1. An upper-layer packet is split into 10 frames, each of which has an 80% chance of arriving undamaged. If no error control is done by the data link protocol, how many times must the message be sent on average to get the entire thing through?

传输1次就成功的概率为：0.8^10=0.107, 首次击中的期望满足几何分布，

为1/0.107=9.3次

1. The following character encoding is used in a data link protocol: A: 01000111 B: 11100011 FLAG: 01111110 ESC: 11100000 Show the bit sequence transmitted (in binary) for the four-character frame A B ESC FLAG when each of the following framing methods is used: (a) Byte count. (b) Flag bytes with byte stuffing. (c) Starting and ending flag bytes with bit stuffing.

P169

1. 4 A B ESC FLAG 共5个字节，首个字节为添加的计数字节4。
2. FLAG A B ESC ESC ESC FLAG FLAG，共8个字节，首末字节为添加的字节，同时第一个和第三个ESC也是添加的字节。
3. 01111110 01000111 11010001 111100000 001111101 0 01111110 , 数据中每5个1断一次
4. The following data fragment occurs in the middle of a data stream for which the bytestuffing algorithm described in the text is used: A B ESC C ESC FLAG FLAG D. What is the output after stuffing?

A B ESC ESC C ESC ESC ESC FLAG ESC FLAG D , 在每个FLAG\ESC前插入一个ESC

1. What is the maximum overhead in byte-stuffing algorithm?

如果全是ESC，那么会多用1倍的空间。

1. One of your classmates, Scrooge, has pointed out that it is wasteful to end each frame with a flag byte and then begin the next one with a second flag byte. One flag byte could do the job as well, and a byte saved is a byte earned. Do you agree?

如果每一帧能紧随其后的话是可以的。但是如果又一帧作为结束帧，那么下一帧是否到来计算机是没办法知晓的。

1. A bit string, 0111101111101111110, needs to be transmitted at the data link layer. What is the string actually transmitted after bit stuffing?

011110111110011111010 每五个1添一个0

1. Can you think of any circumstances under which an open-loop protocol (e.g., a Hamming code) might be preferable to the feedback-type protocols discussed throughout this chapter?

要用反馈的协议的话，需要很短的传输延迟才能有好的效果。所以当延迟特别大的时候，会希望编码能纠正自己的能力更强，所以可以空open-loop。而且反馈的协议要求接受方必须返回反馈，所以发送方的位置会被暴露，如果不想发送方位置暴露，可以用open-loop。

1. To provide more reliability than a single parity bit can give, an error-detecting coding scheme uses one parity bit for checking all the odd-numbered bits and a second parity bit for all the even-numbered bits. What is the Hamming distance of this code?

举个例子，00 –> 0000 01->0101 10->1010 11->1111 发现这些码之间的海明距离都是2，所以编码的海明距离是2

1. Sixteen-bit messages are transmitted using a Hamming code. How many check bits are needed to ensure that the receiver can detect and correct single-bit errors? Show the bit pattern transmitted for the message 1101001100110101. Assume that even parity is used in the Hamming code.

P175

要矫正单个比特的错误，需要至少一个距离为3的编码方案。

现有16个消息位，设有r个校验位，并且能够纠正所有的单个错误。对于2^16的合法消息，任何一个消息都对应有n位非法的码字，它们与该消息的距离为1。这些非法的码字可以构成：将消息对应的合法码字的n位，逐个取反，可以得到n个距离为1的非法码字。因此，每个合法消息需要n+1个位模式来标识它们。由于总共只有2^n个位模式，所以必须有(n+1)\*2^16<=2^n , 带入n=16+r，得到(16+r+1)<=2^r ，得到最小的r=5。

