

滑动窗口实验报告

选择重传协议

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一、实验内容

利用所学数据链路层原理，自己设计一个滑动窗口协议，在仿真环境下编程实现有噪音信道环境下两站点之间无差错双工通信。信道模型为 8000bps 全双工卫星信道，信道传播时延 270 毫秒，信道误码率为 10^{-5} ，信道提供字节流传输服务，网络层分组长度固定为 256 字节。

二、实验目的

通过该实验，进一步巩固和深刻理解数据链路层误码检测的 CRC 校验技术，以及滑动窗口的工作机理。滑动窗口机制的两个主要目标：(1) 实现有噪音信道环境下的无差错传输；(2) 充分利用传输信道的带宽。在程序能够稳定运行并成功实现第一个目标之后，运行程序并检查在信道没有误码和存在误码两种情况下的信道利用率。为实现第二个目标，提高滑动窗口协议信道利用率，需要根据信道实际情况合理地为协议配置工作参数，包括滑动窗口的大小和重传定时器时限以及 ACK 搭载定时器的时限。这些参数的设计，需要充分理解滑动窗口协议的工作原理并利用所学的理论知识，经过认真的推算，计算出最优取值，并通过程序的运行进行验证。

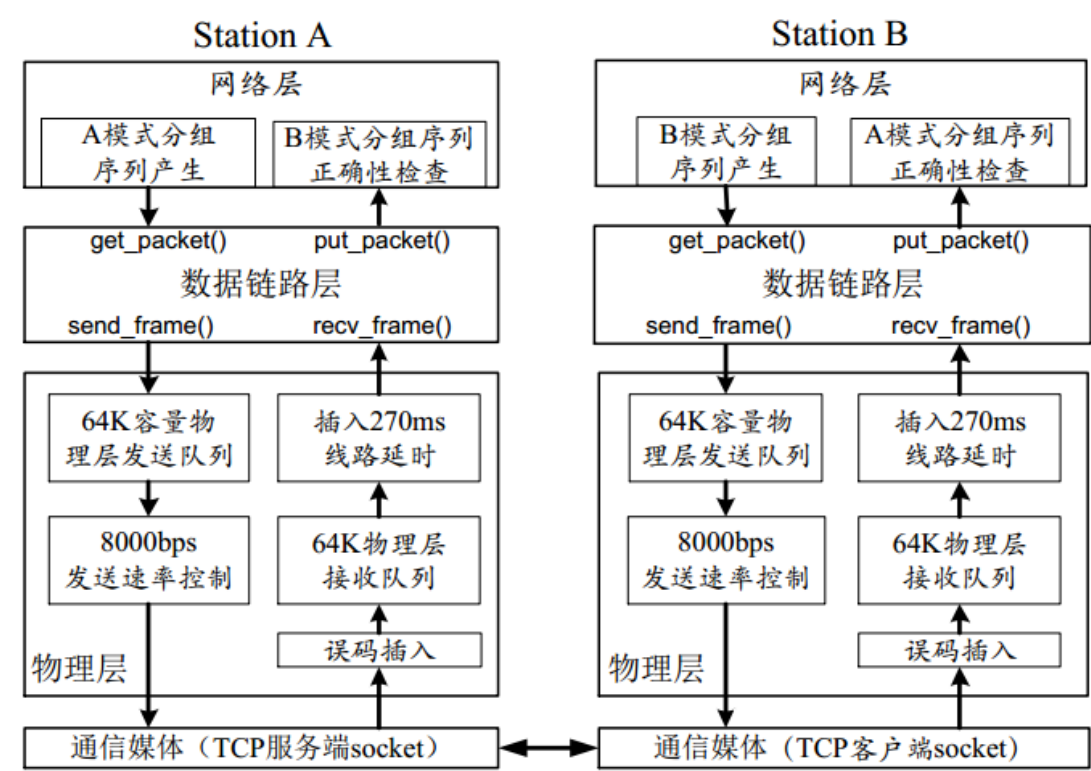
通过该实验提高同学的编程能力和实践动手能力，体验协议软件在设计上各种问题和调试难度，设计在运行期可跟踪分析协议工作过程的协议软件，巩固和深刻理解理论知识并利用这些知识对系统进行优化，对实际系统中的协议分层和协议软件的设计与实现有基本的认识。

三、实验环境

Windows10 PC 机， Microsoft Visual Studio 2017 环境。

四、协议设计

1. 协议的分层结构及层服务



物理层：为数据链路层提供的服务为 8000bps， 270ms 传播延时， 10-5 误码率的字节流传输通道。为了仿真实现上述服务质量的信道，利用在同一台计算机上 TCP socket 完成两个站点之间的通信。由于同一台计算机上 TCP 通信传播时延短、传播速度快、没有误码，物理层仿真程序在发送端利用“令牌桶”算

法限制发送速率以仿真 8000bps 线路；在接收端误码插入模块利用一个伪随机数“随机地”篡改从 TCP 收到的数据，使得所接收到的每个比特出现差错的概率为 10^{-5} ；接收到的数据缓冲后延时 270ms 才提交给数据链路层程序，以仿真信道的传播时延特性。为了简化程序，省略了“成帧”功能，数据链路层利用接口函数 `send_frame()`和 `recv_frame()`发送和接收一帧。

数据链路层：程序由同学自己设计完成，通过物理层提供的帧发送和接收函数，利用物理层提供的服务。通过 `get_packet()`函数从网络层得到一个分组；当数据链路层成功接收到一个分组后，通过 `put_packet()`函数提交给网络层。

网络层：利用数据链路层提供的“可靠的分组传输”服务，在站点 A 与站点 B 之间交换长度固定为 256 字节的数据分组。网络层把产生的分组交付数据链路层，并接受数据链路层提交来的数据分组。

2. 协议工作的正确性验证

如果数据链路层程序能够正确工作，站点 A 通过数据链路层发送的分组流，经过有误码的信道传输后，站点 B 就能够以同样的顺序收到同样内容的分组流。验证数据链路层程序的正确性的一种方法为：在站点 A 记录发送的分组流，在站点 B 记录接收到的分组流，比较这两份记录是否相同。为了简化这项工作，这里的网络层程序实现了一个“分组序列发生器”。“分组序列发生器”根据一个伪随机数公式，按照一种固定的模式产生分组流。在接收方用同样的公式计算一次，比对收到分组的每个字节值是否与约定的模式完全相同，这样就可以验证数据链路层是否实现了承诺的“无差错分组流传输”服务。一旦检查出数据链路层出错，

程序打印错误信息后立刻中止运行。站点 A 到站点 B 方向和站点 B 到站点 A 方向分别使用不同的伪随机数公式, 在全双工通信条件下双向同时进行分组序列的产生和验证。

3. 成帧方案，边界和转义字符的定义及转义方法

采用字节填充的标志字节法。每一帧都用一些特殊的字符 FLAG 作为开始和结束的边界。当有效载荷中含有标志字节或转义字节时, 在每个在有效载荷中出现的标志字节或转义字节前加一个 ESC 转义字节。接收端的数据链路层在将数据送给网络层之前删掉这些转义字符。

4. 帧中各个字段的定义和编码

(1) 字段定义

```
1. struct FRAME
2. {
3.     unsigned char kind;          /* FRAME_DATA, FRAME_ACK, FRAME_N
   AK */
4.     unsigned char ack;          /* ACK 或 NAK 的序号 */
5.     unsigned char seq;          /* 数据帧的序号 */
6.     unsigned char data[PKT_LEN]; /*帧中的数据段*/
7.     unsigned int padding;       /*填充字段*/
8. };
```

KIND	表示帧的类别
ACK	ACK或NAK序列号
SEQ	数据帧序列号
DATA	帧中的数据段

CRC	校验和
-----	-----

(2) 帧格式

DATA Frame:

KIND(1)	SEQ(1)	ACK(1)	DATA(240~256)	CRC(4)
---------	--------	--------	---------------	--------

ACK Frame

KIND(1)	ACK(1)	CRC(4)
---------	--------	--------

NAK Frame

KIND(1)	ACK(1)	CRC(4)
---------	--------	--------

(3) 校验和

CRC校验数据由函数crc32()产生，函数crc32()返回一个32位整数为数据生成CRC-32校验和，并且把这 32比特校验和附在数据字节之后。

多项式定义：采用的CRC校验方案为CRC-32，生成多项式为：

$$X^{32} + X^{26} + X^{23} + X^{22} + X^{16} + X^{12} + X^{11} + X^{10} + X^8 + X^7 + X^5 + X^4 + X^2 + X^1 + 1$$

校验和附加在数据帧尾部，接受方用带校验和的数据来逻辑除以生成多项式，余数为零则数据无误码，反之有误码等待发送方重传。

5. 两个站点间信息交换的过程控制，尤其是误码条件下的控制方案

协议工作时，两个站点通过互发数据包交换数据，而控制讯息则捎带在数据讯息中传递。

当出现帧丢失时，如收到帧的序号有跳跃，或者出现 CRC 校验出错丢弃了某帧，会主动发送 NAK 否定帧（包括 GBN 和 SR 协议）。若长期未产生反向数据帧，则出现 ACK 超时事件，主动发送 ACK 帧提示确认，对方收到确认后，滑动窗口继续发送，若一直未收到确认讯息，则出现数据帧超时事件，发送方会自动重发相应的数据帧。

五、软件设计

1. 数据结构

(1) 帧结构体

```
1. struct FRAME
2. {
3.     unsigned char kind;          /* FRAME_DATA, FRAME_ACK, FRAME_NAK */
4.     unsigned char ack;          /* ACK 或 NAK 的序号 */
5.     unsigned char seq;          /* 数据帧的序号 */
6.     unsigned char data[PKT_LEN]; /* 帧中的数据段 */
7.     unsigned int padding;       /* 填充字段 */
8. };
```

KIND	表示帧的类别
ACK	ACK或NAK序列号

SEQ	数据帧序列号
DATA	帧中的数据段
CRC	校验和

(2) Selective Repeat 协议变量及常量解释

```

1. #define DATA_TIMER 3000 //重发计时器
2. #define ACK_TIMER 1000 //ACK 计时器
3. #define MAX_SEQ 63 //最大序号
4. #define NR_BUFS ((MAX_SEQ + 1) / 2) //最大窗口
5.
6. int no_nak = 1; //no nak has been sent yet,use the nak only when the frame is error for the first time
7. static int phl_ready = 0; //phl_ready = '0' remarks that the physical layer is not ready yet
8. static unsigned char ack_expected = 0; //发送窗口下界
9. static unsigned char next_frame_to_send = 0; //发送窗口上界 + 1
10. static unsigned char frame_expected = 0; //接收窗口下界
11. static unsigned char too_far = NR_BUFS; //接收窗口上界
12. static unsigned char out_buf[NR_BUFS][PKT_LEN]; //发送缓存
13. static unsigned char in_buf[NR_BUFS][PKT_LEN]; //接收缓存
14. int arrived[NR_BUFS]; //指明接收缓冲区满空
15. static unsigned char nbuffered = 0; //指明当前发送缓存数目

```

2. 模块结构

(1) 子程序完成的功能及其参数的意义

①static void put_frame(unsigned char *frame, int len)

该函数实现 4 位 CRC 校验和的添加以及数据帧向物理层的传输。其中参数 frame 为指向数据帧的指针，len 表示当前数据帧的长度。

②static int between(int a, int b, int c)

该函数用于判断当前接收帧是否在接收窗口范围内，决定是否应该缓存或丢弃。若变量 `a` 在使用时代表接收窗口的上界(`frame_expected`)，`c` 代表接收窗口的下界(`too_far`)，则 `b` 代表当前数据帧的序号(`r.seq`)。若 `a` 代表当前发送窗口的上界(`ack_expected`)，`c` 代表发送窗口的下界(`next_frame_to_send`)则 `b` 代表确认序号 (`r.ack`)。

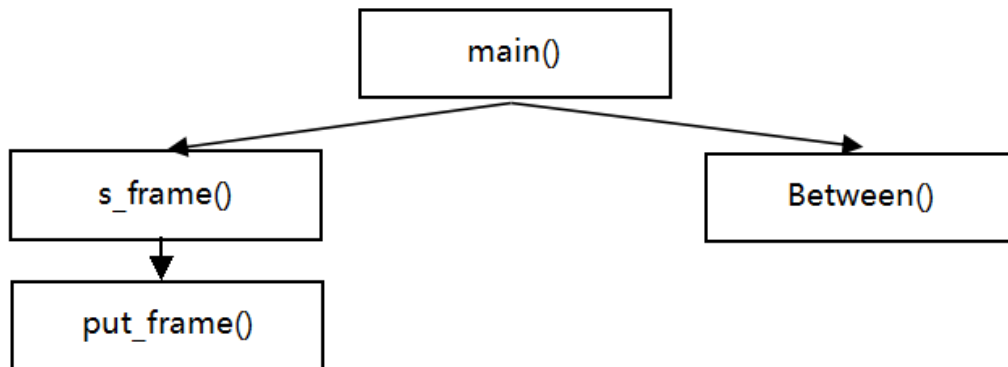
③ **static void s_frame(unsigned char fk, unsigned char frame_nr, unsigned char frame_expected, unsigned char buffer[][PKT_LEN])**

该函数用于发送数据帧、ACK 帧或 NAK 帧。第一个参数决定发送的帧的种类。若 `fk == FRAME_DATA`：当主函数中为 `NETWORK_LAYER_READY` 事件时，在接收到网络层传来的数据之后调用该函数，实现数据帧的帧头和校验和的添加，并调用 `put_frame()` 函数发送数据帧。`Frame_nr`, `frame_expected`, `packet[]`，分别代表当前数据帧的序号位，`ack` 值和数据信息。

若 `fk == FRAME_ACK`：发送单独的 ACK 帧。当一端向另一端发送了一个正确的帧后，如果接受端没有回传的数据帧，则不能捎带会 ACK 确认信息，则需要单独发送 ACK 帧防止数据帧的重传。`Frame_expected` 代表当前需要重传的帧的序号位。

若 `fk == FRAME_NAK`：发送单独的 nak 帧。当状态处于数据接受状态时，首先需要进行校验并判断帧长。若校验出帧传输发生错误且当前状态之前没有传输过 NAK，则需要单独发送 nak 提醒发送端重新进行当前数据帧的发送，减少等待时间，提高信道的利用率。`Framen_expeced` 代表需要重传的帧的序号位。

