

Programming Assignment: Reliable Transport Protocol

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实验环境

Microsoft Windows 10 Version 2004
Microsoft Hyper-V Manager Version 10.0.19041.1
Ubuntu 16.04 xenial w/ x86_64 Linux 4.4.0-142-generic
mininet 2.3.0d6

实现方式

代码整体上使用了面向对象的思路构建发送和接收程序。使用typedef的方式定义了两个类，分别为发送者和接受者，对于每一个实体，都会各生成一个发送对象和一个接收对象，通过对象分别实现发送与接收的功能。

各个类的结构如下：

```
typedef struct {
    int base;
    int next_seq;
    // int message_num;
    int window_size;
    int buffer_ptr; // Top of the buffer.
    struct pkt buffer[BUFFER_SIZE];
    double estimatedRTT;
} sender_class;

typedef struct {
    int expecting_seq;
    struct pkt ack_buffer;
} receiver_class;
```

发送方的对象包含了当前发送的Seq、下个发送的Seq、当前的窗口大小（此实验中为固定值16）、当前缓冲区顶部位置、缓冲区和估计的RTT值，由发送方对象进行管理。接收方的对象包含了目前正在等待接收的包的Seq和一个存在缓冲区的ACK包，ACK包将会在初始化时被构建，而其包含的seqnum和acknum则会由接收方对象进行管理。

发送类和接收类的函数并没有在类中实现，这是因为C语言的伪类并没有访问控制的功能和this指针，使用函数指针的方式管理类函数也会加大代码的复杂度，没有必要多此一举。

代码总共实现了2个初始化函数、2个辅助函数和5个关键函数。

初始化函数

sender_init()和receiver_init()分别负责对发送方对象和接收方对象的初始化，将对象中的元素赋予初值。

辅助函数

1. 辅助函数cal_checksum()负责计算校验位的值，Checksum的计算采用了标准算法，即每16位相加然后取反。
2. 辅助函数highlight_printf()负责部分终端输出的高亮，使用简单的ANSI控制码实现，不支持重定向检测。

关键函数

关键函数中，window_send()、sender_input()、sender_output()和sender_timerinterrupt()函数为发送类的函数，receiver_input()为接收类的函数。

要求中定义的packet格式中并没有标志位，而修改packet的结构体定义是一件很有风险的事情，因此程序使用了一个比较取巧的方法：如果包不是一个ACK包，就将其acknum置为-1，以此作为依据区分发出的数据包和ACK包。

sender_output()

收到从上层的消息后，发送方首先判断缓冲区是否还有空间，如果缓冲区已满，则直接丢弃，否则就将消息填入缓冲区顶部的包中，分配对应的seqnum，计算其校验位，然后将缓冲区顶部指针右移，调用窗口函数决定是否发送。

window_send()

每一次加入新的包后，发送方都会调用窗口函数，如果满足可以发送的条件，则会开始发送，发送前会将acknum置为-1以表示包不是ACK包，同时重新计算校验位，发送开始的同时启动定时器进行计时。

sender_input()

此函数负责处理收到的ACK包，首先在收到包的时候，会对包的内容进行校验，然后确认收到的ACK包是否为期望的ACK包，如果有任何一项不符合，则直接丢弃该包，认为是重发中产生的多余ACK包。如果收到的ACK包确为期望的ACK包，则认为其acknum对应的包已经被成功接收，窗口左侧指针（事实上并不是个指针变量）base向右滑动，如果所有已经发出的包都被收到了，则结束定时器，此次传输成功完成。

sender_timerinterrupt()

如果发送端的定时器超时，则可以判定可能有部分包损毁/丢失/因网络延时太高而无法及时到达，其中前两种情况肯定需要重发，但是实际上是无法区分这三种情况的，因此如果超时发生，则当前窗口内的所有包全部重新进行发送，同时为了避免由于网络延时导致的误判，当超时发生后，将estimatedRTT即定时器超时的值+10（最高不超过10000），以防止因为网络延时原因而反复发送。

| 这一段理论来说是可以复用window_send()函数的，但是实际运行中有一些莫名其妙的
| bug，所以索性重写了窗口发送。

receiver_input()