所以最少需要5个校验位才能保证能纠正单个比特的错误。

核心在于这个式子：2^16\*(n+1)<=2^n

我的理解：每一个合法的码字（原长度为16位，所以共有2^16位格合法码字），都对应了n（n是加了校验码之后的码位）个非法的码字（就是海明距离为1的码字，而且这些非法码字（和其他的合法码字对应的非法码字）不能重复）。那么一个 原来的合法码字加上它对应的非法码字群，共占用了编码后的n+1个（总共是2^n个）。此时合法码字们重新需要占用的个数就是 ： 2^16 \* (n+1)，即每一个合法码字都要占n+1个新位置，而总共的新位置的数量是2^n，自然就要保证 2^16\*(n+1)<=2^n。 带入n=r+16，简化计算得到r。

那么试再举一例：要能纠正2位错误的不等式就是： 2^16\*(1+n\*(n-1)/2)<=2^n，得到r>=9，所以至少需要9位验证码。

然后编码，用海明方法（P175）：

在海明码中，码字的位被连续编号，从最左端的位开始，紧跟在右边的那位是2，依次从左到右编号。2的幂次位（1，2，4，8，16等）是校验位，其余位(3,5,6,7,9,10,11等)用来填充16个数据位。

现在的编码为：

H1 H2 H3 H4 H5 H6 H7 H8 H9 H10 H11 H12 H13 H14 H15 H16 H17 H18 H19 H20 H21

P1 P2 1 P3 1 0 1 P4 0 0 1 1 0 0 1 P5 1 0 1 0 1

现在就是需要把校验位的值算出来，算法：对于第Hi位来说，求后面的其余位中能拆分成i+x的异或和即为第i位的值（偶校验情况），本例中即为：

P1（H1） = H3 ⊕ H5 ⊕ H7 ⊕ H9 ⊕ H11 ⊕ H13 ⊕ H15 ⊕ H17 ⊕ H19 ⊕ H21 = 0

P2（H2） = H3 ⊕ H6 ⊕ H7 ⊕ H10 ⊕ H11 ⊕ H14 ⊕ H15 ⊕ H18 ⊕ H19 = 1

P3（H4） = H5 ⊕ H6 ⊕ H7 ⊕ H12 ⊕ H13 ⊕ H14 ⊕ H15 ⊕ H20 ⊕ H21 = 1

P4（H8） = H9 ⊕ H10 ⊕ H11 ⊕ H12 ⊕ H13 ⊕ H14 ⊕ H15 = 1

P5（H16）= H17 ⊕ H18 ⊕ H19 ⊕ H20 ⊕ H21 = 1

最终的编码为 01111011 00110011 10101 第4位答案？

1. A 12-bit Hamming code whose hexadecimal value is 0xE4F arrives at a receiver. What was the original value in hexadecimal? Assume that not more than 1 bit is in error.

1110 0100 1111 找出校验位为 1100，分别校验的结果是0010，即第2位有误（矫正码错误，对消息码无影响），所以最终的消息码为 10101111，即0xAF。

1. One way of detecting errors is to transmit data as a block of n rows of k bits per row and add parity bits to each row and each column. The bitin the lower-right corner is a parity bit that checks its row and its column. Will this scheme detect all single errors? Double errors? Triple errors? Show that this scheme cannot detect some four-bit errors.

一个肯定能被检测出来。

两个的话分类讨论：如果两个错误都在同一行，那么肯定就不在同一列了，所以列校验码可以检测两个错出来。反之，如果两个错误不在同一行，那么行校验码可以分别检测出出来两个错。

三个：如果三个在同一行，那么肯定就不在同一列了，所以列校验码可以检测两个错出来。如果三个有两个在同一行，那么肯定有另外一行的行校验码把 另外一个单独1行的错误检测出来。剩余情况同理。

四个：不行，因为这种情况检测不出来：四个错误发生的位置满足(x1,y1) (x1,y2) (x2,y1)(x2,y2)。这样的话，出错的行列总是2个错误一块出现，奇偶位无法检测出这种错误。

1. Suppose that data are transmitted in blocks of sizes 1000 bits. What is the maximum error rate under which error detection and retransmission mechanism (1 parity bit per block) is better than using Hamming code? Assume that bit errors are independent of one another and no bit error occurs during retransmission.