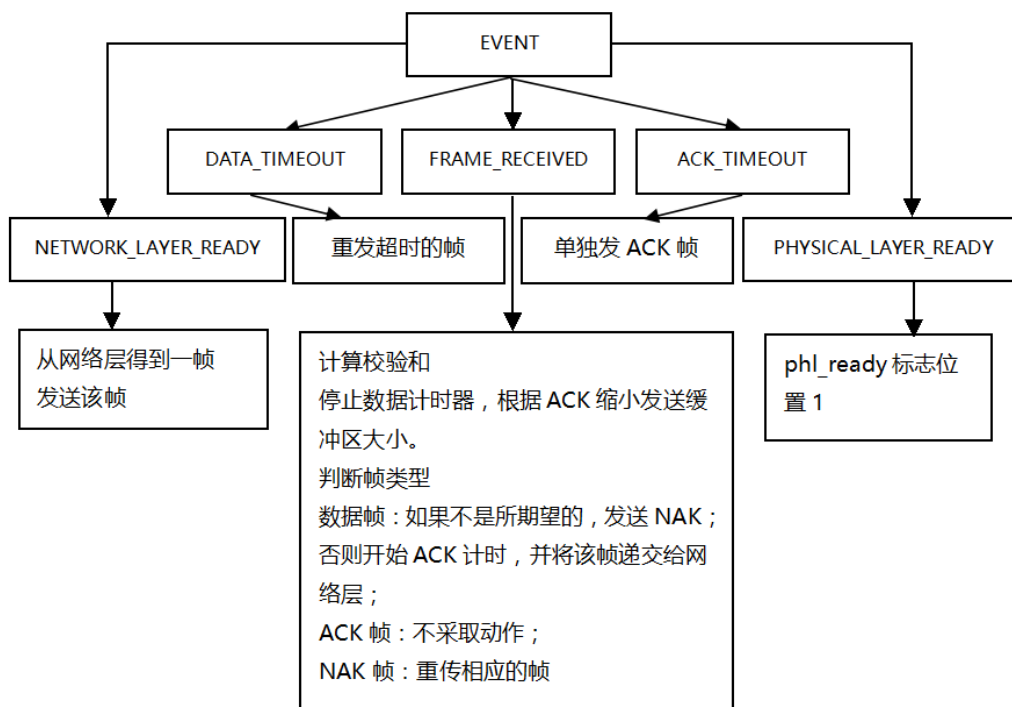
(2) 程序调用关系图



3. 算法流程

(1) 算法流程图

Selective 协议和 GoBack-N 协议算法流程相似，如下所示：



(2) 实现

protocol.h 头文件中的相关定义和函数原型：

```
extern int wait_for_event(int *arg);

#define NETWORK_LAYER_READY 0

#define PHYSICAL_LAYER_READY 1

#define FRAME_RECEIVED 2

#define DATA_TIMEOUT 3

#define ACK_TIMEOUT 4
```

函数 `wait_for_event()` 导致进程等待，直到一个“事件”发生。可能的事件有上述 5 种，函数返回值为上述 5 种事件之一。参数 `arg` 用于获得已发生事件的相关信息，仅用于 `DATA_TIMEOUT` 两种事件，获取产生超时事件的定时器编号。

NETWORK_LAYER_READY：网络层有待发送的分组。此事件发生后才可以调用 `get_packet()` 得到网络层待发送的下一个分组。

PHYSICAL_LAYER_READY：物理层发送队列的长度低于 50 字节。参见“与物理层模块的接口函数”部分。

FRAME_RECEIVED：物理层收到了一整帧。

DATA_TIMEOUT：定时器超时，参数 `arg` 中返回发生超时的定时器的编号。

ACK_TIMEOUT：所设置的搭载 ACK 定时器超时。

数据链路层程序的主控函数的总体流程框架与教科书中的示意性程序类似，但由于所支持的事件种类和流量控制机制不同，在细节处理上不尽相同。程序的

示意性流程如下：

```
1. enable_network_layer();
2. for (;;)
3. {
4.     event = wait_for_event(&arg);
5.     switch (event)
6.     {
7.         case EVENT_NETWORK_LAYER_READY:
8.             len = get_packet(my_buf);
9.             ... ..
10.            break;
11.        case EVENT_PHYSICAL_LAYER_READY:
12.            ... ..
13.            break;
14.        case EVENT_FRAME_RECEIVED:
15.            rbuf_len = recv_frame(rbuf, sizeof rbuf);
16.            ... ..
17.            break;
18.        case EVENT_ACK_TIMEOUT:
19.            ... ..
20.            break;
21.        case EVENT_DATA_TIMEOUT:
22.            ... ..
23.            break;
24.    }
25.    if (...)
26.        enable_network_layer();
27.    else
28.        disable_network_layer();
29.}
```

六、实验结果及分析

1. 实验结果

(1) Selective 协议

(a) 无误码信道数据传输

datalog a --utopia							datalog b --utopia						
982.171	....	2007	packets received,	4191 bps,	52.38%,	Err 0 (0.0e+00)	995.234	....	3768	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
986.223	....	2008	packets received,	4175 bps,	52.19%,	Err 0 (0.0e+00)	997.337	....	3776	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
990.307	....	2009	packets received,	4160 bps,	52.00%,	Err 0 (0.0e+00)	999.452	....	3784	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
994.389	....	2010	packets received,	4145 bps,	51.81%,	Err 0 (0.0e+00)	1001.558	....	3792	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
998.430	....	2011	packets received,	4130 bps,	51.63%,	Err 0 (0.0e+00)	1003.686	....	3800	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1000.539	....	2012	packets received,	4124 bps,	51.55%,	Err 0 (0.0e+00)	1005.781	....	3808	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1002.664	....	2020	packets received,	4131 bps,	51.64%,	Err 0 (0.0e+00)	1007.903	....	3816	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1004.772	....	2028	packets received,	4139 bps,	51.74%,	Err 0 (0.0e+00)	1010.010	....	3824	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1006.893	....	2036	packets received,	4147 bps,	51.83%,	Err 0 (0.0e+00)	1012.118	....	3832	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1009.005	....	2044	packets received,	4154 bps,	51.93%,	Err 0 (0.0e+00)	1014.227	....	3840	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1011.099	....	2052	packets received,	4162 bps,	52.02%,	Err 0 (0.0e+00)	1016.335	....	3848	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1013.210	....	2060	packets received,	4169 bps,	52.12%,	Err 0 (0.0e+00)	1018.459	....	3856	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1015.322	....	2068	packets received,	4177 bps,	52.21%,	Err 0 (0.0e+00)	1020.569	....	3864	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1017.445	....	2076	packets received,	4184 bps,	52.30%,	Err 0 (0.0e+00)	1022.684	....	3872	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1019.553	....	2084	packets received,	4192 bps,	52.39%,	Err 0 (0.0e+00)	1024.793	....	3880	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1021.663	....	2092	packets received,	4199 bps,	52.49%,	Err 0 (0.0e+00)	1026.904	....	3888	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1023.775	....	2100	packets received,	4206 bps,	52.58%,	Err 0 (0.0e+00)	1029.025	....	3896	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1025.897	....	2108	packets received,	4214 bps,	52.67%,	Err 0 (0.0e+00)	1031.137	....	3904	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1028.005	....	2116	packets received,	4221 bps,	52.76%,	Err 0 (0.0e+00)	1033.246	....	3912	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1030.100	....	2124	packets received,	4228 bps,	52.85%,	Err 0 (0.0e+00)	1035.358	....	3920	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1032.227	....	2132	packets received,	4235 bps,	52.94%,	Err 0 (0.0e+00)	1037.453	....	3928	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1034.350	....	2140	packets received,	4243 bps,	53.03%,	Err 0 (0.0e+00)	1039.577	....	3936	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1036.459	....	2148	packets received,	4250 bps,	53.12%,	Err 0 (0.0e+00)	1041.698	....	3944	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1038.569	....	2156	packets received,	4257 bps,	53.21%,	Err 0 (0.0e+00)	1043.809	....	3952	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1040.677	....	2164	packets received,	4264 bps,	53.30%,	Err 0 (0.0e+00)	1045.920	....	3960	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1042.771	....	2172	packets received,	4271 bps,	53.39%,	Err 0 (0.0e+00)	1048.029	....	3968	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1044.884	....	2180	packets received,	4278 bps,	53.48%,	Err 0 (0.0e+00)	1050.136	....	3976	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1047.008	....	2188	packets received,	4285 bps,	53.56%,	Err 0 (0.0e+00)	1052.244	....	3984	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1049.118	....	2196	packets received,	4292 bps,	53.65%,	Err 0 (0.0e+00)	1054.364	....	3992	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1051.228	....	2204	packets received,	4299 bps,	53.74%,	Err 0 (0.0e+00)	1056.473	....	4000	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1053.336	....	2212	packets received,	4306 bps,	53.83%,	Err 0 (0.0e+00)	1058.581	....	4008	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1055.461	....	2220	packets received,	4313 bps,	53.91%,	Err 0 (0.0e+00)	1060.692	....	4016	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1057.570	....	2228	packets received,	4320 bps,	54.00%,	Err 0 (0.0e+00)	1062.801	....	4024	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1059.679	....	2236	packets received,	4327 bps,	54.08%,	Err 0 (0.0e+00)	1064.912	....	4032	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1061.789	....	2244	packets received,	4334 bps,	54.17%,	Err 0 (0.0e+00)	1067.020	....	4040	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1063.900	....	2252	packets received,	4340 bps,	54.25%,	Err 0 (0.0e+00)	1069.130	....	4048	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1066.027	....	2260	packets received,	4347 bps,	54.34%,	Err 0 (0.0e+00)	1071.252	....	4056	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1068.137	....	2268	packets received,	4354 bps,	54.42%,	Err 0 (0.0e+00)	1073.358	....	4064	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1070.243	....	2276	packets received,	4361 bps,	54.51%,	Err 0 (0.0e+00)	1075.467	....	4072	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1072.365	....	2284	packets received,	4367 bps,	54.59%,	Err 0 (0.0e+00)	1077.592	....	4080	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1074.473	....	2292	packets received,	4374 bps,	54.67%,	Err 0 (0.0e+00)	1079.700	....	4088	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1076.583	....	2300	packets received,	4381 bps,	54.76%,	Err 0 (0.0e+00)	1081.815	....	4096	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1078.691	....	2308	packets received,	4387 bps,	54.84%,	Err 0 (0.0e+00)	1083.942	....	4104	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1080.798	....	2316	packets received,	4394 bps,	54.92%,	Err 0 (0.0e+00)	1086.049	....	4112	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1082.904	....	2324	packets received,	4400 bps,	55.01%,	Err 0 (0.0e+00)	1088.159	....	4120	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1085.013	....	2332	packets received,	4407 bps,	55.09%,	Err 0 (0.0e+00)	1090.269	....	4128	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1087.121	....	2340	packets received,	4414 bps,	55.17%,	Err 0 (0.0e+00)	1092.375	....	4136	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1089.262	....	2348	packets received,	4420 bps,	55.25%,	Err 0 (0.0e+00)	1094.485	....	4144	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1091.370	....	2356	packets received,	4426 bps,	55.33%,	Err 0 (0.0e+00)	1096.599	....	4152	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1093.467	....	2364	packets received,	4433 bps,	55.41%,	Err 0 (0.0e+00)	1098.725	....	4160	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1095.574	....	2372	packets received,	4439 bps,	55.49%,	Err 0 (0.0e+00)	1100.832	....	4168	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1097.702	....	2380	packets received,	4446 bps,	55.57%,	Err 0 (0.0e+00)	1102.924	....	4176	packets received,	7758 bps,	96.97%,	Err 0 (0.0e+00)
1099.810	....	2388	packets received,	4452 bps,	55.65%,	Err 0 (0.0e+00)	1105.064	....	4184	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)
1104.470	....	2391	packets received,	4439 bps,	55.49%,	Err 0 (0.0e+00)	1107.168	....	4192	packets received,	7757 bps,	96.97%,	Err 0 (0.0e+00)

(b) 站点 A 分组层平缓方式发出数据，站点 B 周期性交替“发送 100 秒，停发 100 秒”

