

# 计算机网络实验3-3报告

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## 计算机网络实验3-3报告

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## 一、实验目的

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在实验3-2的基础上，选择实现一种拥塞控制算法，也可以是改进的算法，完成给定测试文件的传输

## 二、协议设计

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### 1、报文格式

源端口号					目的端口号				
源IP									
目的IP									
初始序号Seq									
确认序号Ack									
数据段长度Length					接收窗口大小				
ACK	SYN	FIN	ST	OV	校验和				
数据段									

标识	含义
源端口号	发送此报文的终端所对应的端口号
目的端口号	接收此报文的终端所对应的端口号
源IP	发送此报文的终端IP地址
目的IP	接收此报文的终端IP地址
初始序号seq	初始序号值，代表当前报文状态，也用于去除冗余
确认序号ack	与seq相应，用以进行回复
数据段长度Length	代表本次报文中数据段有效信息的长度
接收窗口大小	可以接受或缓存的数据包的数量
ACK	标志位，接收到上一次报文
SYN	标志位，申请建立连接
FIN	标志位，申请断开连接
ST	标志位，本次报文为一个文件的首个报文

标识	含义
OV	标志位，本次报文为当前文件的最后一个报文
校验和	存放校验和。

## 2、RENO算法

### Slow Start (慢启动)

slow start 慢启动算法

初始用塞窗口设置为1，慢启动阈值设置为sssthresh，此时可以传1个MSS大小的数据，每收到一个ACK，用塞窗口cwnd加一，这样每过一个RTT，cwnd翻倍，指数上升。达到sssthresh进入用塞避免阶段

### 拥塞避免算法

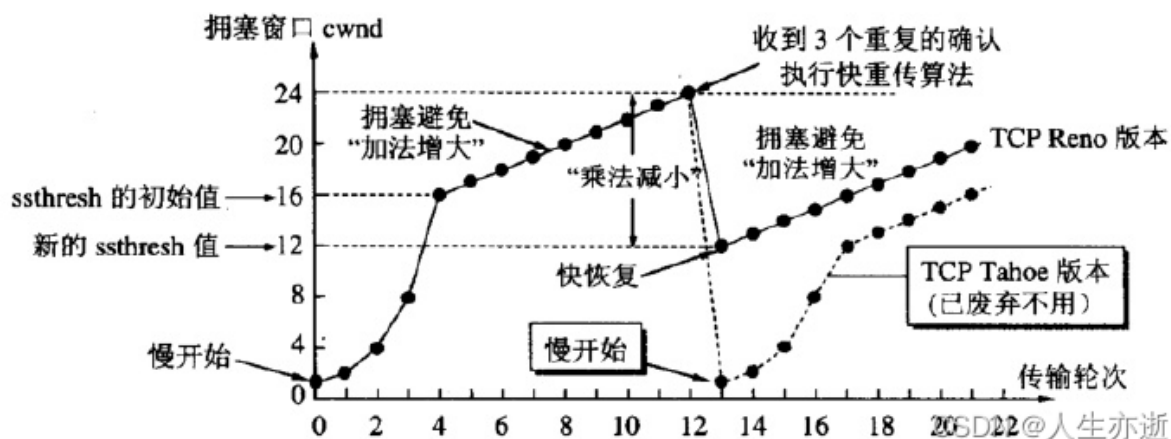
每经过一个RTT（往返时间）拥塞窗口cwnd加1，相当于进行了一个可发送窗口的线性探测（AI）

