE(wsaData.wVersion) != 2 || HIBYTE(wsaData.wVersion) != 2)
    {
        printf("Could not find a usable version of Winsock.dll\n");
        WSACleanup();
    }
    else {
        printf("The Winsock 2.2 dll was found okay\n");
    }
}
```

```
//双向传输，所以服务器端也要设置丢包率
float packetLossRatio = 0;
float ackLossRatio = 0;
srand((unsigned)time(NULL));

SOCKET sockServer = socket(AF_INET, SOCK_DGRAM, IPPROTO_UDP);
//设置套接字为非阻塞模式
int iMode = 1; //1: 非阻塞, 0: 阻塞
ioctlsocket(sockServer, FIONBIO, (u_long FAR*) & iMode); //非阻塞设置
SOCKADDR_IN addrServer; //服务器地址
//addrServer.sin_addr.S_un.S_addr = inet_addr(SERVER_IP);
addrServer.sin_addr.S_un.S_addr = htonl(INADDR_ANY); //两者均可
addrServer.sin_family = AF_INET;
addrServer.sin_port = htons(SERVER_PORT);
err = bind(sockServer, (SOCKADDR*)&addrServer, sizeof(SOCKADDR));
if (err) {
    err = GetLastError();
    printf("Could not bind the port %d for socket. Error code is %d\n", SERVER_PORT,
err);
    WSACleanup();
    return -1;
}
SOCKADDR_IN addrClient; //客户端地址
int length = sizeof(SOCKADDR);
char buffer[BUFFER_LENGTH]; //数据发送接收缓冲区
ZeroMemory(buffer, sizeof(buffer));
//将测试数据读入内存
std::ifstream icin;
icin.open("../test.txt");
char data[1024 * PACKET_NUM];
ZeroMemory(data, sizeof(data));
icin.read(data, 1024 * PACKET_NUM);
icin.close();
totalPacket = sizeof(data) / 1024;
//printf("%d\n", totalPacket);
int recvSize;
for (int i = 0; i < SEQ_SIZE; ++i) {
    ack[i] = TRUE;
}
while (true) {
    //非阻塞接收，若没有收到数据，返回值为-1
    recvSize = recvfrom(sockServer, buffer, BUFFER_LENGTH, 0,
((SOCKADDR*)&addrClient), &length);
    if (recvSize < 0) {
```

```

        Sleep(200);
        continue;
    }
    printf("recv from client: %s\n", buffer);
    if (strcmp(buffer, "-time") == 0) {
        getCurTime(buffer);
    }
    else if (strcmp(buffer, "-quit") == 0) {
        strcpy_s(buffer, strlen("Good bye!") + 1, "Good bye!");
    }
    else if (strcmp(buffer, "-testsr") == 0) {
        //进入 gbn 测试阶段
        //首先 server (server 处于 0 状态) 向 client 发送 205 状态码 (server 进入 1 状态)
        //server 等待 client 回复 200 状态码, 如果收到 (server 进入 2 状态), 则开始传输文件, 否则延时等待直至超时
        //在文件传输阶段, server 发送窗口大小设为
        for (int i = 0; i < SEQ_SIZE; ++i) {
            ack[i] = TRUE;
        }
        ZeroMemory(buffer, sizeof(buffer));
        int recvSize;
        int waitCount = 0;
        printf("Begin to test GBN protocol, please don't abort the process\n");
        //加入了一个握手阶段
        //首先服务器向客户端发送一个 205 的状态码 (我自己定义的) 表示服务器准备好了, 可以发送数据
        //客户端收到 205 之后回复一个 200 的状态码, 表示客户端准备好了, 可以接收数据了
        //服务器收到 200 状态码之后, 就开始使用 GBN 发送数据了
        printf("Shake hands stage\n");
        int stage = 0;
        bool runFlag = true;
        int flag = 0;
        while (runFlag) {
            if (flag) {
                break;
            }
            switch (stage) {
                case 0://发送 205 阶段
                    buffer[0] = 205;
                    sendto(sockServer, buffer, strlen(buffer) + 1, 0, (SOCKADDR*)&addrClient, sizeof(SOCKADDR));
                    Sleep(100);

```

