THE UNIVERSITY
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School of Computer Science

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Computer Networks

SOLUTIONS TO SELECTED PROBLEMS

Set 3 – The Data Link Layer

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Framing

1. What is the difference between bit-oriented and byte-oriented protocols?

2. Assuming a framing protocol that uses bit staffing, show the bit sequence transmitted over the link when the frame contains the following bit sequence: 11010111110101111101011111110. [Peterson 3.4]. Do the same with bit string 01111011111101111110 [Tanenbaum 3.3]

ANSWER

110101111**0**01011111**0**10101111**0**110

011110111110011111**0**10

3. Suppose the following sequence of bits arrive over a link: 11010111 11010111 11001011 1110110. Show the resulting frame after any bits have been removed. Indicate any errors that might have been introduced in the frame. . [Peterson 3.5]

ANSWER

11010111 11**0**10111 11**0**01011 111**0**110 → 11010111 11101111 10101111 1110

4. The following data fragment occurs in the middle of a data stream for which the character-stuffing algorithm described in the text is used: DLE,STX,A,DLE,B,DLE,ETX. What is the output after stuffing? [Tanenbaum 3.2]

ANSWER

After stuffing the bytes areDLE STX,A,DLE,DLE,B,DLE,ETX

Error detection and Correction

5. Distinguish between even and odd parity

6. Suppose some static (noise) of duration 0.01sec affects the communication line for a 14400bps modem. How many bits could be affected? [Shay 4.3]

ANSWER

144 bits.

7. Explain how parity bits can be used to detect burst errors.

ANSWER

Book work. Lecture slides and Tanenbaum section 3.2.1

8. Suppose we want to devise a single-bit error correcting Hamming code for a 16-bit data string. How many parity bits are needed? How about for a 32-bit data string? [Shay 4.13]

ANSWER

If r is the number of parity bits and m is the number of data bits then $(m+r+1)<=2^r$ For m=16 r=5 and for m=32, r=6.

9. Construct the Hamming code for the following data string: 01100111 [Shay p. 212]

ANSWER

This is straightforward. For this one, you may also find the table in next question helpful.

10. The following Hamming-coded (single bit correction) string was received: 010101010111. Is there an error? If yes, in which position? [Shay p. 213]

ANSWER

Interpret the above as: p_1 p_2 m_1 p_3 m_2 m_3 m_4 p_4 m_5 m_6 m_7 m_8. Then construct Table below to help you identify which bit positions contribute to each parity bit. The rest is straightforward.

Position	Binary	Bit	Parity bits for this position
1.	0001	p_1	p_1
2.	0010	p_2	p_2
3.	0011	m_1	p_1 p_2
4.	0100	p_3	p3
5.	0101	m_2	p3 p1
6.	0110	m_3	p3 p2
7.	0111	m_4	p3 p2 p1
8.	1000	p_4	p4
9.	1001	m_5	p4 p1
10.	1010	m_6	p4 p2
11.	1011	m_7	p4 p2 p1
12.	1100	m_8	p4 p3

p_1 and p_3 parity checks fail. Thus the error is in the position (put 1 if p fails and 0 otherwise): p_1 p_2 p_3 p_4 = 1010=5.

11. Describe the principle and basic steps of CRC. Is it an error correction or error detection code?

12.Given two polynomials $A(x)$ and $B(x)$ show the result of $\mod 2 \frac{A(x)}{B(x)}$.

$A(x) = x^7 + x^6 + x^4 + x^2 + x + 1$ $B(x) = x^3 + x$

ANSWER

$A(x) = 11010111$
$B(x) = 1010$

By using XOR the result is: $\mod 2 \frac{A(x)}{B(x)} = 101 = x^2 + 1$

13.Suppose we want to send 10101011000 and 10101011001 strings using CRC with generator polynomial $x^3 + x + 1$. Show strings, with CRC code attached, as they will leave the sender. Explain your answer.

ANSWER

First string

a) *Append three zeros (= degree of generator polynomial) to the original message*

10101011000000.

b) *Do modulo 2 of* $\frac{10101011000000}{1011}$

c) *Result of mod2 is 11 so the string will have to be altered as follows:*

10101011000011. This is the first message that will be sent.

Second string

a) *Append three zeros (= degree of generator polynomial) to the original message*

10101011001000.

b) *Do modulo 2 of* $\frac{10101011001000}{1011}$

c) *Result of mod2 is 0 so there is no need to change any of the appended bits*

d) *Hence, the string with CRC code that will be sent is as shown in step a.*

14.Communication line uses CRC with generator polynomial $x^8 + x^5 + x^4 + x^2 + 1$ and receiver gets two messages:

- 100110011110101011111000

- 100110011110101011100000
-

1) Do these messages contain errors?
2) If at least one is correct then find out the original message(s)?
3) Will any of the messages need to be discarded or retransmitted?