1000比特的是数据需要r位的检测码，则满足 (1000+r+1)<=2^r 得到 r>=9.98，所以需要10位校验位。故用海明码的话，每一块需要的码位是 1010个。

使用错误重传矫正机制的话：设每位发生错误的概率为p，那么每一块发生错误的概率是1000\*p，假设每一次错误都能被检测出来，那么每一次的代价是重传一次块。所以总码位t是t=1001+p\*1000\*t 解得 t=1001/(1-p\*1000) 。

1001/(1-p\*1000)< 1010 解得：p<0.000009， 即每位出错概率小于9e-6时，错误重传机制能比海明码节省传输的码位。

1. A block of bits with n rows and k columns uses horizontal and vertical parity bits for error detection. Suppose that exactly 4 bits are inverted due to transmission errors. Derive an expression for the probability that the error will be undetected.

不被检测出来的话是11问中提到的类型。

总共的出错种数有 C(n\*k,4)个，而形成11问的类型有C(n,2)\*C(k,2)种，所以概率为C(n,2)\*C(k,2)/C(n\*k,4)。

1. Using the convolutional coder of Fig. 3-7, what is the output sequence when the input sequence is 10101010 (left to right) and the internal state is initially all zero?

P176 卷积码看不懂

1. Suppose that a message 1001 1100 1010 0011 is transmitted using Internet Checksum (4-bit word). What is the value of the checksum?

P180 Internet校验和

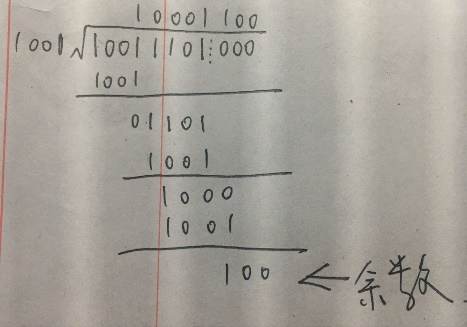
1. What is the remainder obtained by dividing x7 + x5 + 1 by the generator polynomial x3 + 1?

x^7+x^5+1 / x^3+1 = x^4 +x^2-x …… -x^2+x+1

1. A bit stream 10011101 is transmitted using the standard CRC method described in the text. The generator polynomial is x3 + 1. Show the actual bit string transmitted. Suppose that the third bit from the left is inverted during transmission. Show that this error is detected at the receiver’s end. Give an example of bit errors in the bit string transmitted that will not be detected by the receiver.

P181

传输位：10011101 100 其中100是余数



如果第三位错误，就变成了10111101 100，那么用它除以1001，是除不尽的，所以挂掉了。

但是出现错误，满足有1001的倍数（比如左移）加在了传输的位的话，就检测不出来了，比如：加一个1001变成10011100001 , 或者加一个10010变成10011111010，这两个例子都检测不出来了。

1. A 1024-bit message is sent that contains 992 data bits and 32 CRC bits. CRC is computed using the IEEE 802 standardized, 32-degree CRC polynomial. For each of the following, explain whether the errors during message transmission will be detected by the receiver: (a) There was a single-bit error. (b) There were two isolated bit errors. (c) There were 18 isolated bit errors. (d) There were 47 isolated bit errors. (e) There was a 24-bit long burst error. (f) There was a 35-bit long burst error.

P182~183介绍错误检测

1. 可以，只发生一位错误，并且G(x)至少有两项（32阶），所以能检测1位错误。
2. 可以，只要G(x)种有三项以上的系数不为1（很容易，因为第x^31和1已经占了两位了，再随便找一位就可以了，那么就可以保护出现的两位错误。
3. 如果是偶数位发生了错误，那么不能有一个G(x)能断定所有的偶数位错误。
4. 如果是奇数位错误，那么只要G(x)含系数x+1，即可捕捉所有的奇数位错误。
5. 带r个校验位的多项式编码可以检测到所有长度小于等于r的突发错误。突发错误相当于一段连续的111…1，且长度小于r，所以总是有余数。
6. 不能
7. In the discussion of ARQ protocol in Section 3.3.3, a scenario was outlined that resulted in the receiver accepting two copies of the same frame due to a loss of acknowledgement frame. Is it possible that a receiver may accept multiple copies of the same frame when none of the frames (message or acknowledgement) are lost?