datalink a										datalink b									
774.145	....	1577	packets received,	4179	bps,	52.24%,	Err	34	(1.0e-05)	793.142	....	2937	packets received,	7595	bps,	94.94%,	Err	64	(1.0e-05)
778.217	....	1578	packets received,	4160	bps,	52.00%,	Err	34	(1.0e-05)	795.239	....	2945	packets received,	7596	bps,	94.95%,	Err	64	(1.0e-05)
782.350	....	1579	packets received,	4140	bps,	51.76%,	Err	34	(1.0e-05)	797.364	....	2953	packets received,	7596	bps,	94.95%,	Err	64	(1.0e-05)
786.468	....	1580	packets received,	4121	bps,	51.52%,	Err	34	(1.0e-05)	799.492	....	2961	packets received,	7597	bps,	94.96%,	Err	64	(1.0e-05)
790.649	....	1581	packets received,	4102	bps,	51.28%,	Err	34	(1.0e-05)	801.602	....	2969	packets received,	7597	bps,	94.96%,	Err	64	(1.0e-05)
794.825	....	1582	packets received,	4083	bps,	51.04%,	Err	34	(1.0e-05)	803.703	....	2977	packets received,	7598	bps,	94.97%,	Err	64	(1.0e-05)
799.756	....	1583	packets received,	4060	bps,	50.76%,	Err	35	(1.0e-05)	805.833	....	2985	packets received,	7598	bps,	94.97%,	Err	65	(1.0e-05)
801.866	....	1589	packets received,	4065	bps,	50.81%,	Err	35	(1.0e-05)	807.941	....	2993	packets received,	7598	bps,	94.98%,	Err	65	(1.0e-05)
803.960	....	1597	packets received,	4075	bps,	50.94%,	Err	35	(1.0e-05)	810.038	....	3001	packets received,	7599	bps,	94.99%,	Err	65	(1.0e-05)
806.077	....	1605	packets received,	4085	bps,	51.06%,	Err	35	(1.0e-05)	812.146	....	3009	packets received,	7599	bps,	94.99%,	Err	65	(1.0e-05)
808.187	....	1613	packets received,	4094	bps,	51.18%,	Err	35	(1.0e-05)	814.268	....	3017	packets received,	7600	bps,	95.00%,	Err	65	(1.0e-05)
810.307	....	1621	packets received,	4104	bps,	51.30%,	Err	35	(1.0e-05)	816.396	....	3025	packets received,	7600	bps,	95.00%,	Err	65	(1.0e-05)
812.432	....	1629	packets received,	4113	bps,	51.41%,	Err	35	(9.9e-06)	818.504	....	3033	packets received,	7600	bps,	95.00%,	Err	65	(9.9e-06)
814.534	....	1632	packets received,	4110	bps,	51.38%,	Err	36	(1.0e-05)	820.613	....	3036	packets received,	7588	bps,	94.85%,	Err	66	(1.0e-05)
816.643	....	1644	packets received,	4130	bps,	51.62%,	Err	36	(1.0e-05)	822.722	....	3048	packets received,	7599	bps,	94.98%,	Err	66	(1.0e-05)
818.750	....	1652	packets received,	4139	bps,	51.74%,	Err	36	(1.0e-05)	824.831	....	3056	packets received,	7599	bps,	94.99%,	Err	66	(1.0e-05)
820.879	....	1660	packets received,	4148	bps,	51.85%,	Err	36	(1.0e-05)	826.959	....	3064	packets received,	7599	bps,	94.99%,	Err	66	(1.0e-05)
822.990	....	1668	packets received,	4157	bps,	51.97%,	Err	36	(1.0e-05)	829.069	....	3072	packets received,	7600	bps,	95.00%,	Err	66	(1.0e-05)
825.627	....	1673	packets received,	4157	bps,	51.96%,	Err	37	(1.0e-05)	831.173	....	3080	packets received,	7600	bps,	95.00%,	Err	66	(9.9e-06)
827.738	....	1685	packets received,	4176	bps,	52.20%,	Err	37	(1.0e-05)	835.675	....	3082	packets received,	7584	bps,	94.55%,	Err	69	(1.0e-05)
829.845	....	1693	packets received,	4185	bps,	52.31%,	Err	37	(1.0e-05)	837.785	....	3098	packets received,	7584	bps,	94.80%,	Err	69	(1.0e-05)
831.969	....	1701	packets received,	4194	bps,	52.42%,	Err	37	(1.0e-05)	839.911	....	3104	packets received,	7580	bps,	94.75%,	Err	69	(1.0e-05)
834.082	....	1709	packets received,	4203	bps,	52.54%,	Err	37	(1.0e-05)	842.005	....	3111	packets received,	7578	bps,	94.72%,	Err	69	(1.0e-05)
836.191	....	1717	packets received,	4212	bps,	52.65%,	Err	37	(1.0e-05)	844.113	....	3117	packets received,	7574	bps,	94.67%,	Err	69	(1.0e-05)
839.641	....	1725	packets received,	4214	bps,	52.68%,	Err	38	(1.0e-05)	847.303	....	3123	packets received,	7560	bps,	94.49%,	Err	71	(1.0e-05)
841.781	....	1737	packets received,	4233	bps,	52.91%,	Err	38	(1.0e-05)	850.465	....	3132	packets received,	7553	bps,	94.41%,	Err	72	(1.1e-05)
843.887	....	1745	packets received,	4242	bps,	53.02%,	Err	38	(1.0e-05)	852.560	....	3143	packets received,	7561	bps,	94.51%,	Err	72	(1.1e-05)
846.012	....	1753	packets received,	4250	bps,	53.13%,	Err	38	(1.0e-05)	854.685	....	3151	packets received,	7561	bps,	94.52%,	Err	73	(1.1e-05)
848.139	....	1761	packets received,	4259	bps,	53.24%,	Err	38	(1.0e-05)	857.589	....	3157	packets received,	7550	bps,	94.38%,	Err	74	(1.1e-05)
850.263	....	1769	packets received,	4268	bps,	53.34%,	Err	38	(9.9e-06)	859.698	....	3168	packets received,	7558	bps,	94.47%,	Err	74	(1.1e-05)
852.383	....	1777	packets received,	4276	bps,	53.45%,	Err	38	(9.9e-06)	861.824	....	3176	packets received,	7558	bps,	94.48%,	Err	74	(1.1e-05)
854.491	....	1785	packets received,	4285	bps,	53.56%,	Err	38	(9.9e-06)	863.945	....	3184	packets received,	7558	bps,	94.48%,	Err	74	(1.1e-05)
856.615	....	1793	packets received,	4293	bps,	53.67%,	Err	38	(9.8e-06)	866.053	....	3192	packets received,	7559	bps,	94.49%,	Err	74	(1.1e-05)
859.792	....	1801	packets received,	4297	bps,	53.71%,	Err	39	(1.0e-05)	868.178	....	3200	packets received,	7559	bps,	94.49%,	Err	74	(1.1e-05)
862.429	....	1810	packets received,	4305	bps,	53.81%,	Err	41	(1.0e-05)	870.287	....	3208	packets received,	7560	bps,	94.50%,	Err	74	(1.1e-05)
864.554	....	1820	packets received,	4318	bps,	53.97%,	Err	41	(1.0e-05)	872.394	....	3216	packets received,	7560	bps,	94.51%,	Err	74	(1.1e-05)
866.649	....	1828	packets received,	4326	bps,	54.08%,	Err	41	(1.0e-05)	874.506	....	3224	packets received,	7561	bps,	94.51%,	Err	74	(1.1e-05)
868.760	....	1836	packets received,	4335	bps,	54.18%,	Err	41	(1.0e-05)	876.614	....	3232	packets received,	7561	bps,	94.52%,	Err	74	(1.1e-05)
870.868	....	1844	packets received,	4343	bps,	54.29%,	Err	41	(1.0e-05)	878.726	....	3240	packets received,	7562	bps,	94.52%,	Err	74	(1.1e-05)
872.980	....	1852	packets received,	4351	bps,	54.39%,	Err	41	(1.0e-05)	881.633	....	3247	packets received,	7553	bps,	94.41%,	Err	76	(1.1e-05)
875.089	....	1860	packets received,	4360	bps,	54.49%,	Err	41	(1.0e-05)	883.739	....	3258	packets received,	7561	bps,	94.51%,	Err	76	(1.1e-05)
877.214	....	1868	packets received,	4368	bps,	54.60%,	Err	41	(1.0e-05)	885.874	....	3266	packets received,	7561	bps,	94.51%,	Err	76	(1.1e-05)
879.329	....	1876	packets received,	4376	bps,	54.70%,	Err	42	(1.0e-05)	887.982	....	3273	packets received,	7559	bps,	94.49%,	Err	77	(1.1e-05)
881.457	....	1884	packets received,	4384	bps,	54.80%,	Err	42	(1.0e-05)	890.107	....	3281	packets received,	7560	bps,	94.49%,	Err	77	(1.1e-05)
884.345	....	1891	packets received,	4386	bps,	54.82%,	Err	44	(1.1e-05)	892.217	....	3289	packets received,	7560	bps,	94.50%,	Err	77	(1.1e-05)
886.453	....	1901	packets received,	4398	bps,	54.98%,	Err	44	(1.1e-05)	894.328	....	3297	packets received,	7560	bps,	94.51%,	Err	77	(1.1e-05)
889.627	....	1908	packets received,	4399	bps,	54.99%,	Err	45	(1.1e-05)	896.452	....	3305	packets received,	7561	bps,	94.51%,	Err	77	(1.1e-05)
891.753	....	1920	packets received,	4416	bps,	55.20%,	Err	45	(1.1e-05)	898.546	....	3313	packets received,	7561	bps,	94.52%,	Err	77	(1.1e-05)
893.861	....	1928	packets received,	4424	bps,	55.30%,	Err	45	(1.1e-05)	900.664	....	3321	packets received,	7562	bps,	94.52%,	Err	77	(1.1e-05)
895.970	....	1936	packets received,	4432	bps,	55.40%,	Err	45	(1.1e-05)	902.767	....	3329	packets received,	7562	bps,	94.53%,	Err	77	(1.1e-05)
898.079	....	1944	packets received,	4440	bps,	55.50%,	Err	45	(1.1e-05)	904.887	....	3337	packets received,	7563	bps,	94.53%,	Err	77	(1.1e-05)
900.205	....	1952	packets received,	4447	bps,	55.59%,	Err	45	(1.1e-05)	906.987	....	3345	packets received,	7563	bps,	94.54%,	Err	77	(1.1e-05)
904.495	....	1954	packets received,	4431	bps,	55.39%,	Err	45	(1.1e-05)	909.100	....	3353	packets received,	7564	bps,	94.55%,	Err	78	(1.1e-05)
908.584	....	1955	packets received,	4413	bps,	55.16%,	Err	45	(1.1e-05)	911.222	....	3360	packets received,	7562	bps,	94.52%,	Err	78	(1.1e-05)

(c) 无误码信道，站点 A 和站点 B 的分组层都洪水式产生分组

a) datalink a - flood --utopia										b) datalink b - flood --utopia											
448.852	1696	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	448.844	.....	1696	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
450.962	1704	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	450.958	.....	1704	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
453.071	1712	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	453.082	.....	1712	packets	received,	7757	bps,	96.96%,	Err	0	(0.0e+00)
455.179	1720	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	455.186	.....	1720	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
457.299	1728	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	457.295	.....	1728	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
459.407	1736	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	459.418	.....	1736	packets	received,	7757	bps,	96.96%,	Err	0	(0.0e+00)
461.516	1744	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	461.524	.....	1744	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
463.626	1752	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	463.632	.....	1752	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
465.752	1760	packets	received,	7757	bps,	96.96%,	Err	0	(0.0e+00)	465.741	.....	1760	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
467.859	1768	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	467.847	.....	1768	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
469.969	1776	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	469.957	.....	1776	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
472.080	1784	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	472.064	.....	1784	packets	received,	7758	bps,	96.97%,	Err	0	(0.0e+00)
474.192	1792	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	474.190	.....	1792	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
476.302	1800	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	476.302	.....	1800	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
478.413	1808	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	478.412	.....	1808	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
480.522	1816	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	480.533	.....	1816	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
482.630	1824	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	482.642	.....	1824	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
484.754	1832	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	484.748	.....	1832	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
486.862	1840	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	486.878	.....	1840	packets	received,	7757	bps,	96.96%,	Err	0	(0.0e+00)
488.968	1848	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	488.967	.....	1848	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
491.076	1856	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	491.091	.....	1856	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
493.202	1864	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	493.197	.....	1864	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
495.311	1872	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	495.304	.....	1872	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
497.423	1880	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	497.412	.....	1880	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
499.531	1888	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	499.537	.....	1888	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
501.655	1896	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	501.644	.....	1896	packets	received,	7757	bps,	96.96%,	Err	0	(0.0e+00)
503.550	1904	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	503.567	.....	1904	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
505.558	1912	packets	received,	7758	bps,	96.97%,	Err	0	(0.0e+00)	505.873	.....	1912	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
507.995	1920	packets	received,	7757	bps,	96.96%,	Err	0	(0.0e+00)	507.981	.....	1920	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
510.090	1928	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	510.104	.....	1928	packets	received,	7757	bps,	96.96%,	Err	0	(0.0e+00)
512.211	1936	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	512.197	.....	1936	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
514.320	1944	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	514.306	.....	1944	packets	received,	7758	bps,	96.97%,	Err	0	(0.0e+00)
516.445	1952	packets	received,	7757	bps,	96.96%,	Err	0	(0.0e+00)	516.431	.....	1952	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
518.551	1960	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	518.536	.....	1960	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
520.657	1968	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	520.657	.....	1968	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
522.761	1976	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	522.760	.....	1976	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
524.884	1984	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	524.884	.....	1984	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
526.991	1992	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	526.991	.....	1992	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
529.099	2000	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	529.099	.....	2000	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
531.207	2008	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	531.207	.....	2008	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
533.332	2016	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	533.318	.....	2016	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
535.440	2024	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	535.428	.....	2024	packets	received,	7758	bps,	96.97%,	Err	0	(0.0e+00)
537.548	2032	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	537.552	.....	2032	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
539.673	2040	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	539.659	.....	2040	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
541.776	2048	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	541.774	.....	2048	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
543.880	2056	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	543.880	.....	2056	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
546.004	2064	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	545.989	.....	2064	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
548.115	2072	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	548.115	.....	2072	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
550.226	2080	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	550.226	.....	2080	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
552.336	2088	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	552.326	.....	2088	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
554.446	2096	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	554.436	.....	2096	packets	received,	7758	bps,	96.97%,	Err	0	(0.0e+00)
556.571	2104	packets	received,	7757	bps,	96.96%,	Err	0	(0.0e+00)	556.558	.....	2104	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
558.666	2112	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	558.674	.....	2112	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)
560.775	2120	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)	560.783	.....	2120	packets	received,	7757	bps,	96.97%,	Err	0	(0.0e+00)