Justify your answers.

ANSWER

1)

Generator polynomial is 100110101. Modulo 2 of $\frac{100110011110101011100000}{100110101}$ yields result 0. Therefore, from the CRC point of view, this message has been received error free.

The same operation yields result 1000 for the second string. Thus, from the CRC point of view, the second string contains errors.

2)

The original message can be obtained from the first message by removing 8 (= degree of generator polynomial) least significant bits. So the original message is

100110011110101.

3)

Second message contains errors and will have to be discarded and retransmitted.

Data Link Protocols

15. Using the following definitions and values, calculate the channel utilisation and the effective data rate of the stop-and-wait data link protocol [Shay p.257]:

R=transmission rate(10Mbps)
S=signal speed (200 meters/μsec)
D=distance between sender and receiver(200meters)
T=time to create one frame (1 μsec)
F=number of bits in a frame(200)
N=number of data bits in a frame(160)
A=number of bits in an acknowledgement (40)

ANSWER

(The following is from Shay's book, pp 257-259)

First determine the time required to construct and send a frame. Assume the sender begins at time zero. The sender will have got information and put it into a frame at time T. The next step is to transmit the frame (put its bits on the channel). Since R is the data rate, the 1/R is the time needed to transmit 1 bit. Therefore F/R is the time needed to transmit one frame. The total time used so far is T+F/R.

Once the sender has transmitted the frame, the bits require time to travel through the channel to the receiver. The travel time is D/S. Thus, after the last bit is transmitted, it requires another D/S time units to reach the receiver. Therefore, the receiver receives the last bit at time T+F/R+D/S. note that the amount of time a frame is in transit is F/R+D/S.

For the stop and wait protocol, the receiver must send an acknowledgement. A similar argument as above, shows that the time required for the sender to receive the acknowledgement is T+A/R+D/S.

Next question: How much time elapses between sending two data frames? In the stop and wait protocol, the sender must wait for each acknowledgement. Therefore, the elapsed time between sending two consecutive frames is:

Time=(T+F/R+D/S)+(T+A/R+D/S)=2*(T+D/S)+ (F+A)/R.

As stated previously, the amount of time a frame is actually in transit is F/R+D/S. Thus, if P is the percentage of time during which frame bits occupy the channel (i.e. the channel utilization):

P=100*(F/R+D/S)/(2*(T+D/S)+(F+A)/R)=… substitute the specified numbers… = 75%.

The effective data rate is the actual number of data bits (as opposed to the maximum number of bits or capacity) sent per unit of time. To calculate the effective data rate, we divide the number of data bits (N) sent by the elapsed time between sending two frames. Thus:

Effective data rate=N/(2*(T+D/S)+(F+A)/R)=…=5.7bits/μsec.

16. Describe the operation of a receiver in the go-back-n and selective-repeat sliding window protocols.

ANSWER

Book work. Lecture slides and Tanenbaum sections 3.4.2 and 3.4.3

17. The general strategy of using acknowledgements and timeouts to implement reliable delivery is sometimes called Automatic Repeat Request (ARQ). Consider an ARQ protocol that uses only negative acknowledgements (NAKs) in case of errors but no positive acknowledgements. Describe what timeouts would need to be scheduled. Explain why an ACK-based protocol is usually preferred to a NAK-based protocol.

ANSWER

Assume a NAK is sent only when an out-of-order packet arrives. Then, the receiver must maintain a RESEND-NAK timer in case a NAK or the packet NAKed is lost. The problem is that the sender may not send a packet following on that is lost (thereby triggering the NAK) meaning that the sender is going to have to maintain a timeout anyway. The RESEND-NAK timeout just adds unnecessary complexity.

18. Two stations, A and B, are connected via a point-to-point link and exchange frames both employing the go-back-n sliding window protocol with window size 7. For each of the following events, describe the actions of both the sending and receiving protocols, specifying the buffer contents and the state of each protocol after responding to the event [Shay 5.7]:

    (a) Station A sends frames 0 through 6. Station B receives them in order but frame 4 was damaged.
    (b) Station A sends frames 0 through 6. Station B receives them in order. Station B sends one data frame to A (which A receives correctly) after receiving frame 4 but before receiving frame 5.
    (c) Same scenario as in (b) but the data frame sent to A is damaged.
    (d) Station A has 12 frames to send to B (which B receives correctly) but B has nothing to send to A.