### 快速重传算法

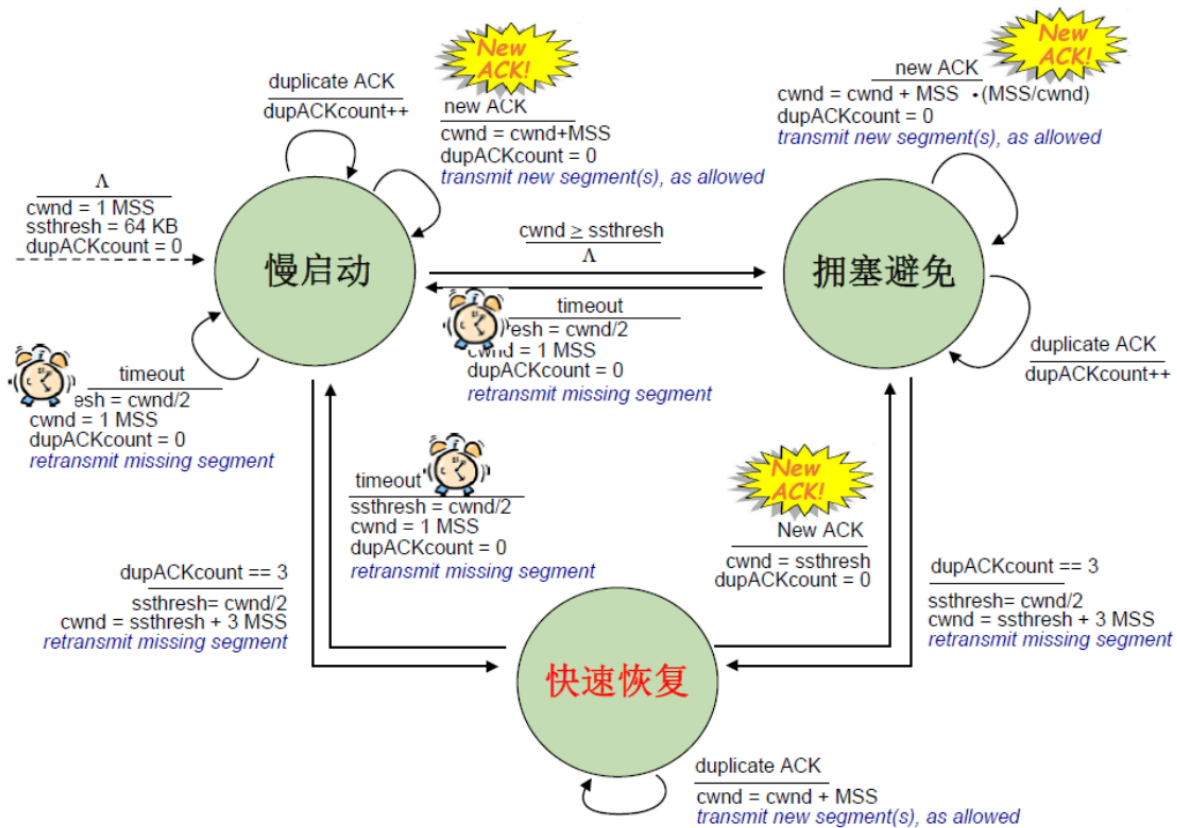
sender 连续收到3个相同的ACK，立即重传，设置新的慢启动门限为sssthresh = cwnd / 2

### 快速恢复算法

快速重传后立即执行快速恢复算法，设置cwnd = sssthresh = cwnd / 2，然后进行拥塞避免算法（MD）没有慢启动的过程。其中cwnd窗口呈现周期性变化。



(注：图片取自网上)



### 三、核心代码分析

#### 1、慢启动

```

1  if (state == SS)
2  {
3      windowLength++;
4      ConfirmCount = 0;
5      if (windowLength > ssthresh)
6      {
7          state = CA;
8      }
9  }

```

每收到一个ack，接收窗口大小加1，实现指数增长

窗口大于慢启动阈值，进入拥塞避免阶段

## 2、拥塞避免

```
1  else if (state == CA)
2  {
3      //拥塞避免阶段
4      ConfirmCount = 0;
5      newAckCount++;
6      if (newAckCount >= windowLength)
7      {
8          newAckCount = 0;
9          windowLength++;
10     }
11 }
```