这个函数是用于接收并发送ACK的函数，出于对函数名整齐可读的考虑没有使用send_ack()作为函数名。

首先在收到包的时候，会对包的内容进行校验，并且将seqnum与接收器内部存储的expecting_seq进行比较，已确定是否为所需要的包。由于链路不会打乱包的顺序，因此接收器不设缓冲区，直接判断。如果收到的包完全正确，则将接收器的ACK包中acknum改为收到包的SEQ并发回，然后在终端上打印收到的内容，并更新接收方期望的seqnum值；如果收到的包重复，则直接丢弃不管，继续接收；如果包校验和不对或者seqnum超前，则认为发生了损毁或者丢包，发回的ACK仍为上一次的acknum，以等待发送端超时重发。

接口函数

接口函数即为测试函数会调用的函数，如A_input()等。

由于采用了对象的方式，因此接口函数的篇幅不大，直接调用对应对象函数进行初始化、接收、重传等操作。

唯一需要在接口函数中进行操作的是在实体接收到一个包时，判断包是数据包还是ACK包的函数，这里举A_input()为例，使用acknum判断包的类型，然后分别传入接收端或者发送端的input函数进行对应的处理，从而完成数据包的接收。

```
void A_input(struct pkt packet)
{
    if (-1 == packet.acknum)
    {
        receiver_input(0, &receiver_A, packet);
    }
    else
        sender_input(0, &sender_A, packet);
}
```

Bonus实现

由于程序面向的是发送端对象而非接收端对象，因此对于不同的实体函数内容基本一样，只需要更改传入的对象即可。

实现效果

提供了Makefile文件用于编译和测试，也可以直接使用如下的指令进行测试：

```
./prog2 100 0.1 0.3 1000 2
```

即丢包率为0.1，损毁率为0.3，发送10个包（两个实体总共10个），结果（部分）如下：

```
minaduki@mininet-vm:~/computer_networking/assignments/ReliableTransportProtocol
----- Stop and Wait Network Simulator Version 1.1 -----
```

----- SCOP AND WALT NETWORK SIMULATOR VERSION 1.1 -----

the number of messages to simulate: 10
packet loss probability: 0.100000
packet corruption probability: 0.300000
average time between messages from sender's layer5: 1000.000000
TRACE: 2

EVENT time: 1870.573975, type: 1, fromlayer5 entity: 1
B_sender_output: Added message. Allocated SEQ = 1.
window_send: Sending SEQ = 1.

EVENT time: 1877.939087, type: 2, fromlayer3 entity: 0
A_receiver_input: Received packet SEQ = 1. Sending ACK = 1.
A_receiver_input: Content:aaaaaaaaaaaaaaaaaaaa
TOLAYER3: packet being corrupted
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 1886.575195, type: 2, fromlayer3 entity: 1
B_sender_input: Packet corrupted. Dropping packet.

EVENT time: 1890.573975, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 1899.818481, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 1920.573975, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being lost