    ANSWER

    (a) Station A sends frames 0 through 6. Station B receives them in order but frame 4 was damaged.

Answer. B will send a NAK, acknowledging frame 3 and not accept frames 4,5 and 6. It is now expecting frame 4. A will advance the window including frames 4,5,6 which it will resend when the NAK arrives. A can now accept frames 7, 0, 1,2 from the higher level protocol, store them to buffers and send them to B.

    (b) Station A sends frames 0 through 6. Station B receives them in order. Station B sends one data frame to A (which A receives correctly) after receiving frame 4 but before receiving frame 5.

Answer. After receiving the ACK, A dvances its window including frames 4 and 6. It can now accept frames 7, 0, 1, 2, 2 and store them in the buffer. Assuming the frame it received from B had sequence 0, A will next expecting frame 1. Station B is now expecting frame 5 from Aand is able to accept (from its higher level protocol) and buffer frames 1,2,3,4,5,6.

    (c) Same scenario as in (b) but the data frame sent to A is damaged.

Answer. The same events as in part B occur again. However, in addition A will send a NAK to B indicating the last frame it received. Assuming it has received none so far, the NAK will inform B that frame 0 did not arrive correctly and B can resend it.

    (e) Station A has 12 frames to send to B (which B receives correctly) but B has nothing to send to A.

    Answer. A will send frames 0 through 6 and wait for an ACK. Assuming they arrive correctly, B's ACK timer eventually expires and acknowledges frame 6. When A gets the ACK it advances its window gets frames 7,0,1,2,3, buffers them and sends them to B.

19. Two stations, A and B, are connected via a point-to-point link and exchange frames both employing the selective repeat sliding window protocol with window sizes of 4. For each of the following events, describe the actions of both the sending and receiving protocols, specifying the buffer contents and the state of each protocol after responding to the event [Shay 5.10]:

    (a) Station A sends frames 0 through 3. All except frame 2 arrive. Frame 2 is lost.
    (b) Station A sends frames 0 through 3. They arrive at B in the order 0,1,3,2
    (d) Station A sends frames 0 through 3. Station B receives frames 0 and 1 and sends a piggyback Ack which A receives.
    (e) Same scenario as in (c) but the Ack gets lost

ANSWER

(a) Station A sends frames 0 through 3. All except frame 2 arrive. Frame 2 is lost.

Answer. Until A receives an Ack frames 0 through 3 are still outstanding and in A's window. Its window is at its limit and will accept no more frames from its patron. Station B accepts frames 0,1 and 3 and delivers frames 0 and 1 to its patron. B's receiving window now corresponds to frames 2,3,4 and 5 with frame 3 being buffered. B sends a NAK for and is currently expecting 2. When A gets the NAK it will resend frame 2 and remove 0 and 1 from its window. It can now accept two more frames from its patron.

(b) Station A sends frames 0 through 3. They arrive at B in the order 0,1,3,2

Answer. Frames 0-3 will stay in A's buffer until it receives an ACK for them. Station *B* accepts all four frames and delivers them to its patron (although it delivers 0 and 1 after it receives frame 1 and delivers 2 and 3 after it receives frame 2). B's receiving window is advanced to accept any of frames 4, 5, 6, and *7,* although it will be expecting frame 4. By receiving frame 3 out of order *B* sends a NAK for frame 2. When A gets it, A will resend frame 2. When it arrives at *B* it will be rejected because it is not in *B's* window. Eventually *B* will ACK all four frames received and, if A gets the ACK then A will also advance its window to accept up to four more frames from its patron.

(c) Station A sends frames 0 through 3. Station B receives frames 0 and 1 and sends a piggyback Ack which A receives.

Answer. Station A advances its sending window *(sw~2)* and can accept frames 4 and *5* from its patron. Station *B* delivers frames 0 and 1 to its patron and advances its receiving window to accept frames 2, 3, 4, and 5.

(d) Same scenario as in (c) but the Ack gets lost

Answer. Station A's window will not change but eventually frame timers will expire causing A to resend the related frames. As before station *B* delivers frames 0 and 1 to its patron and advances its receiving window to accept frames 2, 3, 4, and *5.* When the duplicate frames 0 and I arrive *B* will ignore them