每接收到完整窗口的确认 (ACK), 将发送窗口大小增加 1, 窗口的增长速度从指数变为线性

## 3、快速恢复

```
1  else if (state == QR)
2  {
3      windowLength = ssthresh;
4      ConfirmCount = 0;
5      state = CA;
6  }
```

窗口大小变为慢启动阈值, 进入拥塞避免

## 4、快速重传

```
1  if (recvack == lastConfirmAck)
2  {
3      ConfirmCount++;
4      if (ConfirmCount == 3)
5      {
6          //三次ack重复, 重传窗口内第一个包
7          cout << "快速恢复" << endl;
8          ssthresh = windowLength / 2;
9          if (ssthresh == 0)
10             ssthresh++;
11             windowLength = ssthresh + 3;
12             CubicRepetition();
13             state = QR;
14         }
15     }
16
17     void CubicRepetition()
18     {
19         // 遍历发送窗口中的所有数据包
20         slidingwindow[0].clock = clock();
21         for (size_t i = 0; i < slidingwindow.size(); ++i)
22         {
23             sendto(sockSrv, slidingwindow[i].buffer,
24                 sizeof(slidingwindow[i].buffer), 0, (SOCKADDR*)&Server, len);
25         }
26     }
27 }
```

```
24 |         sendlog(slidingwindow[i].buffer);
25 |     }
26 | }
```

如果重复收到3次最后确认的ack，进入快速重传，将滑动窗口里的数据包统统发送

## 四、程序展示

### 1、日志输出

如图所示，可以看到Seq、ACK、标志位、校验和、发送窗口大小、接收窗口、慢启动阈值、当前状态

接收窗口大小为1，这里的接收窗口的值是希望接收下一个的ack，即接收窗口的位置

当前状态有0、1、2，分别代表SS（慢启动）、CA（拥塞避免）、QR（快速恢复）

```
*****
**发送端**
*****
13:45:59 [send] Seq: 41 Ack: 0 ACK: 0 SYN: 1 FIN: 0 ST: 0 OV: 0 校验和: 0x8163 sendWin:1 ssthresh:32 state:0
13:45:59 [recv] Seq: 41 Ack: 42 ACK: 1 SYN: 1 FIN: 0 ST: 0 OV: 0 校验和: 0x9136 recvWin:1
13:45:59 [send] Seq: 0 Ack: 42 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa062 sendWin:1 ssthresh:32 state:0
*****连接成功*****
*****开始发文件*****
13:45:59 [send] Seq: 1 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 1 OV: 0 校验和: 0xc969 sendWin:1 ssthresh:32 state:0
13:45:59 [recv] Seq: 0 Ack: 1 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa088 recvWin:2
*****发送第1个文件 该文件大小为1655888字节*****
13:45:59 [send] Seq: 2 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd34f sendWin:2 ssthresh:32 state:0
13:45:59 [send] Seq: 3 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3cd3 sendWin:2 ssthresh:32 state:0
13:45:59 [recv] Seq: 0 Ack: 2 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa087 recvWin:3
13:45:59 [recv] Seq: 0 Ack: 3 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa086 recvWin:4
13:45:59 [send] Seq: 4 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd34d sendWin:4 ssthresh:32 state:0
13:45:59 [send] Seq: 5 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3cd1 sendWin:4 ssthresh:32 state:0
13:45:59 [send] Seq: 6 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd34b sendWin:4 ssthresh:32 state:0
13:45:59 [send] Seq: 7 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3ccf sendWin:4 ssthresh:32 state:0