(d) 站点 A/B 的分组层都洪水式产生分组

datalink a --flood					datalink b --flood				
242.523	902	packets received,	7644 bps,	95.55%, Err 17 (8.8e-06)	247.270	917	packets received,	7622 bps,	95.27%, Err 19 (9.6e-06)
244.657	910	packets received,	7644 bps,	95.55%, Err 17 (8.7e-06)	249.380	924	packets received,	7615 bps,	95.18%, Err 20 (1.0e-05)
246.750	918	packets received,	7646 bps,	95.57%, Err 17 (8.6e-06)	251.487	932	packets received,	7616 bps,	95.20%, Err 20 (1.0e-05)
248.870	926	packets received,	7646 bps,	95.58%, Err 17 (8.6e-06)	253.607	940	packets received,	7617 bps,	95.21%, Err 20 (9.9e-06)
250.976	934	packets received,	7647 bps,	95.59%, Err 17 (8.5e-06)	255.714	947	packets received,	7610 bps,	95.13%, Err 21 (1.0e-05)
253.098	942	packets received,	7648 bps,	95.60%, Err 17 (8.4e-06)	257.824	955	packets received,	7611 bps,	95.14%, Err 21 (1.0e-05)
255.220	950	packets received,	7649 bps,	95.61%, Err 17 (8.3e-06)	259.933	963	packets received,	7613 bps,	95.16%, Err 21 (1.0e-05)
257.340	958	packets received,	7649 bps,	95.62%, Err 17 (8.3e-06)	262.056	971	packets received,	7614 bps,	95.17%, Err 21 (1.0e-05)
259.476	963	packets received,	7611 bps,	95.14%, Err 18 (8.7e-06)	264.160	979	packets received,	7615 bps,	95.19%, Err 21 (1.0e-05)
262.082	975	packets received,	7644 bps,	95.55%, Err 18 (8.6e-06)	266.281	987	packets received,	7616 bps,	95.20%, Err 21 (9.9e-06)
264.206	983	packets received,	7644 bps,	95.55%, Err 18 (8.5e-06)	268.391	995	packets received,	7617 bps,	95.21%, Err 21 (9.8e-06)
266.313	991	packets received,	7645 bps,	95.57%, Err 18 (8.5e-06)	270.500	1003	packets received,	7618 bps,	95.23%, Err 21 (9.7e-06)
268.423	999	packets received,	7646 bps,	95.58%, Err 19 (8.9e-06)	272.621	1010	packets received,	7611 bps,	95.14%, Err 22 (1.0e-05)
270.529	1006	packets received,	7640 bps,	95.50%, Err 19 (8.8e-06)	274.728	1018	packets received,	7613 bps,	95.16%, Err 22 (1.0e-05)
272.650	1014	packets received,	7640 bps,	95.50%, Err 19 (8.7e-06)	276.847	1026	packets received,	7614 bps,	95.17%, Err 22 (1.0e-05)
276.075	1022	packets received,	7605 bps,	95.06%, Err 20 (9.1e-06)	279.482	1031	packets received,	7578 bps,	94.73%, Err 23 (1.0e-05)
278.201	1034	packets received,	7635 bps,	95.44%, Err 20 (9.0e-06)	281.607	1043	packets received,	7609 bps,	95.11%, Err 23 (1.0e-05)
281.632	1042	packets received,	7600 bps,	95.00%, Err 22 (9.8e-06)	283.713	1051	packets received,	7610 bps,	95.12%, Err 23 (1.0e-05)
283.743	1054	packets received,	7630 bps,	95.38%, Err 22 (9.7e-06)	285.850	1059	packets received,	7610 bps,	95.13%, Err 23 (1.0e-05)
285.866	1062	packets received,	7631 bps,	95.39%, Err 22 (9.6e-06)	287.941	1067	packets received,	7612 bps,	95.15%, Err 23 (1.0e-05)
287.973	1070	packets received,	7632 bps,	95.40%, Err 22 (9.6e-06)	290.336	1071	packets received,	7577 bps,	94.72%, Err 24 (1.0e-05)
290.354	1074	packets received,	7598 bps,	94.97%, Err 23 (9.9e-06)	292.442	1083	packets received,	7607 bps,	95.08%, Err 24 (1.0e-05)
292.465	1086	packets received,	7627 bps,	95.34%, Err 23 (9.9e-06)	294.549	1091	packets received,	7608 bps,	95.10%, Err 24 (1.0e-05)
294.575	1094	packets received,	7628 bps,	95.35%, Err 23 (9.8e-06)	296.656	1099	packets received,	7609 bps,	95.11%, Err 24 (1.0e-05)
296.683	1102	packets received,	7629 bps,	95.36%, Err 23 (9.7e-06)	298.760	1107	packets received,	7610 bps,	95.12%, Err 24 (1.0e-05)
298.803	1109	packets received,	7623 bps,	95.28%, Err 24 (1.0e-05)	300.900	1115	packets received,	7611 bps,	95.13%, Err 25 (1.0e-05)
300.910	1117	packets received,	7624 bps,	95.30%, Err 24 (1.0e-05)	303.007	1123	packets received,	7612 bps,	95.15%, Err 25 (1.0e-05)
303.039	1125	packets received,	7624 bps,	95.30%, Err 24 (9.9e-06)	305.109	1131	packets received,	7613 bps,	95.16%, Err 25 (1.0e-05)
305.140	1133	packets received,	7625 bps,	95.32%, Err 24 (9.9e-06)	307.247	1139	packets received,	7614 bps,	95.17%, Err 25 (1.0e-05)
307.263	1141	packets received,	7626 bps,	95.33%, Err 24 (9.8e-06)	309.357	1147	packets received,	7615 bps,	95.18%, Err 25 (1.0e-05)
309.357	1149	packets received,	7627 bps,	95.34%, Err 25 (1.0e-05)	311.465	1155	packets received,	7616 bps,	95.20%, Err 25 (1.0e-05)
312.808	1157	packets received,	7596 bps,	94.94%, Err 26 (1.0e-05)	313.588	1163	packets received,	7616 bps,	95.20%, Err 25 (1.0e-05)
314.906	1169	packets received,	7623 bps,	95.29%, Err 26 (1.0e-05)	315.678	1171	packets received,	7618 bps,	95.22%, Err 25 (9.9e-06)
317.013	1177	packets received,	7624 bps,	95.30%, Err 26 (1.0e-05)	317.800	1179	packets received,	7618 bps,	95.23%, Err 25 (9.9e-06)
319.141	1185	packets received,	7625 bps,	95.31%, Err 26 (1.0e-05)	319.922	1187	packets received,	7619 bps,	95.24%, Err 25 (9.8e-06)
321.247	1193	packets received,	7626 bps,	95.32%, Err 26 (1.0e-05)	322.032	1195	packets received,	7620 bps,	95.25%, Err 25 (9.7e-06)
323.342	1201	packets received,	7627 bps,	95.34%, Err 26 (1.0e-05)	324.141	1203	packets received,	7621 bps,	95.26%, Err 25 (9.7e-06)
325.462	1209	packets received,	7628 bps,	95.34%, Err 26 (1.0e-05)	326.260	1211	packets received,	7622 bps,	95.27%, Err 25 (9.6e-06)
327.568	1217	packets received,	7629 bps,	95.36%, Err 26 (9.9e-06)	328.367	1219	packets received,	7623 bps,	95.28%, Err 25 (9.5e-06)
329.677	1225	packets received,	7629 bps,	95.37%, Err 26 (9.9e-06)	330.476	1227	packets received,	7624 bps,	95.30%, Err 25 (9.5e-06)
331.797	1233	packets received,	7630 bps,	95.38%, Err 26 (9.8e-06)	332.598	1235	packets received,	7624 bps,	95.30%, Err 25 (9.4e-06)
333.921	1241	packets received,	7631 bps,	95.38%, Err 26 (9.8e-06)	334.709	1243	packets received,	7625 bps,	95.32%, Err 25 (9.4e-06)
336.034	1249	packets received,	7631 bps,	95.39%, Err 26 (9.7e-06)	336.815	1251	packets received,	7626 bps,	95.33%, Err 25 (9.3e-06)
338.127	1257	packets received,	7633 bps,	95.41%, Err 26 (9.6e-06)	338.924	1259	packets received,	7627 bps,	95.34%, Err 25 (9.2e-06)
340.239	1265	packets received,	7633 bps,	95.42%, Err 26 (9.6e-06)	341.035	1267	packets received,	7628 bps,	95.35%, Err 25 (9.2e-06)
342.622	1269	packets received,	7604 bps,	95.05%, Err 27 (9.9e-06)	343.145	1275	packets received,	7629 bps,	95.36%, Err 25 (9.1e-06)
344.732	1281	packets received,	7621 bps,	95.26%, Err 27 (9.8e-06)	345.795	1280	packets received,	7600 bps,	95.00%, Err 26 (9.4e-06)
347.388	1286	packets received,	7600 bps,	95.00%, Err 28 (1.0e-05)	347.917	1292	packets received,	7624 bps,	95.30%, Err 26 (9.4e-06)
349.496	1298	packets received,	7625 bps,	95.31%, Err 28 (1.0e-05)	350.026	1300	packets received,	7625 bps,	95.31%, Err 26 (9.3e-06)
351.606	1301	packets received,	7596 bps,	94.95%, Err 29 (1.0e-05)	352.133	1308	packets received,	7626 bps,	95.32%, Err 26 (9.2e-06)
353.712	1313	packets received,	7621 bps,	95.26%, Err 29 (1.0e-05)	354.250	1316	packets received,	7627 bps,	95.33%, Err 26 (9.2e-06)
355.838	1321	packets received,	7621 bps,	95.26%, Err 29 (1.0e-05)	356.356	1324	packets received,	7628 bps,	95.34%, Err 26 (9.1e-06)
357.948	1329	packets received,	7622 bps,	95.27%, Err 30 (1.0e-05)	358.480	1332	packets received,	7628 bps,	95.35%, Err 26 (9.1e-06)
360.054	1336	packets received,	7617 bps,	95.21%, Err 30 (1.0e-05)	360.584	1340	packets received,	7629 bps,	95.36%, Err 26 (9.0e-06)

(e) 站点 A/B 的分组层都洪水式产生分组，线路误码率设为 10^{-4}

datalink a --flood --ber=1e-4					datalink b --flood --ber=1e-4				
236.455	593	packets received,	5144 bps,	64.30%, Err 192 (1.0e-04)	219.466	555	packets received,	5188 bps,	64.85%, Err 176 (1.0e-04)
239.922	600	packets received,	5130 bps,	64.12%, Err 195 (1.0e-04)	224.254	556	packets received,	5086 bps,	63.58%, Err 180 (1.0e-04)
243.087	606	packets received,	5113 bps,	63.92%, Err 196 (1.0e-04)	226.363	572	packets received,	5184 bps,	64.79%, Err 180 (9.9e-05)
246.263	616	packets received,	5131 bps,	64.13%, Err 197 (1.0e-04)	229.543	578	packets received,	5165 bps,	64.57%, Err 182 (9.9e-05)
248.388	628	packets received,	5186 bps,	64.82%, Err 198 (1.0e-04)	232.470	583	packets received,	5144 bps,	64.30%, Err 185 (1.0e-04)
251.566	630	packets received,	5136 bps,	64.20%, Err 200 (9.9e-05)	235.106	586	packets received,	5113 bps,	63.91%, Err 187 (9.9e-05)
254.729	642	packets received,	5169 bps,	64.61%, Err 203 (1.0e-04)	238.294	593	packets received,	5104 bps,	63.80%, Err 189 (9.9e-05)
258.194	654	packets received,	5195 bps,	64.94%, Err 205 (9.9e-05)	241.484	602	packets received,	5113 bps,	63.92%, Err 193 (1.0e-04)
260.302	665	packets received,	5240 bps,	65.49%, Err 206 (9.9e-05)	244.134	603	packets received,	5066 bps,	63.33%, Err 197 (1.0e-04)
262.426	671	packets received,	5244 bps,	65.55%, Err 207 (9.9e-05)	247.309	610	packets received,	5059 bps,	63.24%, Err 198 (1.0e-04)
264.548	673	packets received,	5217 bps,	65.22%, Err 208 (9.8e-05)	252.349	619	packets received,	5031 bps,	62.89%, Err 203 (1.0e-04)
266.656	686	packets received,	5276 bps,	65.95%, Err 208 (9.8e-05)	255.524	631	packets received,	5065 bps,	63.31%, Err 205 (1.0e-04)
269.580	692	packets received,	5264 bps,	65.80%, Err 211 (9.8e-05)	260.822	642	packets received,	5048 bps,	63.10%, Err 209 (1.0e-04)
273.029	700	packets received,	5258 bps,	65.72%, Err 214 (9.8e-05)	265.052	654	packets received,	5060 bps,	63.25%, Err 214 (1.0e-04)
275.410	701	packets received,	5220 bps,	65.25%, Err 216 (9.8e-05)	270.081	661	packets received,	5019 bps,	62.74%, Err 219 (1.0e-04)
281.218	715	packets received,	5214 bps,	65.17%, Err 224 (1.0e-04)	277.246	675	packets received,	4993 bps,	62.41%, Err 225 (1.0e-04)
284.938	719	packets received,	5175 bps,	64.68%, Err 230 (1.0e-04)	280.692	679	packets received,	4961 bps,	62.01%, Err 227 (1.0e-04)
288.114	729	packets received,	5189 bps,	64.86%, Err 231 (1.0e-04)	282.801	694	packets received,	5032 bps,	62.91%, Err 227 (1.0e-04)
291.565	744	packets received,	5233 bps,	65.41%, Err 234 (1.0e-04)	284.909	696	packets received,	5010 bps,	62.62%, Err 229 (1.0e-04)
294.713	748	packets received,	5204 bps,	65.06%, Err 235 (1.0e-04)	288.898	701	packets received,	4976 bps,	62.20%, Err 232 (1.0e-04)
297.904	759	packets received,	5224 bps,	65.30%, Err 239 (1.0e-04)	292.075	714	packets received,	5013 bps,	62.66%, Err 234 (1.0e-04)
301.100	763	packets received,	5196 bps,	64.95%, Err 241 (1.0e-04)	294.997	717	packets received,	4984 bps,	62.30%, Err 237 (1.0e-04)
303.225	776	packets received,	5248 bps,	65.59%, Err 242 (1.0e-04)	298.174	726	packets received,	4993 bps,	62.41%, Err 238 (1.0e-04)
305.332	779	packets received,	5231 bps,	65.39%, Err 243 (1.0e-04)	300.299	737	packets received,	5032 bps,	62.91%, Err 239 (1.0e-04)
307.712	783	packets received,	5218 bps,	65.22%, Err 244 (9.9e-05)	302.936	741	packets received,	5016 bps,	62.70%, Err 242 (1.0e-04)
310.362	792	packets received,	5232 bps,	65.41%, Err 245 (1.0e-04)	306.386	748	packets received,	5006 bps,	62.57%, Err 245 (1.0e-04)
313.540	795	packets received,	5199 bps,	64.99%, Err 250 (1.0e-04)	311.423	759	packets received,	4997 bps,	62.47%, Err 251 (1.0e-04)
316.732	800	packets received,	5179 bps,	64.74%, Err 251 (9.9e-05)	314.601	771	packets received,	5025 bps,	62.81%, Err 253 (1.0e-04)
319.893	809	packets received,	5185 bps,	64.82%, Err 257 (1.0e-04)	316.722	783	packets received,	5069 bps,	63.36%, Err 253 (1.0e-04)
323.083	811	packets received,	5147 bps,	64.33%, Err 259 (1.0e-04)	318.828	791	packets received,	5087 bps,	63.59%, Err 253 (9.9e-05)
326.259	819	packets received,	5147 bps,	64.34%, Err 261 (1.0e-04)	321.744	797	packets received,	5079 bps,	63.49%, Err 255 (9.9e-05)
329.179	828	packets received,	5157 bps,	64.47%, Err 264 (1.0e-04)	324.950	803	packets received,	5067 bps,	63.33%, Err 259 (1.0e-04)
332.355	833	packets received,	5139 bps,	64.23%, Err 267 (1.0e-04)	327.045	815	packets received,	5109 bps,	63.87%, Err 259 (9.9e-05)
335.790	846	packets received,	5165 bps,	64.57%, Err 269 (1.0e-04)	329.167	818	packets received,	5095 bps,	63.69%, Err 263 (1.0e-04)
337.916	848	packets received,	5145 bps,	64.31%, Err 271 (1.0e-04)	334.747	824	packets received,	5047 bps,	63.09%, Err 266 (9.9e-05)
341.081	858	packets received,	5157 bps,	64.47%, Err 272 (1.0e-04)	338.451	838	packets received,	5076 bps,	63.45%, Err 270 (1.0e-04)
343.206	868	packets received,	5185 bps,	64.81%, Err 274 (1.0e-04)	340.572	845	packets received,	5087 bps,	63.59%, Err 270 (9.9e-05)
345.314	871	packets received,	5171 bps,	64.64%, Err 275 (1.0e-04)	345.871	849	packets received,	5033 bps,	62.91%, Err 2

利用率如下表所示：

序号	命令	说明	运行时间 (秒)	Selective 算法 线路利用率(%)	
				A	B
1	datalink a -- utopia datalink b -- utopia	无误码信道数据传输	3500	55.49	96.97
2	datalink a datalink b	站点 A 分组层平缓方式发出数据, 站点 B 周期性交替“发送 100 秒, 停发 100 秒”	3500	55.16	95.03
3	datalink a --flood --utopia datalink b --flood --utopia	无误码信道, 站点 A 和站点 B 的分组层都洪水式产生分组	3500	96.97	96.97
4	datalink a --flood datalink b --flood	站点 A/B 的分组层都洪水式产生分组	3500	94.98	95.13
5	datalink a --flood --ber=1e-4 datalink b --flood --ber=1e-4	站点 A/B 的分组层都洪水式产生分组, 线路误码率设为 10^{-4}	3500	64.24	62.13