```
        stage = 1;
        break;
    case 1://等待接收 200 阶段, 没有收到则计数器+1, 超时则放弃此次“连接”, 等待从第一步开始
        recvSize = recvfrom(sockServer, buffer, BUFFER_LENGTH, 0,
        ((SOCKADDR*)&addrClient), &length);
        if (recvSize < 0) {
            ++waitCount;
            if (waitCount > 20) {
                runFlag = false;
                printf("Timeout error\n");
                break;
            }
            Sleep(500);
            continue;
        }
        else {
            if ((unsigned char)buffer[0] == 200) {
                printf("Begin a file transfer\n");
                printf("File size is %dB, each packet is 1024B and packet total
num is % d\n", sizeof(data), totalPacket);
                curSeq = 0;
                curAck = 0;
                waitCount = 0;
                stage = 2;
            }
        }
        break;
    case 2://数据传输阶段
        if (seqIsAvailable()) {
            //发送给客户端的序列号从 1 开始
            buffer[0] = curSeq + 1;
            ack[curSeq] = TRUE;//设为等待接收
            //数据发送的过程中应该判断是否传输完成
            //为简化过程此处并未实现
            memcpy(&buffer[1], data + 1024 * totalSeq, 1024);
            printf("send a packet with a seq of %d\n", curSeq);
            sendto(sockServer, buffer, BUFFER_LENGTH, 0,
        (SOCKADDR*)&addrClient, sizeof(SOCKADDR));
            ++curSeq;
            curSeq %= SEQ_SIZE;
            ++totalSeq;
            Sleep(500);
        }
    }
```

```
        //等待 Ack, 若没有收到, 则返回值为-1, 计数器+1
        recvSize = recvfrom(sockServer, buffer, BUFFER_LENGTH, 0,
        ((SOCKADDR*)&addrClient), &length);
        if (recvSize < 0) {
            waitCount++;
            //20 次等待 ack 则超时重传
            if (waitCount > 20)
            {
                timeoutHandler();
                waitCount = 0;
            }
        }
        else {
            //收到 ack
            ackHandler(buffer[0]);
            waitCount = 0;
            //printf("%d\n", totalAck);
            if (totalAck == totalPacket) {
                flag = 1;
                strcpy(buffer, "All Finished!\n");
            }
        }
        Sleep(500);
        break;
    }
}

sendto(sockServer, buffer, strlen(buffer) + 1, 0, (SOCKADDR*)&addrClient,
sizeof(SOCKADDR));
Sleep(500);
}
//关闭套接字, 卸载库
closesocket(sockServer);
WSACleanup();
return 0;
}
```

## SR\_Client.cpp

```
// GBN_client.cpp: 定义控制台应用程序的入口点。
//
#include <stdlib.h>
#include <WinSock2.h>
#include <time.h>
```

```

#include <stdio.h>
#include <fstream>
#pragma comment(lib,"ws2_32.lib")
#define SERVER_PORT 12340 //接收数据的端口号
#define SERVER_IP "127.0.0.1" // 服务器的 IP 地址
const int BUFFER_LENGTH = 1026;
const int PACKET_NUM = 25;
const int SEQ_SIZE = 20; //接收端序列号个数，为 1~20
const int RECV_WIND_SIZE = 10; //接收窗口大小为 10，SR 中应满足接收窗口和发送窗口的大小和小于等于总序列号个数

int curSeq; //当前数据包的 seq
int curAck; //当前等待确认的 ack
int totalPacket; //需要发送的包总数
BOOL ack[SEQ_SIZE]; //接收方窗口

int totalSeq; //已发送的包的总数
int totalAck; //确认收到（ack）的包的总数
/*****
/* -time 从服务器端获取当前时间
-quit 退出客户端
-testgbn [X][Y] 测试 GBN 协议实现可靠数据传输
[X] [0,1] 模拟数据包丢失的概率
[Y] [0,1] 模拟 ACK 丢失的概率
*/
*****/

void printTips() {
    printf("*****\n");
    printf("| -time to get current time          |\n");
    printf("| -quit to exit client                  |\n");
    printf("| -testsr [X] [Y] to test the gbn      |\n");
    printf("*****\n");
}