P190

有可能，因为在发送端，可能会发送两次。比方说发送端的物理层传输受阻，导致传输阻塞在物理层，同时链路层的计时器仍在计时，那么就有可能超时导致重传。

1. A channel has a bit rate of 4 kbps and a propagation delay of 20 msec. For what range of frame sizes does stop-and-wait give an efficiency of at least 50%?

效率：传输数据的时间/（传输数据时间+延迟时间）=x\*4kbps / (x\*4kbps + 2\*20msec) >=50% ,解得x>=160bits。

1. In protocol 3, is it possible for the sender to start the timer when it is already running? If so, how might this occur? If not, why is it impossible?

协议三P190 带有重传机制的肯定确认协议

有可能，传送端程序如果接收到了返回的确认信息但不是满足s.ack==next\_frame\_to\_send的话，会不停止而开始下一次的传输帧。相当于收到一条错误的确认信息也会激发下一次的传输。我觉得应该把外面的那个if也写成while。

1. A 3000-km-long T1 trunk is used to transmit 64-byte frames using protocol 5. If the propagation speed is 6 μsec/km, how many bits should the sequence numbers be?

协议5 P197~199

？没看懂 翻译一波

为了有效地工作，序列空间（实际上，发送方的窗口大小）必须足够大，以允许发送方在收到第一个确认之前继续发送。传播时间为18ms。在T1速度下，即1.536Mbps（不包括1个报头位），64字节帧需要0.300毫秒。因此，第一帧在其传输开始后完全到达18.3毫秒。确认需要18毫秒才能返回，加上一小部分（可以忽略不计）时间才能完全到达。总之，这个时间是36.3毫秒，所以发射器必须有足够的窗口空间来保持36.3毫秒。一个框架需要0.3毫秒，因此需要121个框架来填充管道。需要七位序列号。

1. Imagine a sliding window protocol using so many bits for sequence numbers that wraparound never occurs. What relations must hold among the four window edges and the window size, which is constant and the same for both the sender and the receiver?

设窗口大小为W，发送方的窗口大小为（SL,SR）,接受方的窗口大小为（RL,RR）。那么要满足：

0<=SR-SL+1<=W+1

RR-RL+1=W

SL<=RL<=SR+1

1. If the procedure between in protocol 5 checked for the condition a ≤ b ≤ c instead of the condition a ≤ b<c, would that have any effect on the protocol’s correctness or efficiency? Explain your answer.

协议5 P197~199 一个采用了回退n机制的滑动窗口协议

会出错，因为可能导致一圈下来恰好接上了。比方说考虑1位的窗口，那么如果改成了a<=b<=c那么不就没什么作用了。

1. In protocol 6, when a data frame arrives, a check is made to see if the sequence number differs from the one expected and no nak is true. If both conditions hold, a NAK is sent. Otherwise, the auxiliary timer is started. Suppose that the else clause were omitted. Would this change affect the protocol’s correctness?

协议六P200 ~ 203 一个采用了选择重传机制的滑动窗口协议

有可能造成死锁，假设一批帧正确到达并被接受。接受者会把窗户提前。现在假设所有的确认都丢失了。发送者最终会超时并再次发送第一帧。然后接收器会发送一个NAK。如果这个包丢失了，从那时起，发送方将保持超时并发送一个已经被接受的帧，但是接收方将忽略它。设置辅助计时器最终会返回正确的确认，从而重新同步。

1. Suppose that the three-statement while loop near the end of protocol 6 was removed from the code. Would this affect the correctness of the protocol or just the performance? Explain your answer.