(2) GoBack-N 协议

(a) 无误码信道数据传输

dataink a --utopia					dataink b --utopia				
399.198	...	802	packets received,	4127 bps, 51.59%, Err 0 (0.0e+00)	414.472	...	1568	packets received,	7756 bps, 96.96%, Err 0 (0.0e+00)
401.341	...	806	packets received,	4126 bps, 51.57%, Err 0 (0.0e+00)	416.576	...	1576	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
403.451	...	814	packets received,	4145 bps, 51.81%, Err 0 (0.0e+00)	418.698	...	1584	packets received,	7756 bps, 96.96%, Err 0 (0.0e+00)
405.560	...	822	packets received,	4164 bps, 52.05%, Err 0 (0.0e+00)	420.806	...	1592	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
407.682	...	830	packets received,	4182 bps, 52.28%, Err 0 (0.0e+00)	422.911	...	1600	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
409.785	...	838	packets received,	4201 bps, 52.51%, Err 0 (0.0e+00)	425.020	...	1608	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
411.891	...	846	packets received,	4219 bps, 52.74%, Err 0 (0.0e+00)	427.146	...	1616	packets received,	7756 bps, 96.96%, Err 0 (0.0e+00)
413.995	...	854	packets received,	4238 bps, 52.97%, Err 0 (0.0e+00)	429.251	...	1624	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
416.130	...	862	packets received,	4255 bps, 53.19%, Err 0 (0.0e+00)	431.358	...	1632	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
418.222	...	870	packets received,	4273 bps, 53.41%, Err 0 (0.0e+00)	433.469	...	1640	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
420.346	...	878	packets received,	4291 bps, 53.63%, Err 0 (0.0e+00)	435.592	...	1648	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
422.453	...	886	packets received,	4308 bps, 53.85%, Err 0 (0.0e+00)	437.699	...	1656	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
424.563	...	894	packets received,	4325 bps, 54.07%, Err 0 (0.0e+00)	439.816	...	1664	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
426.672	...	902	packets received,	4342 bps, 54.28%, Err 0 (0.0e+00)	441.924	...	1672	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
428.797	...	910	packets received,	4359 bps, 54.49%, Err 0 (0.0e+00)	444.032	...	1680	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
430.905	...	918	packets received,	4376 bps, 54.70%, Err 0 (0.0e+00)	446.136	...	1688	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
433.010	...	926	packets received,	4392 bps, 54.91%, Err 0 (0.0e+00)	448.256	...	1696	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
435.121	...	934	packets received,	4409 bps, 55.11%, Err 0 (0.0e+00)	450.373	...	1704	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
437.245	...	942	packets received,	4425 bps, 55.31%, Err 0 (0.0e+00)	452.492	...	1712	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
439.352	...	950	packets received,	4441 bps, 55.51%, Err 0 (0.0e+00)	454.597	...	1720	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
441.475	...	958	packets received,	4457 bps, 55.71%, Err 0 (0.0e+00)	456.719	...	1728	packets received,	7756 bps, 96.96%, Err 0 (0.0e+00)
443.582	...	966	packets received,	4473 bps, 55.91%, Err 0 (0.0e+00)	458.816	...	1736	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
445.686	...	974	packets received,	4488 bps, 56.10%, Err 0 (0.0e+00)	460.939	...	1744	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
447.810	...	982	packets received,	4504 bps, 56.30%, Err 0 (0.0e+00)	463.045	...	1752	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
449.918	...	990	packets received,	4519 bps, 56.49%, Err 0 (0.0e+00)	465.150	...	1760	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
452.027	...	998	packets received,	4534 bps, 56.68%, Err 0 (0.0e+00)	467.276	...	1768	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
454.149	...	1006	packets received,	4549 bps, 56.86%, Err 0 (0.0e+00)	469.380	...	1776	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
456.240	...	1014	packets received,	4564 bps, 57.05%, Err 0 (0.0e+00)	471.487	...	1784	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
458.355	...	1022	packets received,	4579 bps, 57.24%, Err 0 (0.0e+00)	473.593	...	1792	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
460.461	...	1030	packets received,	4594 bps, 57.42%, Err 0 (0.0e+00)	475.716	...	1800	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
462.583	...	1038	packets received,	4608 bps, 57.60%, Err 0 (0.0e+00)	477.825	...	1808	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
464.690	...	1046	packets received,	4622 bps, 57.78%, Err 0 (0.0e+00)	479.937	...	1816	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
466.799	...	1054	packets received,	4637 bps, 57.96%, Err 0 (0.0e+00)	482.060	...	1824	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
468.924	...	1062	packets received,	4651 bps, 58.13%, Err 0 (0.0e+00)	484.167	...	1832	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
471.031	...	1070	packets received,	4665 bps, 58.31%, Err 0 (0.0e+00)	486.275	...	1840	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
473.141	...	1078	packets received,	4679 bps, 58.48%, Err 0 (0.0e+00)	488.380	...	1848	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
475.268	...	1086	packets received,	4692 bps, 58.65%, Err 0 (0.0e+00)	490.504	...	1856	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
477.363	...	1094	packets received,	4706 bps, 58.82%, Err 0 (0.0e+00)	492.609	...	1864	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
479.487	...	1102	packets received,	4719 bps, 58.99%, Err 0 (0.0e+00)	494.718	...	1872	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
481.597	...	1110	packets received,	4733 bps, 59.16%, Err 0 (0.0e+00)	496.826	...	1880	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
483.704	...	1118	packets received,	4746 bps, 59.32%, Err 0 (0.0e+00)	498.932	...	1888	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
485.813	...	1126	packets received,	4759 bps, 59.49%, Err 0 (0.0e+00)	501.054	...	1896	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
487.938	...	1134	packets received,	4772 bps, 59.65%, Err 0 (0.0e+00)	503.159	...	1904	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
490.032	...	1142	packets received,	4785 bps, 59.81%, Err 0 (0.0e+00)	505.268	...	1912	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
492.154	...	1150	packets received,	4798 bps, 59.97%, Err 0 (0.0e+00)	507.397	...	1920	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
494.264	...	1158	packets received,	4810 bps, 60.13%, Err 0 (0.0e+00)	509.508	...	1928	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
496.371	...	1166	packets received,	4823 bps, 60.29%, Err 0 (0.0e+00)	511.615	...	1936	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
498.497	...	1174	packets received,	4835 bps, 60.44%, Err 0 (0.0e+00)	513.729	...	1944	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
504.402	...	1182	packets received,	4811 bps, 60.14%, Err 0 (0.0e+00)	515.834	...	1952	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
508.488	...	1183	packets received,	4776 bps, 59.71%, Err 0 (0.0e+00)	517.948	...	1960	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
512.560	...	1184	packets received,	4742 bps, 59.28%, Err 0 (0.0e+00)	520.076	...	1968	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
516.774	...	1185	packets received,	4708 bps, 58.85%, Err 0 (0.0e+00)	522.171	...	1976	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)
520.893	...	1186	packets received,	4674 bps, 58.43%, Err 0 (0.0e+00)	524.297	...	1984	packets received,	7757 bps, 96.96%, Err 0 (0.0e+00)

(b) 站点 A 分组层平缓方式发出数据，站点 B 周期性交替“发送 100 秒，停发 100 秒”

datalink a										datalink b									
316.922	....	754 packets received,	4892 bps,	61.16%,	Err 15	(9.0e-06)				357.352	....	1257 packets received,	7223 bps,	90.29%,	Err 26	(9.1e-06)			
321.156	....	755 packets received,	4834 bps,	60.43%,	Err 15	(9.0e-06)				359.462	....	1261 packets received,	7203 bps,	90.04%,	Err 27	(9.0e-06)			
325.288	....	756 packets received,	4779 bps,	59.73%,	Err 15	(9.0e-06)				361.587	....	1265 packets received,	7184 bps,	89.79%,	Err 28	(9.7e-06)			
329.408	....	757 packets received,	4725 bps,	59.06%,	Err 15	(9.0e-06)				363.698	....	1273 packets received,	7187 bps,	89.84%,	Err 28	(9.6e-06)			
333.464	....	758 packets received,	4673 bps,	58.42%,	Err 15	(9.0e-06)				365.793	....	1277 packets received,	7168 bps,	89.60%,	Err 30	(1.0e-05)			
337.629	....	759 packets received,	4622 bps,	57.77%,	Err 15	(8.9e-06)				368.174	....	1282 packets received,	7150 bps,	89.37%,	Err 31	(1.1e-05)			
341.742	....	760 packets received,	4572 bps,	57.15%,	Err 15	(8.9e-06)				370.298	....	1290 packets received,	7153 bps,	89.41%,	Err 31	(1.0e-05)			
345.906	....	761 packets received,	4523 bps,	56.53%,	Err 15	(8.9e-06)				372.401	....	1298 packets received,	7156 bps,	89.46%,	Err 31	(1.0e-05)			
350.023	....	762 packets received,	4475 bps,	55.94%,	Err 15	(8.9e-06)				374.528	....	1306 packets received,	7160 bps,	89.49%,	Err 31	(1.0e-05)			
354.106	....	763 packets received,	4429 bps,	55.36%,	Err 15	(8.9e-06)				376.638	....	1314 packets received,	7163 bps,	89.54%,	Err 31	(1.0e-05)			
358.175	....	764 packets received,	4384 bps,	54.80%,	Err 15	(8.9e-06)				379.526	....	1321 packets received,	7146 bps,	89.33%,	Err 32	(1.1e-05)			
362.277	....	765 packets received,	4340 bps,	54.25%,	Err 15	(8.9e-06)				381.647	....	1329 packets received,	7149 bps,	89.37%,	Err 32	(1.0e-05)			
366.363	....	766 packets received,	4297 bps,	53.71%,	Err 15	(8.8e-06)				383.759	....	1337 packets received,	7153 bps,	89.41%,	Err 32	(1.0e-05)			
370.385	....	767 packets received,	4256 bps,	53.20%,	Err 15	(8.8e-06)				385.872	....	1345 packets received,	7156 bps,	89.45%,	Err 32	(1.0e-05)			
374.464	....	768 packets received,	4215 bps,	52.69%,	Err 15	(8.8e-06)				387.978	....	1353 packets received,	7159 bps,	89.49%,	Err 32	(1.0e-05)			
378.537	....	769 packets received,	4175 bps,	52.18%,	Err 15	(8.8e-06)				390.080	....	1361 packets received,	7163 bps,	89.54%,	Err 32	(1.0e-05)			
382.610	....	770 packets received,	4136 bps,	51.69%,	Err 15	(8.8e-06)				392.202	....	1365 packets received,	7145 bps,	89.31%,	Err 34	(1.1e-05)			
386.662	....	771 packets received,	4097 bps,	51.22%,	Err 15	(8.8e-06)				394.325	....	1373 packets received,	7148 bps,	89.35%,	Err 34	(1.1e-05)			
390.731	....	772 packets received,	4060 bps,	50.75%,	Err 15	(8.8e-06)				397.496	....	1381 packets received,	7132 bps,	89.15%,	Err 36	(1.1e-05)			
394.787	....	773 packets received,	4023 bps,	50.29%,	Err 15	(8.8e-06)				399.586	....	1389 packets received,	7136 bps,	89.20%,	Err 36	(1.1e-05)			
398.867	....	774 packets received,	3987 bps,	49.84%,	Err 15	(8.7e-06)				401.696	....	1397 packets received,	7139 bps,	89.24%,	Err 37	(1.2e-05)			
401.068	....	777 packets received,	3980 bps,	49.76%,	Err 15	(8.7e-06)				403.803	....	1401 packets received,	7122 bps,	89.03%,	Err 37	(1.1e-05)			
403.194	....	785 packets received,	4000 bps,	50.00%,	Err 15	(8.6e-06)				405.938	....	1409 packets received,	7125 bps,	89.06%,	Err 37	(1.1e-05)			
405.299	....	793 packets received,	4020 bps,	50.25%,	Err 15	(8.6e-06)				408.062	....	1417 packets received,	7128 bps,	89.10%,	Err 37	(1.1e-05)			
407.421	....	801 packets received,	4039 bps,	50.49%,	Err 15	(8.4e-06)				410.165	....	1425 packets received,	7132 bps,	89.14%,	Err 37	(1.1e-05)			
409.527	....	809 packets received,	4059 bps,	50.73%,	Err 15	(8.4e-06)				412.273	....	1433 packets received,	7135 bps,	89.19%,	Err 37	(1.1e-05)			
411.632	....	817 packets received,	4078 bps,	50.97%,	Err 15	(8.3e-06)				414.407	....	1441 packets received,	7138 bps,	89.22%,	Err 37	(1.1e-05)			
413.755	....	825 packets received,	4096 bps,	51.20%,	Err 15	(8.2e-06)				416.513	....	1449 packets received,	7141 bps,	89.26%,	Err 37	(1.1e-05)			
415.858	....	833 packets received,	4115 bps,	51.44%,	Err 15	(8.1e-06)				418.623	....	1453 packets received,	7124 bps,	89.06%,	Err 38	(1.1e-05)			
417.981	....	841 packets received,	4133 bps,	51.67%,	Err 15	(8.1e-06)				420.747	....	1461 packets received,	7127 bps,	89.09%,	Err 38	(1.1e-05)			
420.087	....	849 packets received,	4152 bps,	51.90%,	Err 15	(8.0e-06)				422.854	....	1469 packets received,	7131 bps,	89.13%,	Err 38	(1.1e-05)			
422.211	....	857 packets received,	4170 bps,	52.12%,	Err 15	(7.9e-06)				424.962	....	1477 packets received,	7134 bps,	89.17%,	Err 38	(1.1e-05)			
424.319	....	865 packets received,	4188 bps,	52.35%,	Err 15	(7.8e-06)				427.083	....	1485 packets received,	7137 bps,	89.21%,	Err 38	(1.1e-05)			
427.225	....	872 packets received,	4193 bps,	52.41%,	Err 16	(8.3e-06)				429.192	....	1493 packets received,	7140 bps,	89.25%,	Err 38	(1.1e-05)			
429.350	....	880 packets received,	4210 bps,	52.63%,	Err 16	(8.2e-06)				431.300	....	1501 packets received,	7143 bps,	89.29%,	Err 38	(1.1e-05)			
431.460	....	888 packets received,	4228 bps,	52.85%,	Err 16	(8.1e-06)				433.437	....	1509 packets received,	7146 bps,	89.32%,	Err 38	(1.1e-05)			
433.569	....	896 packets received,	4245 bps,	53.06%,	Err 16	(8.1e-06)				435.545	....	1517 packets received,	7149 bps,	89.36%,	Err 38	(1.1e-05)			
435.675	....	904 packets received,	4262 bps,	53.28%,	Err 16	(8.0e-06)				437.651	....	1525 packets received,	7152 bps,	89.40%,	Err 38	(1.1e-05)			
437.782	....	912 packets received,	4279 bps,	53.49%,	Err 16	(7.9e-06)				439.758	....	1533 packets received,	7155 bps,	89.43%,	Err 38	(1.1e-05)			
439.909	....	920 packets received,	4296 bps,	53.70%,	Err 16	(7.9e-06)				441.872	....	1541 packets received,	7158 bps,	89.47%,	Err 38	(1.1e-05)			
442.013	....	928 packets received,	4312 bps,	53.90%,	Err 16	(7.8e-06)				443.982	....	1549 packets received,	7160 bps,	89.51%,	Err 38	(1.1e-05)			
444.139	....	932 packets received,	4310 bps,	53.88%,	Err 17	(8.2e-06)				446.114	....	1557 packets received,	7163 bps,	89.54%,	Err 38	(1.1e-05)			
446.248	....	940 packets received,	4327 bps,	54.08%,	Err 17	(8.1e-06)				448.221	....	1565 packets received,	7166 bps,	89.57%,	Err 38	(1.1e-05)			
448.367	....	948 packets received,	4343 bps,	54.28%,	Err 17	(8.1e-06)				450.345	....	1573 packets received,	7168 bps,	89.61%,	Err 38	(1.1e-05)			
450.735	....	953 packets received,	4343 bps,	54.28%,	Err 19	(9.0e-06)				452.453	....	1581 packets received,	7171 bps,	89.64%,	Err 38	(1.1e-05)			
452.876	....	961 packets received,	4358 bps,	54.48%,	Err 19	(8.9e-06)				454.561	....	1589 packets received,	7174 bps,	89.68%,	Err 38	(1.0e-05)			
454.987	....	969 packets received,	4374 bps,	54.68%,	Err 19	(8.8e-06)				456.679	....	1597 packets received,	7177 bps,	89.71%,	Err 38	(1.0e-05)			
457.364	....	974 packets received,	4374 bps,	54.67%,	Err 20	(9.2e-06)				458.802	....	1600 packets received,	7157 bps,	89.46%,	Err 39	(1.1e-05)			
459.489	....	982 packets received,	4389 bps,	54.87%,	Err 20	(9.1e-06)				460.916	....	1608 packets received,	7160 bps,	89.49%,	Err 39	(1.1e-05)			
461.744	....	990 packets received,	4403 bps,	55.04%,	Err 20	(9.1e-06)				463.025	....	1616 packets received,	7162 bps,	89.53%,	Err 39	(1.1e-05)			
463.869	....	998 packets received,	4419 bps,	55.23%,	Err 20	(9.0e-06)				465.162	....	1624 packets received,	7165 bps,	89.56%,	Err 39	(1.0e-05)			
465.991	....	1001 packets received,	4412 bps,	55.14%,	Err 21	(9.4e-06)				467.585	....	1632 packets received,	7163 bps,	89.53%,	Err 39	(1.0e-05)			
468.914	....	1007 packets received,	4410 bps,	55.13%,	Err 22	(9.7e-06)				469.712	....	1640 packets received,	7165 bps,	89.56%,	Err 39	(1.0e-05)			
471.073	....	1015 packets received,	4425 bps,	55.31%,	Err 22	(9.6e-06)				471.827	....	1647 packets received,	7163 bps,	89.54%,	Err 39	(1.0e-05)			