13:45:59 [recv] Seq: 0 Ack: 4 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa085 recvWin:5
13:45:59 [send] Seq: 8 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd349 sendWin:5 ssthresh:32 state:0
13:45:59 [send] Seq: 9 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3ccd sendWin:5 ssthresh:32 state:0
13:45:59 [recv] Seq: 0 Ack: 5 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa084 recvWin:6
13:45:59 [send] Seq: 10 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd347 sendWin:6 ssthresh:32 state:0
13:45:59 [send] Seq: 11 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3ccb sendWin:6 ssthresh:32 state:0
13:45:59 [recv] Seq: 0 Ack: 6 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa083 recvWin:7
13:45:59 [recv] Seq: 0 Ack: 7 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa082 recvWin:8
13:45:59 [send] Seq: 8 Ack: 0 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd346 sendWin:8 ssthresh:32 state:0
13:45:59 [send] Seq: 12 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd345 sendWin:9 ssthresh:32 state:0
13:45:59 [send] Seq: 13 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3cc9 sendWin:9 ssthresh:32 state:0
13:45:59 [send] Seq: 14 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd343 sendWin:9 ssthresh:32 state:0
13:45:59 [send] Seq: 15 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3cc7 sendWin:9 ssthresh:32 state:0
13:45:59 [send] Seq: 16 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd341 sendWin:9 ssthresh:32 state:0
13:45:59 [send] Seq: 17 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3cc5 sendWin:9 ssthresh:32 state:0
13:45:59 [recv] Seq: 0 Ack: 9 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa080 recvWin:10
13:45:59 [recv] Seq: 0 Ack: 10 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa07f recvWin:11
13:45:59 [send] Seq: 18 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd33f sendWin:11 ssthresh:32 state:0
13:45:59 [send] Seq: 19 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3cc3 sendWin:11 ssthresh:32 state:0
13:45:59 [send] Seq: 20 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd33d sendWin:11 ssthresh:32 state:0
13:45:59 [send] Seq: 21 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3cc1 sendWin:11 ssthresh:32 state:0
13:45:59 [recv] Seq: 0 Ack: 12 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa07d recvWin:13
13:45:59 [send] Seq: 22 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd33b sendWin:12 ssthresh:32 state:0
13:45:59 [send] Seq: 23 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3cbf sendWin:12 ssthresh:32 state:0
13:45:59 [send] Seq: 24 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd339 sendWin:12 ssthresh:32 state:0
```