EVENT time: 1960.573975, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 1962.052368, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 2010.573975, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 2015.846191, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 2070.573975, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 2074.776611, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 2140.573975, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 2143.304199, type: 2, fromlayer3 entity: 0
A receiver input: Duplicated SEO = 1 received. Dronned.

```
-----  
A_sender_input: Received duplicate ACK. Packet ignored.  
  
EVENT time: 2220.573975, type: 0, timerinterrupt entity: 1  
B_timerinterrupt: Timeout for SEQ = 1. Resending.  
    TOLAYER3: packet being corrupted  
  
EVENT time: 2222.940430, type: 2, fromlayer3 entity: 0  
A_receiver_input: Duplicated SEQ = 1 received. Dropped.  
A_sender_input: Received duplicate ACK. Packet ignored.  
  
EVENT time: 2310.573975, type: 0, timerinterrupt entity: 1  
B_timerinterrupt: Timeout for SEQ = 1. Resending.  
    TOLAYER3: packet being lost  
  
EVENT time: 2410.573975, type: 0, timerinterrupt entity: 1  
B_timerinterrupt: Timeout for SEQ = 1. Resending.  
    TOLAYER3: packet being lost  
  
EVENT time: 2520.573975, type: 0, timerinterrupt entity: 1  
B_timerinterrupt: Timeout for SEQ = 1. Resending.  
  
EVENT time: 2526.822998, type: 2, fromlayer3 entity: 0  
A_receiver_input: Duplicated SEQ = 1 received. Dropped.  
A_sender_input: Received duplicate ACK. Packet ignored.  
  
EVENT time: 2640.573975, type: 0, timerinterrupt entity: 1  
B_timerinterrupt: Timeout for SEQ = 1. Resending.  
  
EVENT time: 2642.054688, type: 2, fromlayer3 entity: 0  
A_receiver_input: Duplicated SEQ = 1 received. Dropped.  
A_sender_input: Received duplicate ACK. Packet ignored.  
  
EVENT time: 2770.573975, type: 0, timerinterrupt entity: 1  
B_timerinterrupt: Timeout for SEQ = 1. Resending.  
  
EVENT time: 2773.204590, type: 2, fromlayer3 entity: 0  
A_receiver_input: Duplicated SEQ = 1 received. Dropped.  
A_sender_input: Received duplicate ACK. Packet ignored.  
  
EVENT time: 2817.214111, type: 1, fromlayer5 entity: 0  
A_sender_output: Added message. Allocated SEQ = 1.  
window_send: Sending SEQ = 1.  
  
EVENT time: 2818.272461, type: 2, fromlayer3 entity: 1  
B_receiver_input: Received packet SEQ = 1. Sending ACK = 1.  
B_receiver_input: Content: bbbbbbbbbb  
    TOLAYER3: packet being lost  
B_sender_input: Received duplicate ACK. Packet ignored.  
  
EVENT time: 2837.214111, type: 0, timerinterrupt entity: 0  
A_timerinterrupt: Timeout for SEQ = 1. Resending.  
  
EVENT time: 2842.488281, type: 2, fromlayer3 entity: 1  
B_receiver_input: Duplicated SEQ = 1 received. Dropped.  
B_sender_input: Received duplicate ACK. Packet ignored.  
  
EVENT time: 2867.214111, type: 0, timerinterrupt entity: 0  
A_timerinterrupt: Timeout for SEQ = 1. Resending.
```

TOLAYER3: packet being lost

EVENT time: 2907.214111, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 2910.573975, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being lost

EVENT time: 2915.995361, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 1 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 2957.214111, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being lost

EVENT time: 3017.214111, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted

EVENT time: 3022.033447, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 1 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 3060.573975, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 3064.235840, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 3087.214111, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted

EVENT time: 3096.125000, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 1 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 3167.214111, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted

EVENT time: 3172.831787, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 1 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 3220.573975, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted

EVENT time: 3222.605713, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 3257.214111, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.

TOLAYER3: packet being corrupted

EVENT time: 3264.957031, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 1 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 3357.214111, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 3363.905518, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 1 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 3390.573975, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted

EVENT time: 3396.046631, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 3467.214111, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 3472.601074, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 1 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 3570.573975, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 3572.278320, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 3587.214111, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being lost

EVENT time: 3717.214111, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 3725.171875, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 1 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 3760.573975, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 3764.966553, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 3857.214111, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 3862.879150, type: 2, fromlayer3 entity: 1
B receiver input: Duplicated SEO = 1 received. Dronned.

B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 3960.573975, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted

EVENT time: 3967.270752, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 4007.214111, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 4016.702393, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 1 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 4167.213867, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted

EVENT time: 4169.719238, type: 2, fromlayer3 entity: 1
B_sender_input: Packet corrupted. Dropping packet.

EVENT time: 4170.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted

EVENT time: 4178.354004, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 4337.213867, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted

EVENT time: 4343.114746, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 1 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 4390.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted

EVENT time: 4399.397461, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 4517.213867, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted

EVENT time: 4518.797852, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 1 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 4620.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 4625.821289, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 4707.213867, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted

EVENT time: 4716.157715, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 1 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 4763.713867, type: 1, fromlayer5 entity: 0
A_sender_output: Added message. Allocated SEQ = 2.
window_send: Sending SEQ = 2.
TOLAYER3: packet being lost

EVENT time: 4860.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being lost

EVENT time: 4907.213867, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted
A_timerinterrupt: Timeout for SEQ = 2. Resending.
TOLAYER3: packet being corrupted

EVENT time: 4910.210449, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 1 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 4911.359375, type: 2, fromlayer3 entity: 1
B_sender_input: Packet corrupted. Dropping packet.

EVENT time: 5110.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 5117.213867, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 1. Resending.
A_timerinterrupt: Timeout for SEQ = 2. Resending.