(c) 无误码信道，站点 A 和站点 B 的分组层都洪水式产生分组

datalink a - flood - utopia										datalink b - flood - utopia									
383.042	....	1448 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				382.985	....	1448 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
385.149	....	1456 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				385.092	....	1456 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
387.258	....	1464 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				387.200	....	1464 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
389.371	....	1472 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				389.323	....	1472 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
391.493	....	1480 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				391.436	....	1480 packets received,	7757 bps,	96.96%,	Err 0	(0.0e+00)			
393.592	....	1488 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				393.544	....	1488 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
395.707	....	1496 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				395.650	....	1496 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
397.831	....	1504 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				397.772	....	1504 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
399.938	....	1512 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				399.877	....	1512 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
402.067	....	1520 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				402.001	....	1520 packets received,	7757 bps,	96.96%,	Err 0	(0.0e+00)			
404.150	....	1528 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				404.119	....	1528 packets received,	7757 bps,	96.96%,	Err 0	(0.0e+00)			
406.262	....	1536 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				406.227	....	1536 packets received,	7757 bps,	96.96%,	Err 0	(0.0e+00)			
408.386	....	1544 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				408.328	....	1544 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
410.493	....	1552 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				410.436	....	1552 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
412.617	....	1560 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				412.542	....	1560 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
414.724	....	1568 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				414.666	....	1568 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
416.838	....	1576 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				416.779	....	1576 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
418.945	....	1584 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				418.887	....	1584 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
421.050	....	1592 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				420.993	....	1592 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
423.172	....	1600 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				423.114	....	1600 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
425.288	....	1608 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				425.222	....	1608 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
427.388	....	1616 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				427.331	....	1616 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
429.516	....	1624 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				429.436	....	1624 packets received,	7758 bps,	96.97%,	Err 0	(0.0e+00)			
431.609	....	1632 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				431.560	....	1632 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
433.714	....	1640 packets received,	7757 bps,	96.96%,	Err 0	(0.0e+00)				433.666	....	1640 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
435.835	....	1648 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				435.771	....	1648 packets received,	7758 bps,	96.97%,	Err 0	(0.0e+00)			
437.956	....	1656 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				437.894	....	1656 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
440.064	....	1664 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				440.002	....	1664 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
442.188	....	1672 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				442.125	....	1672 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
444.296	....	1680 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				444.217	....	1680 packets received,	7758 bps,	96.97%,	Err 0	(0.0e+00)			
446.407	....	1688 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				446.358	....	1688 packets received,	7757 bps,	96.96%,	Err 0	(0.0e+00)			
448.500	....	1696 packets received,	7757 bps,	96.96%,	Err 0	(0.0e+00)				448.465	....	1696 packets received,	7757 bps,	96.96%,	Err 0	(0.0e+00)			
450.625	....	1704 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				450.574	....	1704 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
452.740	....	1712 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				452.626	....	1712 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
454.845	....	1720 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				454.789	....	1720 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
456.965	....	1728 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				456.909	....	1728 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
459.072	....	1736 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				459.016	....	1736 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
461.191	....	1744 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				461.135	....	1744 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
463.299	....	1752 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				463.242	....	1752 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
465.411	....	1760 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				465.349	....	1760 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
467.518	....	1768 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				467.469	....	1768 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
469.626	....	1776 packets received,	7756 bps,	96.96%,	Err 0	(0.0e+00)				469.573	....	1776 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
471.748	....	1784 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				471.685	....	1784 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
473.862	....	1792 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				473.807	....	1792 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
475.974	....	1800 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				475.918	....	1800 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
478.082	....	1808 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				478.027	....	1808 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
480.194	....	1816 packets received,	7756 bps,	96.96%,	Err 0	(0.0e+00)				480.136	....	1816 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
482.300	....	1824 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				482.283	....	1824 packets received,	7757 bps,	96.96%,	Err 0	(0.0e+00)			
484.414	....	1832 packets received,	7756 bps,	96.96%,	Err 0	(0.0e+00)				484.357	....	1832 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
486.524	....	1840 packets received,	7756 bps,	96.96%,	Err 0	(0.0e+00)				486.465	....	1840 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
488.648	....	1848 packets received,	7756 bps,	96.95%,	Err 0	(0.0e+00)				488.587	....	1848 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
490.752	....	1856 packets received,	7756 bps,	96.96%,	Err 0	(0.0e+00)				490.701	....	1856 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			
492.852	....	1864 packets received,	7757 bps,	96.96%,	Err 0	(0.0e+00)				492.818	....	1864 packets received,	7757 bps,	96.96%,	Err 0	(0.0e+00)			
494.974	....	1872 packets received,	7756 bps,	96.96%,	Err 0	(0.0e+00)				494.912	....	1872 packets received,	7757 bps,	96.97%,	Err 0	(0.0e+00)			

(d) 站点 A/B 的分组层都洪水式产生分组

dataink a --flood					dataink b --flood				
192.353	....	678	packets received,	7232 bps, 90.40%, Err 15 (9.8e-06)	193.184	....	673	packets received,	7148 bps, 89.35%, Err 14 (9.1e-06)
194.458	....	686	packets received,	7238 bps, 90.47%, Err 15 (9.6e-06)	195.309	....	681	packets received,	7154 bps, 89.42%, Err 14 (9.0e-06)
196.506	....	694	packets received,	7244 bps, 90.55%, Err 15 (9.5e-06)	197.419	....	689	packets received,	7160 bps, 89.51%, Err 14 (8.9e-06)
198.692	....	702	packets received,	7249 bps, 90.61%, Err 15 (9.4e-06)	199.529	....	697	packets received,	7167 bps, 89.59%, Err 14 (8.8e-06)
200.800	....	710	packets received,	7254 bps, 90.68%, Err 15 (9.3e-06)	201.649	....	705	packets received,	7173 bps, 89.66%, Err 14 (8.7e-06)
202.907	....	718	packets received,	7260 bps, 90.75%, Err 15 (9.2e-06)	203.755	....	713	packets received,	7179 bps, 89.74%, Err 14 (8.6e-06)
205.014	....	726	packets received,	7265 bps, 90.81%, Err 15 (9.2e-06)	205.865	....	721	packets received,	7185 bps, 89.81%, Err 14 (8.5e-06)
207.139	....	734	packets received,	7270 bps, 90.87%, Err 15 (9.1e-06)	207.987	....	729	packets received,	7191 bps, 89.88%, Err 15 (9.1e-06)
209.263	....	742	packets received,	7274 bps, 90.93%, Err 15 (9.0e-06)	210.095	....	733	packets received,	7197 bps, 89.47%, Err 15 (9.0e-06)
211.373	....	750	packets received,	7279 bps, 90.99%, Err 15 (8.9e-06)	212.235	....	741	packets received,	7162 bps, 89.53%, Err 15 (8.9e-06)
213.480	....	758	packets received,	7284 bps, 91.05%, Err 15 (8.8e-06)	214.340	....	749	packets received,	7168 bps, 89.61%, Err 15 (8.8e-06)
215.603	....	766	packets received,	7288 bps, 91.10%, Err 15 (8.7e-06)	216.446	....	757	packets received,	7174 bps, 89.68%, Err 15 (8.7e-06)
217.710	....	774	packets received,	7293 bps, 91.16%, Err 15 (8.6e-06)	218.572	....	765	packets received,	7180 bps, 89.75%, Err 15 (8.6e-06)
219.803	....	782	packets received,	7298 bps, 91.22%, Err 15 (8.5e-06)	220.680	....	773	packets received,	7185 bps, 89.82%, Err 15 (8.5e-06)
221.911	....	790	packets received,	7303 bps, 91.28%, Err 15 (8.5e-06)	222.787	....	777	packets received,	7154 bps, 89.43%, Err 16 (9.0e-06)
225.375	....	798	packets received,	7263 bps, 90.79%, Err 16 (8.9e-06)	224.929	....	785	packets received,	7159 bps, 89.48%, Err 16 (8.9e-06)
227.488	....	806	packets received,	7267 bps, 90.84%, Err 16 (8.8e-06)	226.988	....	792	packets received,	7157 bps, 89.46%, Err 16 (8.9e-06)
229.598	....	814	packets received,	7272 bps, 90.90%, Err 16 (8.7e-06)	229.111	....	800	packets received,	7162 bps, 89.53%, Err 17 (9.3e-06)
231.725	....	822	packets received,	7276 bps, 90.95%, Err 16 (8.6e-06)	231.218	....	803	packets received,	7123 bps, 89.04%, Err 17 (9.2e-06)
233.881	....	829	packets received,	7270 bps, 90.88%, Err 16 (8.6e-06)	233.364	....	811	packets received,	7128 bps, 89.10%, Err 17 (9.2e-06)
235.988	....	837	packets received,	7275 bps, 90.93%, Err 16 (8.5e-06)	235.502	....	819	packets received,	7133 bps, 89.16%, Err 17 (9.1e-06)
238.110	....	845	packets received,	7279 bps, 90.98%, Err 16 (8.4e-06)	237.624	....	827	packets received,	7138 bps, 89.23%, Err 17 (9.0e-06)
240.219	....	853	packets received,	7283 bps, 91.04%, Err 16 (8.3e-06)	239.729	....	835	packets received,	7144 bps, 89.30%, Err 17 (8.9e-06)
242.331	....	861	packets received,	7287 bps, 91.09%, Err 16 (8.3e-06)	241.838	....	843	packets received,	7149 bps, 89.37%, Err 17 (8.8e-06)
244.455	....	869	packets received,	7291 bps, 91.14%, Err 16 (8.2e-06)	245.286	....	851	packets received,	7116 bps, 88.95%, Err 18 (9.2e-06)
246.582	....	877	packets received,	7286 bps, 91.07%, Err 16 (8.1e-06)	247.412	....	859	packets received,	7121 bps, 89.01%, Err 18 (9.1e-06)
248.992	....	885	packets received,	7290 bps, 91.12%, Err 16 (8.1e-06)	249.565	....	867	packets received,	7125 bps, 89.06%, Err 18 (9.1e-06)
251.100	....	893	packets received,	7294 bps, 91.17%, Err 16 (8.0e-06)	251.673	....	871	packets received,	7098 bps, 88.72%, Err 19 (9.5e-06)
253.208	....	901	packets received,	7298 bps, 91.22%, Err 17 (8.4e-06)	253.811	....	879	packets received,	7103 bps, 88.78%, Err 19 (9.4e-06)
255.333	....	905	packets received,	7269 bps, 90.86%, Err 17 (8.3e-06)	255.920	....	887	packets received,	7108 bps, 88.85%, Err 19 (9.3e-06)
257.457	....	913	packets received,	7273 bps, 90.91%, Err 17 (8.3e-06)	258.045	....	895	packets received,	7113 bps, 88.91%, Err 19 (9.3e-06)
259.568	....	921	packets received,	7277 bps, 90.96%, Err 17 (8.2e-06)	260.153	....	903	packets received,	7118 bps, 88.98%, Err 19 (9.2e-06)
261.677	....	929	packets received,	7281 bps, 91.01%, Err 17 (8.1e-06)	262.261	....	911	packets received,	7124 bps, 89.05%, Err 19 (9.1e-06)
264.312	....	935	packets received,	7254 bps, 90.68%, Err 18 (8.5e-06)	264.385	....	919	packets received,	7128 bps, 89.10%, Err 19 (9.0e-06)
266.452	....	943	packets received,	7258 bps, 90.72%, Err 18 (8.5e-06)	267.273	....	925	packets received,	7097 bps, 88.72%, Err 20 (9.4e-06)
268.595	....	951	packets received,	7253 bps, 90.66%, Err 19 (8.9e-06)	269.413	....	933	packets received,	7102 bps, 88.77%, Err 20 (9.3e-06)
271.004	....	954	packets received,	7219 bps, 90.24%, Err 19 (8.5e-06)	271.551	....	941	packets received,	7106 bps, 88.83%, Err 20 (9.3e-06)
273.145	....	962	packets received,	7222 bps, 90.28%, Err 19 (8.7e-06)	273.671	....	948	packets received,	7103 bps, 88.79%, Err 21 (9.6e-06)
275.268	....	970	packets received,	7226 bps, 90.33%, Err 20 (9.1e-06)	275.779	....	951	packets received,	7071 bps, 88.39%, Err 21 (9.6e-06)
277.378	....	972	packets received,	7186 bps, 89.82%, Err 21 (9.5e-06)	277.920	....	959	packets received,	7076 bps, 88.45%, Err 21 (9.5e-06)
279.505	....	980	packets received,	7190 bps, 89.87%, Err 21 (9.4e-06)	281.097	....	965	packets received,	7040 bps, 88.00%, Err 22 (9.8e-06)
281.630	....	988	packets received,	7194 bps, 89.92%, Err 21 (9.4e-06)	283.254	....	973	packets received,	7044 bps, 88.05%, Err 22 (9.8e-06)
284.824	....	994	packets received,	7156 bps, 89.45%, Err 22 (9.7e-06)	285.380	....	976	packets received,	7013 bps, 87.66%, Err 23 (1.0e-05)
286.998	....	1001	packets received,	7152 bps, 89.40%, Err 22 (9.6e-06)	287.526	....	984	packets received,	7018 bps, 87.72%, Err 23 (1.0e-05)
289.107	....	1009	packets received,	7156 bps, 89.45%, Err 22 (9.6e-06)	289.634	....	992	packets received,	7023 bps, 87.79%, Err 24 (1.0e-05)
291.216	....	1017	packets received,	7161 bps, 89.51%, Err 22 (9.5e-06)	291.760	....	995	packets received,	6993 bps, 87.41%, Err 24 (1.0e-05)
294.698	....	1024	packets received,	7125 bps, 89.06%, Err 23 (9.8e-06)	293.899	....	1003	packets received,	6998 bps, 87.47%, Err 24 (1.0e-05)
297.614	....	1030	packets received,	7096 bps, 88.70%, Err 24 (1.0e-05)	296.296	....	1011	packets received,	6996 bps, 87.46%, Err 24 (1.0e-05)
299.763	....	1038	packets received,	7100 bps, 88.75%, Err 24 (1.0e-05)	298.409	....	1019	packets received,	7002 bps, 87.52%, Err 25 (1.1e-05)
301.904	....	1041	packets received,	7070 bps, 88.38%, Err 25 (1.0e-05)	300.532	....	1026	packets received,	7000 bps, 87.50%, Err 25 (1.0e-05)
304.031	....	1049	packets received,	7074 bps, 88.43%, Err 25 (1.0e-05)	302.670	....	1034	packets received,	7005 bps, 87.56%, Err 25 (1.0e-05)