/*****
// Method: lossInLossRatio
// FullName: lossInLossRatio
// Access: public
// Returns: BOOL
// Qualifier: 根据丢失率随机生成一个数字，判断是否丢失,丢失则返回 TRUE，否则返回 FALSE
// Parameter: float lossRatio [0,1]
*****/

BOOL lossInLossRatio(float lossRatio) {
    int lossBound = (int)(lossRatio * 100);

```



```
int r = rand() % 100;
if (r < lossBound) {
    return TRUE;
}
return FALSE;
}
//*****
// Method: seqIsAvailable
// FullName: seqIsAvailable
// Access: public
// Returns: bool
// Qualifier: 当前序列号 seq 是否可接收
//*****
bool seqRecvAvailable(int seq) {
    int step;
    step = seq - curAck;
    step = step >= 0 ? step : step + SEQ_SIZE;
    //序列号是否在当前接收窗口之内
    if (step >= RECV_WIND_SIZE) {
        return false;
    }
    return true;
}
int main(int argc, char* argv[])
{
    //加载套接字库（必须）
    WORD wVersionRequested;
    WSADATA wsaData;
    //套接字加载时错误提示
    int err;
    //版本 2.2
    wVersionRequested = MAKEWORD(2, 2);
    //加载 dll 文件 Scknet 库
    err = WSAStartup(wVersionRequested, &wsaData);
    if (err != 0) {
        //找不到 winsock.dll
        printf("WSAStartup failed with error: %d\n", err);
        return 1;
    }
    if (LOBYTE(wsaData.wVersion) != 2 || HIBYTE(wsaData.wVersion) != 2)
    {
        printf("Could not find a usable version of Winsock.dll\n");
        WSACleanup();
    }
}
```

```

else {
    printf("The Winsock 2.2 dll was found okay\n");
}
SOCKET socketClient = socket(AF_INET, SOCK_DGRAM, 0);
SOCKADDR_IN addrServer;
addrServer.sin_addr.S_un.S_addr = inet_addr(SERVER_IP);
addrServer.sin_family = AF_INET;
addrServer.sin_port = htons(SERVER_PORT);
//接收缓冲区
char buffer[BUFFER_LENGTH];
ZeroMemory(buffer, sizeof(buffer));
int len = sizeof(SOCKADDR);
//为了测试与服务器的连接，可以使用 -time 命令从服务器端获得当前时间
//使用 -testgbn [X] [Y] 测试 GBN 其中[X]表示数据包丢失概率
// [Y]表示 ACK 丢包概率
printTips();
int ret;
int interval = 1; //收到数据包之后返回 ack 的间隔，默认为 1 表示每个都返回 ack，
0 或者负数均表示所有的都不返回 ack
char cmd[128];
float packetLossRatio = 0; //默认包丢失率 0.2
float ackLossRatio = 0; //默认 ACK 丢失率 0.2
//用时间作为随机种子，放在循环的最外面
srand((unsigned)time(NULL));

//将测试数据读入内存
std::ifstream icin;
icin.open("../test.txt");
char data[1024 * PACKET_NUM];
ZeroMemory(data, sizeof(data));
icin.read(data, 1024 * PACKET_NUM);
icin.close();
totalPacket = sizeof(data) / 1024;
int recvSize;
while (true) {
    gets_s(buffer);
    ret = sscanf(buffer, "%s%f%f", &cmd, &packetLossRatio, &ackLossRatio);
    //开始 SR 测试，使用 SR 协议实现 SR 可靠文件传输
    if (!strcmp(cmd, "-testsr")) {
        for (int i = 0; i < SEQ_SIZE; ++i) {
            ack[i] = FALSE;
        }
        FILE* fcli = fopen("clientfile.txt", "w+");
        printf("%s\n", "Begin to test GBN protocol, please don't abort the process");
    }
}

```

