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Data Link Layer I

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Q1

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Consider the case of transmitting 1250 Bytes frame over on a link with a delay of 200ms (millisecond) when the length of the link is 200km. Assume that acknowledgment packets are of negligible size, processing time at a node is negligible, and the link is error-free.

Calculate the transmission efficiency of the following ARQ methods if the transmission rates are 1Kbps, 1Mbps, 1Gbps and the lengths of the same link are 20Km, 200Km, 2000Km, 20000Km respectively.

a. Stop-and-wait ARQ?
b. Go-Back-N ARQ where W is large enough to keep the channel fully busy?
c. Selective-Repeat ARQ where W is 7?

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Q1

Frame Size = L = 1250 * 8 bits = 10000 bits

Prop rate = 200km/(200*10^{-3}s) =1000 km/s

T_{frame} = L / (Transmission rate) (in seconds)

T_{prop} = Distance / (Prop rate)   (in seconds)

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Stop-and-wait ARQ

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$$S = \frac{1}{1+2a}$$

i) T_{frame} = L / (Transmission rate) = 10000 / 1000 = 10s

T_{prop} = Distance / (Prop rate) = 20 /1000 = 0.02s

$a = T_{prop} / T_{frame} = 0.02/10 = 0.002$ $\quad$ s = 1/ (1+2a) = 1/1.002 = 0.996 (99.6%)

ii) T_{frame} = L / (Transmission rate) = 10000 / 1000000 = 0.01s

T_{prop} = Distance / (Prop rate) = 2000 /1000 = 2s

$a = T_{prop} / T_{frame} = 2/0.01 = 200$ $\quad$ s = 1/ (1+2a) = 1/401 = 0.0025 (0.25%)

Distance / Transmission rate	20Km	200Km	2000Km	20000Km
1Kbps	99.8%			
1Mbps			0.25%	
1Gpbs				

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Go-Back-N ARQ with a large W

…… (W >= 2a + 1) to keep the channel fully busy?

$$S = \begin{cases} 1, & \boldsymbol{W \geq 2a+1} \\ \dfrac{W}{(2a+1)}, & \boldsymbol{W < 2a+1} \end{cases}$$

s = 1

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Selective-Repeat ARQ where W = 7

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$$S = \begin{cases} 1, & \boldsymbol{W \geq 2a + 1} \\ \dfrac{W}{(2a+1)}, & \boldsymbol{W < 2a + 1} \end{cases}$$

i) T_{frame} = L / (Transmission rate) = 10000 / 1000 = 10s

T_{prop} = Distance / (Prop rate) = 20 /1000 = 0.02s

$a = T_{prop} / T_{frame} = 0.02/10 = 0.002$ $\quad W \geq 2a + 1$ $\quad s = 1$

ii) T_{frame} = L / (Transmission rate) = 10000 / 1000000 = 0.01s

T_{prop} = Distance / (Prop rate) = 2000 /1000 = 2s

$a = T_{prop} / T_{frame} = 2/0.01 = 200$ $\quad W < 2a + 1$ $\quad s = w/ (1+2a) = 7/401 = 0.0175$ (1.75%)

Distance / Transmission rate	20Km	200Km	2000Km	20000Km
1Kbps	100%			
1Mbps			1.75%	
1Gpbs				

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Q2

Consider a sliding window protocol (Go-Back-N ARQ) used for flow control on a given data link where the data rate is 8,000 bits/second, the propagation delay is 0.25 second, and the frame size is 1600 bits. Assume that acknowledgment packets are of negligible size, processing time at a node is negligible, and the link is error-free. What is the minimum window size which will allow full utilization (efficiency) of the link?

Frame Size = L = 1600 bits

T_{prop} = 0.25s

T_{frame} = 1600 / 8000 = 0.2 s

a = 0.25s / T_{frame} = 1.25

In order to have a full link utilization: $W \geq 2a + 1$

W_{min} = round_up(2 *1.25 + 1) = 4

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Q3

Assume data in 8-bit words as shown below:

10011001 11100010 00100100 10000100

a. Calculate the checksum at the sender's end and the receiver's end

Refer to lecture notes for binary calculation

Sender's End	**Receiver's End**
b1 = 10011001 = 153	b1 = 10011001 = 153
b2 = 11100010 = 226	b2 = 11100010 = 226
b3 = 00100100 = 36	b3 = 00100100 = 36
b4 = 10000100 = 132	b4 = 10000100 = 132
x = (b1 + b2 + b3 + b4) mod 2^8-1	b5 = 11011010 = 218 *(checksum block)*
37 = 547 mod 255	
	x = (b1 + b2 + b3 + b4 + b5) mod 2^8-1
checksum c = -x mod 255	0 = 765 mod 255
c = -37 mod 255	
c = 218	checksum c = -0 mod 255
c = 11011010	c = -0 mod 255
	c = 0
	c = 0

Codeword = 10011001 11100010 00100100 10000100 11011010

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Q3

Assume data in 8-bit words as shown below:

10011001 11100010 00100100 10000100

b. State an example of an error that checksum fails to detect?