那个循环内的语句是在处理nbuffered的更新和ack\_expected的更新。如果没有这个循环去等候的话，会导致不能够实时更新ack\_expercted，这会导致一直在重复的等待。

1. The distance from earth to a distant planet is approximately 9 × 1010 m. What is the channel utilization if a stop-and-wait protocol is used for frame transmission on a 64 Mbps point-to-point link? Assume that the frame size is 32 KB and the speed of light is 3 × 108 m/s.

P196

利用率= w/（1+2\*BD），其中停-等式协议的w=1，BD=带宽\*延迟/帧大小=9e10m/3e8m/s=300s，带宽是64Mbps，帧大小是32KB=256Kb。

所以最后的利用率为 1/(1+2\*300\*64\*1e3/256) = 6.67e-6

1. In the previous problem, suppose a sliding window protocol is used instead. For what send window size will the link utilization be 100%? You may ignore the protocol processing times at the sender and the receiver.

恰好是w=1+2\*BD=150001即可。

1. In protocol 6, the code for frame arrival has a section used for NAKs. This section is invoked if the incoming frame is a NAK and another condition is met. Give a scenario where the presence of this other condition is essential.

P197NAK

NAK是否定确认。

P199协议六 选择重传

是这一行：if((r.kind == nak) && between(ack\_expected(r.ack+1)%(MAX\_SEQ+1) , next\_frame\_to\_send))

它会重传一次r.ack+1的内容（其实就是上一次的内容）。这样的好处在于可以部分解决返回端返回NAK的问题，并且比只用超时重传的效率高。具体来说：A向B发送1，B未收到返回nak，然后A收到nak马上又发送一次1，所以相比于A自己等timeout，重传的速度更快。

1. Consider the operation of protocol 6 over a 1-Mbps perfect (i.e., error-free) line. The maximum frame size is 1000 bits. New packets are generated 1 second apart. The timeout interval is 10 msec. If the special acknowledgement timer were eliminated, unnecessary timeouts would occur. How many times would the average message be transmitted?

每一帧的时间是1000bits/1Mbps=0.001s，就是说10ms这个间隔是能够让一帧完美到达，而不超时的。

但是由于接受方的等待时间会超时（10ms<1s），所以他会返回一个nak，导致发送端再传一次帧。所以每一个帧被传2次。

1. In protocol 6, MAX SEQ = 2n − 1. While this condition is obviously desirable to make efficient use of header bits, we have not demonstrated that it is essential. Does the protocol work correctly for MAX SEQ = 4, for example?

不，这个实现会失败。当MaxSeq=4时，我们得到NrBufs=2（因为NrBufs=(MaxSeq+1）/2)。偶数序列号使用缓冲区0，奇数序列号使用缓冲区1（只有0，1）。此映射意味着帧4和0都使用相同的缓冲区。假设帧0–3被接收和确认了，接收器窗口现在包含4和0。如果4丢失，0到达，它将被放入缓冲区0中，到达的[0]将被设置为true。帧到达代码中的循环将执行一次，并将无序消息传递给主机。此协议要求MaxSeq为奇数才能正常工作。但是，滑动窗口协议的其他实现并不都是这样的。

1. Frames of 1000 bits are sent over a 1-Mbps channel using a geostationary satellite whose propagation time from the earth is 270 msec. Acknowledgements are always piggybacked onto data frames. The headers are very short. Three-bit sequence numbers are used. What is the maximum achievable channel utilization for (a) Stop-and-wait? (b) Protocol 5? (c) Protocol 6?

传输的时间1000bits/1Mbps=0.001s，所以一个循环的时间为 2\*(0.001s+0.27s)=0.542s。

对于a)停等式：每次能传输1帧，1/542=0.18%.

1. 协议5：每次能传输7帧(2^3-1=7)，1/542=1.29%.
2. 协议6：每次能传输4帧（7+1/2=4），1/542=0.74%.
3. Compute the fraction of the bandwidth that is wasted on overhead (headers and retransmissions) for protocol 6 on a heavily loaded 50-kbps satellite channel with data frames consisting of 40 header and 3960 data bits. Assume that the signal propagation time from the earth to the satellite is 270 msec. ACK frames never occur. NAK frames are 40 bits. The error rate for data frames is 1%, and the error rate for NAK frames is negligible. The sequence numbers are 8 bits.