可以看到文件传输速率和吞吐量

```
13:46:02 [recv] Seq: 0 Ack: 148 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0f5 recvWin:149
13:46:02 [send] Seq: 155 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3d3b sendWin:7 ssthresh:1 state:1
13:46:03 [recv] Seq: 0 Ack: 149 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0f4 recvWin:150
13:46:03 [recv] Seq: 0 Ack: 150 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0f3 recvWin:151
13:46:03 [recv] Seq: 0 Ack: 151 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0f2 recvWin:152
13:46:03 [recv] Seq: 0 Ack: 152 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0f1 recvWin:153
13:46:03 [recv] Seq: 0 Ack: 153 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0f0 recvWin:154
13:46:03 [recv] Seq: 0 Ack: 154 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0ef recvWin:155
13:46:03 [send] Seq: 156 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd3b5 sendWin:8 ssthresh:1 state:1
13:46:03 [send] Seq: 157 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3d39 sendWin:8 ssthresh:1 state:1
13:46:03 [send] Seq: 158 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd3b3 sendWin:8 ssthresh:1 state:1
13:46:03 [recv] Seq: 0 Ack: 155 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0ee recvWin:156
13:46:03 [send] Seq: 159 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3d37 sendWin:8 ssthresh:1 state:1
13:46:03 [send] Seq: 160 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd3b1 sendWin:8 ssthresh:1 state:1
13:46:03 [send] Seq: 161 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd3b5 sendWin:8 ssthresh:1 state:1
13:46:03 [send] Seq: 162 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd3af sendWin:8 ssthresh:1 state:1
13:46:03 [send] Seq: 163 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd3d3 sendWin:8 ssthresh:1 state:1
13:46:03 [recv] Seq: 0 Ack: 156 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0ed recvWin:157
13:46:03 [send] Seq: 164 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd3ad sendWin:8 ssthresh:1 state:1
13:46:03 [recv] Seq: 0 Ack: 158 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0eb recvWin:159
13:46:03 [recv] Seq: 0 Ack: 159 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0ea recvWin:160
13:46:03 [send] Seq: 165 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0x3d31 sendWin:9 ssthresh:1 state:1
13:46:03 [send] Seq: 166 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xd3ab sendWin:9 ssthresh:1 state:1
13:46:03 [send] Seq: 167 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 1 校验和: 0x4e8c sendWin:9 ssthresh:1 state:1
13:46:03 [recv] Seq: 0 Ack: 160 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0e9 recvWin:161
13:46:03 [recv] Seq: 0 Ack: 161 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0e8 recvWin:162
13:46:03 [recv] Seq: 0 Ack: 162 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0e7 recvWin:163
13:46:03 [recv] Seq: 0 Ack: 163 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0e6 recvWin:164
13:46:03 [recv] Seq: 0 Ack: 164 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0e5 recvWin:165
13:46:03 [recv] Seq: 0 Ack: 165 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0e4 recvWin:166
13:46:03 [recv] Seq: 0 Ack: 166 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0e3 recvWin:167
超时重传
13:46:04 [send] Seq: 167 Ack: 0 ACK: 0 SYN: 0 FIN: 0 ST: 0 OV: 1 校验和: 0x4e8c sendWin:1 ssthresh:4 state:0
13:46:04 [recv] Seq: 167 Ack: 167 ACK: 1 SYN: 0 FIN: 0 ST: 0 OV: 0 校验和: 0xa0e2 recvWin:168
*****文件发送成功*****
文件传输时间: 4.76 s
吞吐量: 0.331744MB/s
*****开始关闭连接*****
13:46:04 [send] Seq: 18467Ack: 0 ACK: 0 SYN: 0 FIN: 1 ST: 0 OV: 0 校验和: 0x1bd3 sendWin:2 ssthresh:4 state:0
13:46:04 [recv] Seq: 18467Ack: 18468ACK: 1 SYN: 0 FIN: 1 ST: 0 OV: 0 校验和: 0x1052 recvWin:
*****连接结束*****
请按任意键继续...
```