EVENT time: 5118.142578, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 5121.387695, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 1 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 5128.989746, type: 2, fromlayer3 entity: 1
B_receiver_input: Received packet SEQ = 2. Sending ACK = 2.
B_receiver_input: Content: cccccccccccccccccc
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 5138.120605, type: 2, fromlayer3 entity: 0
A_sender_input: Got ACK = 2.

EVENT time: 5370.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.

EVENT time: 5374.952148, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 5529.646484, type: 1, fromlayer5 entity: 1
B_sender_output: Added message. Allocated SEQ = 2.
window_send: Sending SEQ = 2.

EVENT time: 5535.588867, type: 2, fromlayer3 entity: 0
A_receiver_input: Received packet SEQ = 2. Sending ACK = 2.
A_receiver_input: Content: dddddddddd dddd dddd
TOLAYER3: packet being lost
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 5640.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
B_timerinterrupt: Timeout for SEQ = 2. Resending.

EVENT time: 5647.405273, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 5656.605469, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 2 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 5920.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
B_timerinterrupt: Timeout for SEQ = 2. Resending.

EVENT time: 5929.923340, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 5933.185547, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 2 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 6210.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
B_timerinterrupt: Timeout for SEQ = 2. Resending.

EVENT time: 6217.374512, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 6219.862793, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 2 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 6405.025879, type: 1, fromlayer5 entity: 0
A_sender_output: Added message. Allocated SEQ = 3.
window_send: Sending SEQ = 3.
TOLAYER3: packet being corrupted

EVENT time: 6406.431641, type: 2, fromlayer3 entity: 1
B_receiver_input: Received packet SEQ = 3. Sending ACK = 3.
B_receiver_input: Content: Zeeeeeeeeeeeeeeeeeee
TOLAYER3: packet being lost
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 6510.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted
B_timerinterrupt: Timeout for SEQ = 2. Resending.

EVENT time: 6520.288574, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 6523.303223, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 2 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 6625.025879, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 3. Resending.

EVENT time: 6630.758789, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 3 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 6820.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
B_timerinterrupt: Timeout for SEQ = 2. Resending.
TOLAYER3: packet being lost

EVENT time: 6830.178711, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 6855.025879, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 3. Resending.

EVENT time: 6863.607422, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 3 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 7095.025879, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 3. Resending.

EVENT time: 7098.439941, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 3 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 7140.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
TOLAYER3: packet being corrupted
B_timerinterrupt: Timeout for SEQ = 2. Resending.
TOLAYER3: packet being lost

EVENT time: 7145.767090, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 1 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 7345.025879, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 3. Resending.
 TOLAYER3: packet being corrupted

EVENT time: 7349.457031, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 3 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 7470.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
 TOLAYER3: packet being lost
B_timerinterrupt: Timeout for SEQ = 2. Resending.
 TOLAYER3: packet being corrupted

EVENT time: 7479.569824, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 2 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 7605.025879, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 3. Resending.

EVENT time: 7612.045898, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 3 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 7628.443359, type: 1, fromlayer5 entity: 1
B_sender_output: Added message. Allocated SEQ = 3.
window_send: Sending SEQ = 3.
 TOLAYER3: packet being lost

EVENT time: 7645.067383, type: 1, fromlayer5 entity: 1
B_sender_output: Added message. Allocated SEQ = 4.
window_send: Sending SEQ = 4.
 TOLAYER3: packet being lost

EVENT time: 7810.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 1. Resending.
 TOLAYER3: packet being lost
B_timerinterrupt: Timeout for SEQ = 2. Resending.
B_timerinterrupt: Timeout for SEQ = 3. Resending.
 TOLAYER3: packet being corrupted
B_timerinterrupt: Timeout for SEQ = 4. Resending.

EVENT time: 7816.737305, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 2 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 7822.151855, type: 2, fromlayer3 entity: 0
A_receiver_input: Packet corrupted. Sending last ACK = 2.
A_sender_input: Packet corrupted. Dropping packet.

EVENT time: 7828.472168, type: 2, fromlayer3 entity: 0
A_receiver_input: Unexpected SEQ = 4 received. Sending last ACK = 2.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 7829.170410, type: 2, fromlayer3 entity: 1
B_sender_input: Got ACK = 2.