一帧的信息花费是3960 bits，而1帧会损失1%\*(40+3960) 重传消耗+40 每帧的头消耗+ 1%\*40返回的nak消耗=80.4 bits 所以最终的效率为80.4/(3960+80.4)=1.99%

1. Consider an error-free 64-kbps satellite channel used to send 512-byte data frames in one direction, with very short acknowledgements coming back the other way. What is the maximum throughput for window sizes of 1, 7, 15, and 127? The earth-satellite propagation time is 270 msec.

P200

传输从t=0开始。当t=4096/64000=64ms时，发送最后一位。在t＝334ms时，最后一位到达卫星并发送非常短的ACK。t=604ms时，ACK到达地球。这里的数据速率为4096位，604毫秒，或约6781bps。窗口大小为7帧时，整个窗口的传输时间为448ms，此时发送方必须停止。在604毫秒时，第一次确认到达，循环可以再次开始。共传输了7×4096=28672位，604ms。数据速率为47470.2 bps。只有当第一个ACK在t＝604ms时发射机仍在发送时，才可能发生连续传输。也就是说如果窗口大小大于传输值604毫秒，则可以满速。对于窗口大小≥10的情况，满足此条件，因此对于大于等于10的任何窗口大小，数据速率都是64 kbps

1. A 100-km-long cable runs at the T1 data rate. The propagation speed in the cable is 2/3 the speed of light in vacuum. How many bits fit in the cable?

电缆中的传播速度为200000m/s，因此100公里电缆将在500μs内填充完毕。每个T1帧在125μs内发送193位。这对应于四个帧，即电缆上的772位。

1. Give at least one reason why PPP uses byte stuffing instead of bit stuffing to prevent accidental flag bytes within the payload from causing confusion.

PPP是设计用来在软件中实现的，而不是像HDLC这样的位结构协议几乎总是在硬件中实现的。在软件实现中，完全使用字节比单独使用位要简单得多。此外，PPP被设计用于调制解调器，调制解调器以1字节（而不是1位）为单位接收和传输数据。

1. What is the minimum overhead to send an IP packet using PPP? Count only the overhead introduced by PPP itself, not the IP header overhead. What is the maximum overhead?

每帧至少有2个flag字节、1个协议字节和2个校验字节，每帧总共有5个开销字节。最大开销为2个字节，地址和控制各1个字节，协议2个字节，校验和4个字节。总共有10个开销字节。

1. A 100-byte IP packet is transmitted over a local loop using ADSL protocol stack. How many ATM cells will be transmitted? Briefly describe their contents.

AAL5帧将由2个PPP protcol字节、100个PPP有效负载字节、一些填充字节和8个尾部字节组成。要使此帧大小为48的倍数，填充字节数将为34。这将产生大小为144字节的AAL5帧。这可以在三个ATM信元中找到。第一个ATM信元将包含IP包的2个PPP protcol字节和46个字节，第二个信元将包含IP包的下48个字节，最后，第三个ATM信元将包含IP包的最后6个字节、34个填充字节和8个AAL5尾字节。

1. The goal of this lab exercise is to implement an error-detection mechanism using the standard CRC algorithm described in the text. Write two programs, generator and verifier. The generator program reads from standard input a line of ASCII text containing an n-bit message consisting of a string of 0s and 1s. The second line is the kbit polynomial, also in ASCII. It outputs to standard output a line of ASCII text with n + k 0s and 1s representing the message to be transmitted. Then it outputs the polynomial, just as it read it in. The verifier program reads in the output of the generator program and outputs a message indicating whether it is correct or not. Finally, write a program, alter, that inverts 1 bit on the first line depending on its argument (the bit number counting the leftmost bit as 1) but copies the rest of the two lines correctly. By typing generator <file | verifier you should see that the message is correct, but by typing generator <file | alter arg | verifier you should get the error message.