Router

路由IP: 127.0.0.2

端口: 8088

丢包率: 0.1 %

确定

日志

count:910.  
count:911.  
count:912.  
count:913.

## 2、快速恢复

如图所示，重复收到68的ack，说明seq为69的包发生丢失，快速重传发送窗口中的所有数据包

发送窗口大小也从9变为7 ( $9/2+3=7$ )

状态也从1到2（拥塞避免到快速恢复）

13:46:01 [send]	Seq: 66	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd30f	sendWin: 8	ssthresh: 1	state: 1
13:46:01 [recv]	Seq: 0	Ack: 59	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa04e	recvWin: 60		
13:46:01 [recv]	Seq: 0	Ack: 60	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa04d	recvWin: 61		
13:46:01 [recv]	Seq: 0	Ack: 61	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa04c	recvWin: 62		
13:46:01 [send]	Seq: 67	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3c93	sendWin: 8	ssthresh: 1	state: 1
13:46:01 [send]	Seq: 68	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd30d	sendWin: 8	ssthresh: 1	state: 1
13:46:01 [send]	Seq: 69	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3c91	sendWin: 8	ssthresh: 1	state: 1
13:46:01 [recv]	Seq: 0	Ack: 62	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa04b	recvWin: 63		
13:46:01 [send]	Seq: 70	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd30b	sendWin: 8	ssthresh: 1	state: 1
13:46:01 [recv]	Seq: 0	Ack: 63	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa04a	recvWin: 64		
13:46:01 [send]	Seq: 71	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3c8f	sendWin: 9	ssthresh: 1	state: 1
13:46:01 [send]	Seq: 72	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd309	sendWin: 9	ssthresh: 1	state: 1
13:46:01 [recv]	Seq: 0	Ack: 64	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa049	recvWin: 65		
13:46:01 [recv]	Seq: 0	Ack: 65	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa048	recvWin: 66		
13:46:01 [recv]	Seq: 0	Ack: 66	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa047	recvWin: 67		
13:46:01 [recv]	Seq: 0	Ack: 67	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa046	recvWin: 68		
13:46:01 [recv]	Seq: 0	Ack: 68	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa045	recvWin: 69		
13:46:01 [send]	Seq: 73	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3c8d	sendWin: 9	ssthresh: 1	state: 1
13:46:01 [send]	Seq: 74	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd307	sendWin: 9	ssthresh: 1	state: 1
13:46:01 [send]	Seq: 75	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3c8b	sendWin: 9	ssthresh: 1	state: 1
13:46:01 [recv]	Seq: 0	Ack: 68	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa045	recvWin: 69		
13:46:01 [recv]	Seq: 0	Ack: 68	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa045	recvWin: 69		
13:46:01 [send]	Seq: 76	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd305	sendWin: 9	ssthresh: 1	state: 1
13:46:01 [send]	Seq: 77	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3c89	sendWin: 9	ssthresh: 1	state: 1
13:46:01 [recv]	Seq: 0	Ack: 68	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa045	recvWin: 69		
快速恢复											
13:46:01 [send]	Seq: 69	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3c91	sendWin: 7	ssthresh: 4	state: 2
13:46:01 [send]	Seq: 70	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd30b	sendWin: 7	ssthresh: 4	state: 2
13:46:01 [send]	Seq: 71	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3c8f	sendWin: 7	ssthresh: 4	state: 2
13:46:01 [send]	Seq: 72	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd309	sendWin: 7	ssthresh: 4	state: 2
13:46:01 [send]	Seq: 73	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3c8d	sendWin: 7	ssthresh: 4	state: 2
13:46:01 [send]	Seq: 74	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd307	sendWin: 7	ssthresh: 4	state: 2
13:46:01 [send]	Seq: 75	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3c8b	sendWin: 7	ssthresh: 4	state: 2
13:46:01 [send]	Seq: 76	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd305	sendWin: 7	ssthresh: 4	state: 2
13:46:01 [send]	Seq: 77	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3c89	sendWin: 7	ssthresh: 4	state: 2
13:46:01 [recv]	Seq: 0	Ack: 68	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa045	recvWin: 69		
13:46:01 [recv]	Seq: 0	Ack: 68	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa045	recvWin: 69		
13:46:01 [send]	Seq: 78	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd303	sendWin: 18	ssthresh: 4	state: 2
13:46:01 [recv]	Seq: 0	Ack: 68	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd303	recvWin: 69		
13:46:01 [send]	Seq: 79	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3c87	sendWin: 11	ssthresh: 4	state: 2
13:46:01 [recv]	Seq: 0	Ack: 69	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa044	recvWin: 70		
13:46:01 [recv]	Seq: 0	Ack: 70	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa043	recvWin: 71		
13:46:01 [recv]	Seq: 0	Ack: 71	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa042	recvWin: 72		
13:46:01 [recv]	Seq: 0	Ack: 71	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa042	recvWin: 72		