(e) 站点 A/B 的分组层都洪水式产生分组，线路误码率设为 10^{-4}

datalink a --flood --ber=1e-4					datalink b --flood --ber=1e-4				
335.910	...	540 packets received,	3298 bps,	41.23%, Err 234 (9.9e-05)	340.183	...	512 packets received,	3088 bps,	38.60%, Err 237 (1.0e-04)
338.063	...	543 packets received,	3295 bps,	41.19%, Err 236 (9.9e-05)	342.611	...	514 packets received,	3078 bps,	38.47%, Err 239 (1.0e-04)
340.738	...	548 packets received,	3300 bps,	41.25%, Err 237 (9.9e-05)	352.959	...	517 packets received,	3005 bps,	37.56%, Err 245 (1.0e-04)
342.885	...	552 packets received,	3303 bps,	41.29%, Err 241 (1.0e-04)	357.490	...	525 packets received,	3013 bps,	37.66%, Err 246 (9.9e-05)
346.082	...	556 packets received,	3296 bps,	41.20%, Err 243 (1.0e-04)	359.665	...	533 packets received,	3040 bps,	38.00%, Err 247 (9.9e-05)
348.219	...	564 packets received,	3323 bps,	41.54%, Err 243 (9.9e-05)	363.111	...	537 packets received,	3034 bps,	37.92%, Err 251 (9.9e-05)
355.113	...	569 packets received,	3287 bps,	41.09%, Err 249 (1.0e-04)	365.271	...	545 packets received,	3061 bps,	38.26%, Err 251 (9.9e-05)
357.258	...	573 packets received,	3290 bps,	41.13%, Err 252 (1.0e-04)	368.450	...	549 packets received,	3057 bps,	38.21%, Err 253 (9.9e-05)
360.676	...	579 packets received,	3293 bps,	41.17%, Err 254 (1.0e-04)	370.608	...	557 packets received,	3083 bps,	38.54%, Err 256 (9.9e-05)
362.818	...	581 packets received,	3283 bps,	41.06%, Err 256 (1.0e-04)	372.733	...	559 packets received,	3076 bps,	38.46%, Err 256 (9.9e-05)
365.246	...	586 packets received,	3291 bps,	41.14%, Err 260 (1.0e-04)	376.471	...	566 packets received,	3084 bps,	38.53%, Err 258 (9.9e-05)
367.373	...	589 packets received,	3289 bps,	41.11%, Err 260 (1.0e-04)	378.868	...	569 packets received,	3081 bps,	38.51%, Err 262 (9.9e-05)
370.839	...	596 packets received,	3297 bps,	41.21%, Err 262 (1.0e-04)	383.416	...	571 packets received,	3055 bps,	38.19%, Err 267 (1.0e-04)
374.594	...	603 packets received,	3302 bps,	41.28%, Err 263 (1.0e-04)	385.834	...	576 packets received,	3062 bps,	38.28%, Err 270 (1.0e-04)
378.352	...	608 packets received,	3296 bps,	41.20%, Err 265 (1.0e-04)	389.582	...	580 packets received,	3054 bps,	38.17%, Err 274 (1.0e-04)
381.015	...	609 packets received,	3279 bps,	40.98%, Err 266 (9.9e-05)	391.715	...	584 packets received,	3058 bps,	38.23%, Err 276 (1.0e-04)
383.155	...	612 packets received,	3276 bps,	40.96%, Err 268 (1.0e-04)	393.871	...	592 packets received,	3083 bps,	38.54%, Err 277 (1.0e-04)
385.553	...	618 packets received,	3288 bps,	41.10%, Err 270 (1.0e-04)	397.367	...	594 packets received,	3066 bps,	38.33%, Err 280 (1.0e-04)
389.026	...	620 packets received,	3269 bps,	40.86%, Err 273 (1.0e-04)	399.474	...	597 packets received,	3065 bps,	38.32%, Err 280 (1.0e-04)
391.725	...	622 packets received,	3257 bps,	40.71%, Err 274 (1.0e-04)	405.013	...	599 packets received,	3033 bps,	37.92%, Err 283 (1.0e-04)
393.886	...	630 packets received,	3281 bps,	41.01%, Err 275 (9.9e-05)	407.698	...	603 packets received,	3034 bps,	37.92%, Err 285 (1.0e-04)
399.032	...	631 packets received,	3244 bps,	40.54%, Err 279 (1.0e-04)	410.108	...	606 packets received,	3031 bps,	37.88%, Err 288 (1.0e-04)
404.594	...	635 packets received,	3219 bps,	40.24%, Err 285 (1.0e-04)	412.249	...	609 packets received,	3030 bps,	37.87%, Err 289 (1.0e-04)
407.181	...	642 packets received,	3234 bps,	40.42%, Err 285 (1.0e-04)	414.373	...	615 packets received,	3044 bps,	38.05%, Err 289 (9.9e-05)
409.561	...	649 packets received,	3250 bps,	40.63%, Err 285 (1.0e-04)	416.481	...	618 packets received,	3043 bps,	38.04%, Err 293 (1.0e-04)
412.229	...	651 packets received,	3239 bps,	40.49%, Err 289 (1.0e-04)	420.202	...	620 packets received,	3026 bps,	37.83%, Err 294 (1.0e-04)
414.373	...	659 packets received,	3262 bps,	40.77%, Err 289 (1.0e-04)	425.661	...	623 packets received,	3002 bps,	37.52%, Err 298 (1.0e-04)
418.075	...	666 packets received,	3267 bps,	40.84%, Err 292 (1.0e-04)	427.943	...	626 packets received,	3000 bps,	37.50%, Err 301 (1.0e-04)
420.214	...	669 packets received,	3265 bps,	40.82%, Err 294 (1.0e-04)	433.167	...	627 packets received,	2969 bps,	37.11%, Err 304 (1.0e-04)
422.624	...	670 packets received,	3251 bps,	40.64%, Err 296 (1.0e-04)	438.931	...	631 packets received,	2948 bps,	36.85%, Err 307 (1.0e-04)
426.092	...	673 packets received,	3239 bps,	40.49%, Err 300 (1.0e-04)	441.070	...	635 packets received,	2953 bps,	36.91%, Err 308 (1.0e-04)
429.533	...	678 packets received,	3237 bps,	40.47%, Err 303 (1.0e-04)	443.462	...	637 packets received,	2946 bps,	36.82%, Err 310 (1.0e-04)
431.681	...	686 packets received,	3259 bps,	40.74%, Err 303 (1.0e-04)	445.618	...	639 packets received,	2941 bps,	36.76%, Err 314 (1.0e-04)
433.778	...	694 packets received,	3281 bps,	41.02%, Err 303 (1.0e-04)	449.464	...	644 packets received,	2938 bps,	36.73%, Err 316 (1.0e-04)
437.162	...	699 packets received,	3279 bps,	40.99%, Err 307 (1.0e-04)	451.594	...	648 packets received,	2943 bps,	36.78%, Err 317 (1.0e-04)
441.316	...	702 packets received,	3262 bps,	40.76%, Err 311 (1.0e-04)	455.296	...	654 packets received,	2946 bps,	36.82%, Err 319 (1.0e-04)
447.338	...	707 packets received,	3241 bps,	40.52%, Err 315 (1.0e-04)	457.444	...	662 packets received,	2965 bps,	37.10%, Err 319 (1.0e-04)
449.464	...	709 packets received,	3235 bps,	40.44%, Err 315 (1.0e-04)	459.534	...	665 packets received,	2968 bps,	37.09%, Err 321 (1.0e-04)
451.587	...	715 packets received,	3247 bps,	40.59%, Err 315 (1.0e-04)	461.697	...	668 packets received,	2967 bps,	37.09%, Err 323 (1.0e-04)
454.793	...	718 packets received,	3238 bps,	40.47%, Err 319 (1.0e-04)	463.836	...	676 packets received,	2989 bps,	37.36%, Err 324 (1.0e-04)
457.441	...	725 packets received,	3250 bps,	40.63%, Err 320 (1.0e-04)	465.935	...	680 packets received,	2993 bps,	37.41%, Err 329 (1.0e-04)
459.564	...	733 packets received,	3271 bps,	40.89%, Err 321 (1.0e-04)	470.698	...	681 packets received,	2967 bps,	37.09%, Err 332 (1.0e-04)
465.005	...	734 packets received,	3237 bps,	40.46%, Err 325 (1.0e-04)	472.823	...	683 packets received,	2962 bps,	37.03%, Err 333 (1.0e-04)
467.146	...	742 packets received,	3257 bps,	40.72%, Err 326 (1.0e-04)	474.967	...	687 packets received,	2966 bps,	37.08%, Err 335 (1.0e-04)
469.259	...	750 packets received,	3278 bps,	40.97%, Err 326 (1.0e-04)	477.093	...	695 packets received,	2987 bps,	37.34%, Err 336 (1.0e-04)
471.359	...	758 packets received,	3298 bps,	41.22%, Err 326 (9.9e-05)	480.667	...	699 packets received,	2982 bps,	37.28%, Err 340 (1.0e-04)
478.271	...	761 packets received,	3263 bps,	40.79%, Err 331 (1.0e-04)	482.812	...	702 packets received,	2982 bps,	37.27%, Err 342 (1.0e-04)
480.400	...	769 packets received,	3283 bps,	41.03%, Err 332 (9.9e-05)	484.965	...	710 packets received,	3002 bps,	37.53%, Err 342 (1.0e-04)
482.526	...	770 packets received,	3272 bps,	40.90%, Err 332 (9.9e-05)	488.158	...	713 packets received,	2995 bps,	37.44%, Err 344 (1.0e-04)
484.682	...	774 packets received,	3275 bps,	40.93%, Err 333 (9.9e-05)	492.588	...	720 packets received,	2997 bps,	37.47%, Err 346 (1.0e-04)
490.180	...	777 packets received,	3250 bps,	40.63%, Err 340 (1.0e-04)	494.714	...	723 packets received,	2997 bps,	37.46%, Err 347 (1.0e-04)
494.983	...	785 packets received,	3252 bps,	40.65%, Err 343 (1.0e-04)	497.126	...	729 packets received,	3007 bps,	37.59%, Err 347 (9.9e-05)
497.113	...	789 packets received,	3255 bps,	40.68%, Err 345 (1.0e-04)	503.141	...	733 packets received,	2987 bps,	37.34%, Err 354 (1.0e-04)
502.535	...	792 packets received,	3232 bps,	40.39%, Err 351 (1.0e-04)	505.276	...	737 packets received,	2991 bps,	37.39%, Err 356 (1.0e-04)

利用率如下表所示：

序号	命令	说明	运行时间 (秒)	GoBackN 算法 线路利用率 (%)	
				A	B
1	datalink a -- utopia datalink b -- utopia	无误码信道数据传输	3500	58.43	96.96
2	datalink a datalink b	站点 A 分组层平缓方式发出数据, 站点 B 周期性交替“发送 100 秒, 停发 100 秒”	3500	55.31	89.54
3	datalink a --flood --utopia datalink b --flood --utopia	无误码信道, 站点 A 和站点 B 的分组层都洪水式产生分组	3500	96.96	96.97
4	datalink a --flood datalink b --flood	站点 A/B 的分组层都洪水式产生分组	3500	88.43	87.56

5	datalink a --flood --ber=1e-4 datalink b --flood --ber=1e-4	站点 A/B 的分组层都洪水式产生分组，线路误码率设为 10^{-4}	3500	40.39	37.39
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2. 结果分析