EVENT time: 7837.292969, type: 2, fromlayer3 entity: 1
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 7875.025879, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 3. Resending.

EVENT time: 7884.396484, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 3 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 8155.025879, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 3. Resending.

EVENT time: 8158.062988, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 3 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 8160.574219, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 3. Resending.
B_timerinterrupt: Timeout for SEQ = 4. Resending.

EVENT time: 8168.292480, type: 2, fromlayer3 entity: 0
A_receiver_input: Received packet SEQ = 3. Sending ACK = 3.
A_receiver_input: Content: ffffffffffffffff
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 8176.425293, type: 2, fromlayer3 entity: 0
A_receiver_input: Received packet SEQ = 4. Sending ACK = 4.
A_receiver_input: Content: ggggggggggggggggggg
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 8176.444336, type: 2, fromlayer3 entity: 1
B_sender_input: Got ACK = 3.

EVENT time: 8180.759277, type: 2, fromlayer3 entity: 1
B_sender_input: Got ACK = 4.

EVENT time: 8445.025391, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 3. Resending.

EVENT time: 8453.754883, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 3 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 8745.025391, type: 0, timerinterrupt entity: 0
A_timerinterrupt: Timeout for SEQ = 3. Resending.
TO_LAYER3: packet being corrupted

EVENT time: 8754.703125, type: 2, fromlayer3 entity: 1
B_receiver_input: Duplicated SEQ = 3 received. Dropped.
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 9036.344727, type: 1, fromlayer5 entity: 0
A_sender_output: Added message. Allocated SEQ = 4.
window_send: Sending SEQ = 4.

EVENT time: 9043.182617. type: 2. fromlayer3 entity: 1

B_receiver_input: Received packet SEQ = 4. Sending ACK = 4.
B_receiver_input: Content: hhhhhhhhhhhhhhhhh
B_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 9046.638672, type: 2, fromlayer3 entity: 0
A_sender_input: Got ACK = 4.

EVENT time: 9267.890625, type: 1, fromlayer5 entity: 1
B_sender_output: Added message. Allocated SEQ = 5.
window_send: Sending SEQ = 5.

EVENT time: 9270.275391, type: 2, fromlayer3 entity: 0
A_receiver_input: Received packet SEQ = 5. Sending ACK = 5.
A_receiver_input: Content: iiiiiiiiiiiiiiii
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 9280.012695, type: 2, fromlayer3 entity: 1
B_sender_input: Got ACK = 5.

EVENT time: 9958.363281, type: 1, fromlayer5 entity: 1
B_sender_output: Added message. Allocated SEQ = 6.
window_send: Sending SEQ = 6.

EVENT time: 9963.712891, type: 2, fromlayer3 entity: 0
A_receiver_input: Received packet SEQ = 6. Sending ACK = 6.
A_receiver_input: Content: jjjjjjjjjjjjjjjj
TOLAYER3: packet being lost
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 10318.363281, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 6. Resending.
TOLAYER3: packet being lost

EVENT time: 10688.363281, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 6. Resending.

EVENT time: 10693.135742, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 6 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 11068.363281, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 6. Resending.

EVENT time: 11071.865234, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 6 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 11458.363281, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 6. Resending.
TOLAYER3: packet being corrupted

EVENT time: 11461.542969, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 6 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 11858.363281, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 6. Resending.

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EVENT time: 11866.335938, type: 2, fromlayer3 entity: 0
A_receiver_input: Duplicated SEQ = 6 received. Dropped.
A_sender_input: Received duplicate ACK. Packet ignored.

EVENT time: 12268.363281, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 6. Resending.
    TOLAYER3: packet being lost

EVENT time: 12688.363281, type: 0, timerinterrupt entity: 1
B_timerinterrupt: Timeout for SEQ = 6. Resending.
    TOLAYER3: packet being corrupted

EVENT time: 12690.823242, type: 2, fromlayer3 entity: 0
A_receiver_input: Packet corrupted. Sending last ACK = 6.
A_sender_input: Packet corrupted. Dropping packet.

EVENT time: 12693.951172, type: 2, fromlayer3 entity: 1
B_sender_input: Got ACK = 6.
    Simulator terminated at time 12693.951172
    after sending 10 msgs from layer5
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小结

通过此次试验，充分了解了可靠传输协议的基本实现方式，对网络传输层有了基本的认识。