## 3、超时重传

但快速恢复重发发送窗口中的所有数据包的时候，再次发送丢包就会发生超时重传

如图所示快速恢复的时候Seq为21的包丢失，发生超时重传，重传当前发送窗口中的所有数据包

发送窗口变为1，慢启动阈值为原来的一半

13:45:59 [send]	Seq: 23	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3cbf	sendWin: 12	ssthresh: 32	state: 0
13:45:59 [send]	Seq: 24	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd339	sendWin: 12	ssthresh: 32	state: 0
13:45:59 [recv]	Seq: 0	Ack: 14	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa07b	recvWin: 15		
13:45:59 [recv]	Seq: 0	Ack: 15	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa07a	recvWin: 16		
13:45:59 [recv]	Seq: 0	Ack: 15	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa07a	recvWin: 16		
13:45:59 [send]	Seq: 25	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3cbd	sendWin: 14	ssthresh: 32	state: 0
13:45:59 [send]	Seq: 26	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd337	sendWin: 14	ssthresh: 32	state: 0
13:45:59 [recv]	Seq: 0	Ack: 15	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa07a	recvWin: 16		
快速恢复											
13:45:59 [send]	Seq: 16	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd341	sendWin: 10	ssthresh: 7	state: 0
13:45:59 [send]	Seq: 17	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3cc5	sendWin: 10	ssthresh: 7	state: 0
13:45:59 [send]	Seq: 18	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd33f	sendWin: 10	ssthresh: 7	state: 0
13:45:59 [send]	Seq: 19	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3cc3	sendWin: 10	ssthresh: 7	state: 0
13:45:59 [send]	Seq: 20	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd33d	sendWin: 10	ssthresh: 7	state: 0
13:45:59 [send]	Seq: 21	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3cc1	sendWin: 10	ssthresh: 7	state: 0
13:45:59 [send]	Seq: 22	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd33b	sendWin: 10	ssthresh: 7	state: 0
13:45:59 [send]	Seq: 23	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3cbf	sendWin: 10	ssthresh: 7	state: 0
13:45:59 [send]	Seq: 24	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd339	sendWin: 10	ssthresh: 7	state: 0
13:45:59 [send]	Seq: 25	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3cbd	sendWin: 10	ssthresh: 7	state: 0
13:45:59 [send]	Seq: 26	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd337	sendWin: 10	ssthresh: 7	state: 0
13:45:59 [recv]	Seq: 0	Ack: 15	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa07a	recvWin: 16		
13:45:59 [recv]	Seq: 0	Ack: 15	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa07a	recvWin: 16		
13:45:59 [send]	Seq: 27	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3cbb	sendWin: 13	ssthresh: 7	state: 2
13:45:59 [send]	Seq: 28	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd335	sendWin: 13	ssthresh: 7	state: 2
13:45:59 [recv]	Seq: 0	Ack: 15	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa07a	recvWin: 16		
13:45:59 [send]	Seq: 29	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3cb9	sendWin: 14	ssthresh: 7	state: 2
13:45:59 [recv]	Seq: 0	Ack: 16	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa079	recvWin: 17		
13:45:59 [recv]	Seq: 0	Ack: 17	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa078	recvWin: 18		
13:45:59 [recv]	Seq: 0	Ack: 18	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa077	recvWin: 19		
13:45:59 [recv]	Seq: 0	Ack: 19	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa076	recvWin: 20		
13:45:59 [recv]	Seq: 0	Ack: 20	ACK: 1	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xa075	recvWin: 21		
超时重传											
13:46:00 [send]	Seq: 21	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3cc1	sendWin: 1	ssthresh: 3	state: 0
13:46:00 [send]	Seq: 22	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd33b	sendWin: 1	ssthresh: 3	state: 0
13:46:00 [send]	Seq: 23	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3cbf	sendWin: 1	ssthresh: 3	state: 0
13:46:00 [send]	Seq: 24	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd339	sendWin: 1	ssthresh: 3	state: 0
13:46:00 [send]	Seq: 25	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3cbd	sendWin: 1	ssthresh: 3	state: 0
13:46:00 [send]	Seq: 26	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd337	sendWin: 1	ssthresh: 3	state: 0
13:46:00 [send]	Seq: 27	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3cbb	sendWin: 1	ssthresh: 3	state: 0
13:46:00 [send]	Seq: 28	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0xd335	sendWin: 1	ssthresh: 3	state: 0
13:46:00 [send]	Seq: 29	Ack: 0	ACK: 0	SYN: 0	FIN: 0	ST: 0	OV: 0	校验和: 0x3cb9	sendWin: 1	ssthresh: 3	state: 0