(1) 描述你所实现的协议软件是否实现了有误码信道环境中无差错传输功能。

实现了有误码信道环境中的无差错传输功能，采用了CRC校验和重传技术使错误得以发现和纠正。

(2) 程序的健壮性如何，能否可靠地长时间运行。

程序健壮性强，在高负荷和高误码率等条件下均能正常工作，实验测试时运行24小时均未出现问题。

(3) 协议参数的选取

滑动窗口的大小，重传定时器的时限，ACK 搭载定时器的时限，这些参数是怎样确定的？根据信道特性数据，分组层分组的大小，以及你的滑动窗口机制，给出定量分析，详细列举出选择这些参数值的具体原因。

实验提供了8000bps全双工卫星信道的模拟环境，分组长度固定为 256 字节，单向传输时延为270ms，信道误码率（默认） 10^{-5} ，帧间间隔1ms。据此数据，我们对两个协议的窗口大小、重传定时器时限和ACK定时器时限进行了理论讨论和实际测试。

① 滑动窗口的大小：

滑动窗口大小直接涉及到信道利用率和数据拥塞问题，若窗口太小，将导致信道利用率过低，信道中长时间没有数据传送；若窗口太大，数据发送过快，将造成接收方被数据淹没，发生拥塞现象导致数据丢失，出错率增加。

因此，为得到尽可能大的信道利用率，滑动窗口的大小 N ，信道传输时延 a ，数据率 c ，帧长度 f 应满足关系式：

$$N \geq [2a + 2 \cdot (f/c)] / (f/c)$$

同时通过实际测试的结果分析得到合适的 N 值，最终发现，在 GBN 协议中， N 取 7 效率最高；在 SR 协议中， N 取 63 效率最高。

② 重传定时器时限和ACK定时器时限：

重传计时器的时限涉及到重传的响应时间，若太大，将导致重传等待的时间过久；若太小，将导致较为频繁的重传，两种情况均将导致信道利用率下降。

下面预估重传定时器时限的下界：根据前面的帧的数据结构可知，一个数据帧包括3字节的帧头、256字节的数据和4字节的 CRC 校验值，总计 263 字节。由信道传输速率为 8000bps 可算得发送时间为 263ms。传播时延固定为 270ms。接收方接收完数据帧后，既可能以捎带 ACK 的方式发送 ACK，也可能由于 ACK定时器超时而发送单独的 ACK 帧。为计算时限下界，显然应取 ACK 定时器的时限，即对方从接收完数据帧到开始发送 ACK 的时间间隔的上界进行计算，记为 t 。现在我们考虑 ACK 帧在物理层队列中排队的等待时间时，以最坏情况进行计算，即在 ACK 帧之前存在等待发送的普通数据帧（已发送0字节）、重传数据帧和 NAK 帧，总计 $263 + 263 + 6 = 532$ 字节，需要花费 532ms 才能发送完成。另外，发送这个ACK 帧的时间为6ms，它在信道上的传输时延为

270ms 。并且，物理层在发送数据帧时会在帧与帧之间添加 1ms 的时间间隔，最坏情况下增加 4ms 的时间。以上时间总计为：

$$263 + 270 + t + 532 + 6 + 270 + 4 = 1345 + t \text{ (ms)}$$

由此可得，重传定时器时限与ACK定时器时限 t 有关。我们知道，ACK定时器时限的一个最低的下界为数据链路层从网络层获得一个数据包的时间，经过多次的测试和分析，我们发现这个下界大约为200ms。而在实际测试中，当ACK定时器时限高于这个下界时可取得较高的效率。

最终，我们通过多次实验观察的方式，确定了 t 的最优值：在 GBN 协议中令ACK定时器时限为 **240 ms**，在SR协议中，令ACK定时器时限为**1000 ms**。由此根据上面推得的重传定时器时间计算公式以及实际测试得到，重传定时器在GBN 协议中取 **2800ms** 最优，在SR协议中取 **3000ms** 最优。

(4) 理论分析

根据所设计的滑动窗口工作机制(Go-Back-N 或者选择重传)，推导出在无差错信道环境下分组层能获得的最大信道利用率；推导出在有误码条件下重传操作及时发生等理想情况下分组层能获得的最大信道利用率。给出理论推导过程。理论推导的目的是得到信道利用率的极限数据。为了简化有误码条件下的最大利用率推导过程，可以对问题模型进行简化，比如：假定超时重传的数据帧的回馈ACK 帧可以 100%正确传输，但是简化问题分析的这些假设必须不会对整个结论产生较大的误差。

无差错信道上，由于需要携带3字节的控制信息和4字节的校验位，因此最大

的信道利用率为 $256 / (256 + 3 + 4) = 97.3\%$ 。信道的最大比特率为 8000bps，即每个字节的发送时延为 1ms。在误码率为 $1e-5$ 的信道上（即每传送 100000 个比特平均会发生 1 个错误），假设信道上始终有数据需要传送，则可以传送 $100000 / ((256 + 3 + 4) * 8)$ 约为 47 个数据包，即每 47 个数据包会有一个出错。假设超时重传的数据帧的反馈 ACK 帧可以 100% 正确传输，出错的是最后一个数据包，且每出错一次，在限定时间内可以正确重传该帧。则每传送 47 个数据包需要传送 $47 + 1 + 1 = 49$ 次。于是此时的信道利用率为 $(47 * 256) / (49 * (256 + 3 + 4))$ 约为 **93.4%**。但由于程序设计并不能够达到理想状态，当一个数据包超时后，往往需要重复多次重传，造成信道浪费。若重传 K 次，则信道利用率为 $(47 * 256) / ((48 + k) * (256 + 3 + 4))$ 。

若平均重传 10 次，信道利用率约为 78.88%。

(5) 实验结果分析

你的程序运行实际达到了什么样的效率，比对理论推导给出的结论，有没有差距？给出原因。有没有改进的办法？如果没有时间把这些方法付诸编程实施，介绍你的方案。

序号	命令	说明	运行时间 (秒)	GoBackN 算法 线路利用率 (%)		Selective 算法线路利用率(%)	
				A	B	A	B
1	datalink a -- utopia datalink b -- utopia	无误码信道数据传输	3500	58.43	96.96	55.49	96.97

2	datalink a datalink b	站点 A 分组层平缓方式发出数据，站点 B 周期性交替“发送 100 秒，停发 100 秒”	3500	55.31	89.54	55.16	95.03
3	datalink a --flood --utopia datalink b --flood --utopia	无误码信道，站点 A 和站点 B 的分组层都洪水式产生分组	3500	96.96	96.97	96.97	96.97
4	datalink a --flood datalink b --flood	站点 A/B 的分组层都洪水式产生分组	3500	88.43	87.56	94.98	95.13
5	datalink a --flood --ber=1e-4 datalink b --flood --ber=1e-4	站点 A/B 的分组层都洪水式产生分组，线路误码率设为 10^{-4}	3500	40.39	37.39	64.24	62.13

我的程序实际达到的效率如上表所示。可见，我们的协议效率基本上都达到了参考效率，但仍然与理想效率（如无误码情况下的 97.3%）有一些差距。原因是我们的程序不能保证在将帧递交给物理层传输时没有延迟，ACK 帧和重传的帧也不能保证 100% 的正确率，并且也不能保证出错的总是最后一个数据包，即不能达到前述假设的理想状态，因此会产生差距。

为了使信道利用率提高，设计了如下方案：

a. 对选择重传协议进行一些修改：当数据链路层从网络层获得一个数据包时，除非当前物理层发送队列是可用的，才会立刻将其发送到物理层，否则会在发送窗口中暂存，等下一个 PHYSICAL_LAYER_READY 事件到来时才会执行发送操作。但是，NAK 帧、ACK 帧和由于重传定时器超时所引起的重发的数据帧不受此限制。一旦有这些帧需要发送，可以不等待 PHYSICAL_LAYER_READY 事件而立即发送到物理层。这样一来，可以有助于对方及时重传己方需要的稍早的帧，并且有助于对方及时确认己方发送窗口的帧，腾出空间接收网络层中等待发

送的数据包；而重传数据帧表明之前的一帧的传输不正确，己方应当尽快重传这一帧以帮助对方尽可能快地获得连续的数据帧，以提取数据包提交给网络层，腾出接收窗口接纳后续的数据帧。

b. 在GBN协议中增加NAK机制,当接收方发现错误时就发送NAK帧提示出错,而不是等待发送方超时重传。经检验,改进后,GBN协议的效率略有提升,但差别并不是很大。

c. 适当减小ACK定时器时限。但效果并不是很好。

(6) 存在的问题

在“表 3 性能测试记录表”中给出了几种测试方案，在测试中你的程序有没有失败，或者，虽未失败，但表现出来的性能仍有差距，你的程序中还存在哪些问题？

一开始把GBN的发送帧函数直接复制到SR中,结果运行程序后收了几帧就出错了,检查后发现,两个协议的发送帧函数不能是一样的,SR有更严格的序号限制,帧的序号应该要对NR_BUFS取余,否则就会校验和和数据对不上,检查CRC时就出错了。

经改正,现已无差错,两个协议均能完成老师的所有要求,信道效率大致能达到参考效率,目前未发现新的问题。

七、研究和探索的问题

1. CRC 校验能力

CRC 校验码的检错能力很强，它除了能检查出离散错外，还能检查出突发错误。本次实验采用的 CRC 校验方案为 CRC-32，与 IEEE802.3 以太网校验和生成多项式相同。生成多项式为：

$$x^{32}+x^{26}+x^{23}+x^{22}+x^{16}+x^{12}+x^{11}+x^{10}+x^8+x^7+x^5+x^4+x^2+x^1+1$$

从其检错能力来看，不能发现传输错误的概率为 2 的-32 次方，几乎接近于 0，因此没有必要增加成本再去达到理论上为 0 的错误率。

另外一个方面，如果 CRC 校验错误而导致给网络层传输了错误数据，那么网络层也可以通过它的校验方式发现错误，采取重传，因此能够进一步保证传输正确性。

2. 程序设计方面的问题

- ① 协议软件跟踪功能对于协议的调试很有意义，通过调用 `dbg_event` 和 `dbg_frame` 函数，可以清楚地观察协议的运行过程，当发生错误时，可通过这两个函数的输出信息推导出错误的产生原因，从而改进协议。我的程序实现了此功能，并用它进行了程序的 debug。
- ② C 语言的 `time.h` 当中提供了一些关于时间操作的函数可以用来实现 get_ms() 函数，如 `clock_t clock()`。该函数返回程序开始执行后占用的处理器时间，如果无法获得占用时间则返回 -1。因为我们计时的起点并不是程序开始之时，而是开始通信之时，所以需要有一个静态变量

start_time 来记录通信起始的时间。然后在每次调用 get_ms()后，获取当前的时间 current_time。然后再返回 start_time-current_time 即可。

- ③ 如果本次实验提供的程序库中不包含 log_printf 和 lprintf 函数，可自己实现。
- ④ Start_timer()函数用于给发出的数据帧计时，一旦在时限内未收到接收方的 ACK，便将缓存中的数据帧重发。因此，在重新调用时应重新开始计时。Start_ack_timer()函数用于等待捎带确认的反向数据帧，若超时了还未有反向数据帧，那么就单独发送一个 ACK 帧。为了使 ACK 定时器时限不至于过长使得发送方超时重发，我们对它的处理方式是，在定时器到时之前重新调用不会刷新原残留时间。

3. 软件测试方面的问题

设计这么多种测试方案的目的是检测此程序在不同信道条件下的传输性能。

可以通过设置各个参数验证协议的正确性：

- u 是测试成帧方案的效率；
- f 用于测试信道满负荷时的传输性能；
- ber 可以改变误码率，从而检验无差错、有差错传输的健壮性及性能。

4. 对等协议实体之间的流量控制

设计的滑动窗口协议解决了两个站点的数据链路层对等实体之间的流量控制问题。在我们设计的协议当中，流量的控制主要通过发送窗口，接收窗口和确认机制来实现。因为有窗口大小的限制，发送方不会一次性发送过多信息导致接

收方被数据所淹没，导致信息丢失。

八、实验总结和心得体会

1. 完成本次实验的实际上机调试时间是多少？

大约四个多小时。

2. 编程工具方面遇到了哪些问题？包括 Windows 环境和 VC 软件的安装问题。

之前已安装过VS2013，因此没有出现任何问题。

3. 编程语言方面遇到了哪些问题？包括 C 语言使用和对 C 语言操控能力上的问题。

没有遇到问题。

4. 协议方面遇到了哪些问题？包括协议机制的设计错误，发现协议死锁，或者不能正确工作，协议参数的调整等问题。

(1) 在一次调试中出现错误“Network Layer is not ready for a new packet”. 经检验发现，在发生事件network_layer_ready时，不应该加上循环，而应该一次只从网络层取一帧，在下一次进入大循环时取第二帧。改正后此问题解决。

(2) 刚开始把GBN的发送帧函数直接复制到SR中，结果运行程序后收了几帧就出错了，检查后发现，两个协议的发送帧函数不能是一样的，SR有更严格的

序号限制，帧的序号应该要对NR_BUFS取余，否则就会校验和数据对不上，检查CRC时就出错了。改正后不再出现此问题。

(3) 教材中的GBN协议未加入ACK定时器和NAK帧，导致协议效率偏低，经过改进后，增加了这两项，使得信道利用率有所提升。

5. 开发库方面遇到了哪些问题？包括库程序中的 BUG，库函数文档不够清楚导致误解，库函数在所提供的功能结构上的缺憾导致编程效率低下。这些问题或建议影响不同模块之间功能界限的划分。

一开始未注意到库函数中已存在send_frame()函数，于是自己编写函数时使用了这个函数名，使得编译错误。改正后无错误。

6. 总结本次实验，你在 C 语言方面，协议软件方面，理论学习方面，软件工程方面等哪些方面上有所提高？

本次实验收获很大。首先，我们体会到了C语言在底层协议中的重要作用，更重要的是，我们充分锻炼了使用C语言编程的能力，使得自己的编程能力有了很大的提高。

其次，通过本次实验，我们对课上看似模糊而遥远的“协议”有了深刻的理解，一些理论上不太懂的问题也在一次次调试和debug中慢慢搞清楚了。在协议的实现过程中，无论是窗口大小的设定、重传定时器和ACK定时器时限的选择，还是函数的编写，都要经过理论的实际测试得出。这些经历大大加深了我们对于数据链路层协议的理解。

另外，在软件工程方面，我们小组成员分工明确，各司其职，为日后的团

队合作打下了良好的基础。并且，我们在编写程序之前就规定好了变量的命名以及各个接口的声明，为之后调试程序和编写实验报告提供了很大的便利。

九、源程序清单

GoBack-N 协议源程序详见“计算机网络滑动窗口实验——GoBack-N 源程序清单.docx”

选择重传协议源程序详见“计算机网络滑动窗口实验——Selective 源程序清单.docx”