```
printf("The loss ratio of packet is %.2f,the loss ratio of ack is % .2f\n",
packetLossRatio, ackLossRatio);
int waitCount = 0;
int stage = 0;
curAck = 0;
BOOL b;
unsigned char u_code;//状态码
unsigned short seq;//包的序列号
unsigned short recvSeq;//接收窗口大小为 1，已确认的序列号
unsigned short waitSeq;//等待的序列号
sendto(socketClient, "-testsr", strlen("-testgbn") + 1, 0,
(SOCKADDR*)&addrServer, sizeof(SOCKADDR));
while (true)
{
    //等待 server 回复设置 UDP 为阻塞模式
    recvfrom(socketClient, buffer, BUFFER_LENGTH, 0,
(SOCKADDR*)&addrServer, &len);
    if (strcmp(buffer, "All Finished!\n") == 0) {
        fclose(fcli);
        break;
    }
    switch (stage) {
    case 0://等待握手阶段
        u_code = (unsigned char)buffer[0];
        if ((unsigned char)buffer[0] == 205)
        {
            printf("Ready for file transmission\n");
            buffer[0] = 200;
            buffer[1] = '\0';
            sendto(socketClient, buffer, 2, 0, (SOCKADDR*)&addrServer,
sizeof(SOCKADDR));
            stage = 1;
            recvSeq = 0;
        }
        break;
    case 1://等待接收数据阶段
        seq = (unsigned short)buffer[0];
        //随机法模拟包是否丢失
        b = lossInLossRatio(packetLossRatio);
        if (b) {
            printf("The packet with a seq of %d loss\n", seq);
            continue;
        }
        printf("recv a packet with a seq of %d\n", seq);
```

```

//在窗口内即接收
if (seqRecvAvailable(seq)) {
    fwrite(&buffer[1], sizeof(char), strlen(buffer) - 1, fcli);
    //输出数据
    printf("%s\n", &buffer[1]);
    recvSeq = seq;
    ack[recvSeq - 1] = TRUE;
    buffer[0] = seq;
    buffer[1] = '\0';
    if (seq - 1 == curAck) {
        int nxt;
        for (int i = 0; i < RECV_WIND_SIZE; ++i) {
            nxt = (curAck + i) % SEQ_SIZE;
            if (!ack[nxt]) break;
        }
        curAck = (nxt + 1) % SEQ_SIZE;
    }
}
else {
    //如果当前一个包都没有收到，则等待 Seq 为 1 的数据包，
    不是则不返回 ACK（因为并没有上一个正确的 ACK）
    recvSeq = seq;
    buffer[0] = recvSeq;
    buffer[1] = '\0';
}
b = lossInLossRatio(ackLossRatio);
if (b) {
    printf("The ack of %d loss\n", (unsigned char)buffer[0]);
    continue;
}
sendto(socketClient, buffer, 2, 0, (SOCKADDR*)&addrServer,
sizeof(SOCKADDR));
printf("send a ack of %d\n", (unsigned char)buffer[0]);
break;
}
Sleep(500);
}
}
//printf("%s\n", buffer);
sendto(socketClient, buffer, strlen(buffer) + 1, 0, (SOCKADDR*)&addrServer,
sizeof(SOCKADDR));
ret = recvfrom(socketClient, buffer, BUFFER_LENGTH, 0,
(SOCKADDR*)&addrServer, &len);
printf("%s\n", buffer);

```

```
        if (!strcmp(buffer, "Good bye!")) {  
            break;  
        }  
        printTips();  
    }  
    //关闭套接字  
    closesocket(socketClient);  
    WSACleanup();  
    return 0;  
}
```