Sender sent 10011001 11100010 00100100 10000100 11011010

Receiver received 11100010 10011001 00100100 10000100 11011010

Can’t be detected by checksum

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Q4

Given the data word (1011011), or data polynomial $D(x) = x^6 + x^4 + x^3 + x^1 + 1$ and given the generator polynomial $G(x) = x + 1$

a. Find the codeword $C(x)$

b. Assume the received message H (x) is **$H(x) = C(x) + E(x)$**, where $E(x)$ is the error polynomial

   i. When $H(x)$ contains no errors show that $H(x)$ is divisible by $G(x)$

   ii. Determine whether the error is detectable when:

   - $E(x) = 1$
   - $E(x) = x + 1$
   - $E(x) = x^3 + x$

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Q4

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Given the data word (1011011), or data polynomial $D(x) = x^6 + x^4 + x^3 + x^1 + 1$ and given the generator polynomial $G(x) = x + 1$ (11)

a. Find the codeword C(x) (For detailed explanation please see lecture notes)

			1	1	0	1	1	0	0
1	1	1	0	1	1	0	1	1	0
		1	1						
			1	1					
			1	1					
			0	0	1	0			
					1	1			
					0	1	1		
						1	1		
						0	0	1	0
								1	1
									1

Remainder

Codeword = 10110111

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Q4

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Given the data word (1011011), or data polynomial $D(x) = x^6 + x^4 + x^3 + x^1 + 1$ and given the generator polynomial $G(x) = x + 1$

b. Assume the received message H (x) is $\mathbf{H(x) = C(x) + E(x)}$, where E(x) is the error polynomial

   i. When H(x) contains no errors show that H(x) is divisible by G(x)

XOR (since E(x) here just indicates which bits are in error during transmission)

Divide H(x) by G(x) and show that the remainder = 0

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Q4

Determine whether the error is detectable when:

- E(x) = 1

Received: 10110111 + 00000001 = 10110110

			1	1	0	1	1	0	1
1	1	1	0	1	1	0	1	1	0
		1	1						
			1	1					
			1	1					
			0	0	1	0			
					1	1			
					0	1	1		
						1	1		
						0	0	1	0
								1	1
									1

Error detected

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Q4

Determine whether the error is detectable when:

- $E(x) = x^3 + x$

Received: 10110111 +
00001010

= 10111101

$$
\begin{array}{cc|cccccccc}
 & & & 1 & 1 & 0 & 1 & 0 & 1 & 0 \\
\hline
1 & 1 & 1 & 0 & 1 & 1 & 1 & 1 & 0 & 1 \\
 & & 1 & 1 & & & & & & \\
\cline{3-4}
 & & & 1 & 1 & & & & & \\
 & & & 1 & 1 & & & & & \\
\cline{3-5}
 & & & 0 & 0 & 1 & 1 & & & \\
 & & & & & 1 & 1 & & & \\
\cline{3-7}
 & & & & & 0 & 0 & 1 & 0 & \\
 & & & & & & & 1 & 1 & \\
\cline{3-9}
 & & & & & & & 0 & 1 & 1 \\
 & & & & & & & & 1 & 1 \\
\cline{3-10}
 & & & & & & & & & 0
\end{array}
$$

Error undetected

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Q5

Show byte-stuffing & destuffing steps for the following data bits if PPP frame is used?

<u>01000001</u> <u>01111101</u> <u>01000010</u> <u>01111110</u> <u>01010000</u> <u>01110000</u> <u>01000110</u>

Convert to Hex: 41 7D 42 7E 50 70 46
Look for the Flag (7E) and Control Escape (7D): 41 <u>7D</u> 42 <u>7E</u> 50 70 46

Stuffing

7D will be replaced by the byte 7D and (7D XOR 20) = 5D
7E will be replaced by the byte 7D and (7E XOR 20) = 5E

Hence the complete byte string to be sent: 7E 41 7D 5D 42 7D 5E 50 70 46 7E

Received bits after Hex Conversion: 7E 41 7D 5D 42 7D 5E 50 70 46 7E

Look for the bytes 7E and 7D: 7E is the flag; If 7D is encountered, look into the next byte
7E 41 7D 5D 42 7D 5E 50 70 46 7E

Replace (7D <next byte>) with (<next byte> XOR 20)
7E 41 7D 42 7E 50 70 46 7E

Destuffing

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Q6 (Optional. For information only)

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In some networks the data link layer requests all damaged frames to be retransmitted. Assume that the acknowledgement frame is never lost. If the probability of a frame being damaged on a particular link is *p*, what is the normalized throughput of the link if stop-and-wait ARG is used?

Hint:

$$\sum_{i=1}^{\infty}(i \times x^{i-1}) = \frac{1}{(1-x)^2} \qquad for(-1 < x < 1)$$

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Q6 (Optional)

The time to transmit a frame successfully is

$$T = T_{frame} + 2\ T_{prop}$$

Suppose the frame or ACK *is lost*, two transmission attempts are required, therefore,

$$T = T_{frame} + \textbf{timeout} + T_{frame} + 2\ T_{prop}$$

Assume timeout = $2\ T_{prop}$

Therefore

$$T = 2\ (T_{frame} + 2\ T_{prop})$$ for two transmissions

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Q6 (Optional)

Suppose for successful transmission each frame has to be transmitted *k* times on average, then

$$T = N_x\,(T_{frame} + 2\,T_{prop})$$

The probability of a frame requires exactly *k* transmissions , *P(k)*, equals the probability of the first *k-1* attempts failing, (p^{k-1}), multiplies the probability of the *k*-th transmission succeeding, (*1-p*).

Therefore the mean number of transmission is

$$N_x = \sum_{k=1}^{\infty}(k \times T(k)) = \sum_{k=1}^{\infty}(k \times (1-p) \times p^{k-1}) = \frac{1}{(1-p)^2}(1-p) = \frac{1}{(1-p)}$$

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Q6 (Optional)

Normalized throughput

$$S = \frac{T_{frame}}{N_x(T_{frame} + 2T_{prop})} = \frac{1}{N_x(1+2a)}$$

$$\boldsymbol{S} = \frac{1-\boldsymbol{P}}{1+2\boldsymbol{a}}$$