VE489 Homework2

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1. Framing maps streams of bits to frames of bits with boundaries, payloads, and possibly control bits, flags, character counts and error checking bits. It packs data into certain sizes to facilitate later transmission.
   Framing is important in logical link layer based on the following benefits.

   - Readability of transmitted bit streams
     By adding beginning, ending and other flags, bit streams can be easily decoded.
   - Transmission Reliability
     With framing, loss of bits can be detected by fixed size frames or frame size indicator bits. Error control bits can be implemented and included in trailers. Flow control is possible so that corruptions on the receiver's side can be avoided. Besides, frames can be distinguished from each other in a certain period.
   - Addressing enabled
     Entries for source and destination addresses are enabled in the frame (but addressing is not necessarily done in LLC).

2. 1) Assume HDLC is applied. Stuffed bits are indicated by italics.
   01111110 01101111 1**0**1101011 10110100 00101111 1**0**1011011 101111**0**1 11010111 11**0**1111**0**0 **01111110**

   2) For every consecutive 5 1s, if the next bit is 0, then it is a stuffed bit and remove this 0. If the next two bits are 10, then a flag is detected. If the next two bits are 11, then an error is detected.
   For the given bit stream, after the first 5 consecutive 1s, two bits 10 are detected, indicating a flag. So, the flag 01111110 is removed. After the second 5 consecutive 1s, a 0 is detected, indicating it is a stuffed bit. So, 0 is removed. After the third 5 consecutive 1s, 11 is detected, indicating bit error. Since bit error only occurs at stuffed bit, the sixth 1 is removed. After the fourth 5 consecutive 1s, 10 is detected. So remove the flag 01111110. Thus, the de-stuffed bit stream is 011111001111110101 0011.

3. 1) Key mechanism of three ARQ protocols discussed in class.

	timeout	ACK/NAK	frame sequence
Stop-and-Wait ARQ	wait for ACK or timeout expiration after every sending	ACK	0, 1 cyclic
Go-Back N ARQ	resend all if window exhausted (or timeout expired)	ACK with sequence	0 to $2^m - 1$ cyclic
Selective Repeat ARQ	timeout causes individual corresponding frame to be resent	ACK with sequence NAK if out of sequence	0 to $2^m - 1$ cyclic

	receiving window	sending window
Stop-and-Wait ARQ	none	none
Go-Back N ARQ	none	$W_s \leq 2^m - 1$
Selective Repeat ARQ	$W_s + W_r \leq 2^m$	$W_s + W_r \leq 2^m$

2) i. Stop-and-Wait ARQ
Error-free:
Denote
t_0 as total time needed to transmit and receive 1 frame,
t_f as T_x, namely time needed to send out the bit stream from the sender side,
t_{ack} as time needed to send out the ack bit stream from the receiver side,
t_{prop} as the propagation time in the channel,
p_{proc} as the process time for a received frame or received ACK
R as the transmission data rate in this channel,
R_{eff} as the effective transmission rate
n_a as the total number of bits of the ACK,
n_f as the total number of bits of the frame,
n_0 as bits for the header and CRC,
η as the transmission efficiency.

$$\begin{aligned} t_0 &= 2p_{proc} + 2p_{prog} + t_f + t_{ack} \\ &= 2p_{proc} + 2p_{prog} + \frac{n_f + n_a}{R} \end{aligned}$$

$$R_{eff} = \frac{n_f - n_0}{t_0}$$

$$\begin{aligned} \eta &= \frac{R_{eff}}{R} \\ &= \frac{1 - \frac{n_0}{n_f}}{1 + \frac{n_a}{n_f} + \frac{2(t_{prop} + t_{proc})R}{n_f}} \end{aligned}$$

Erroneous:
Denote
P_e as the probability that a frame arrives with error,
η_e as the transmission efficiency with error.

$$\begin{aligned}\eta_e &= \eta \times (1 - P_e) \\ &= (1 - P_e)\frac{1 - \frac{n_0}{n_f}}{1 + \frac{n_a}{n_f} + \frac{2(t_{prop}+t_{proc})R}{n_f}}\end{aligned}$$

ii. Go-Back N ARQ
Error-free:

$$\begin{aligned}\eta &= \frac{R_{eff}}{R} \\ &= \frac{\frac{n_f - n_0}{t_0}}{R} \\ &= 1 - \frac{n_0}{n_f}\end{aligned}$$

Errorneous:
Denote t_e as total time needed for transmitting and receiving 1 frame if error occurs with probability P_e,

$$t_e = (1 - P_e)t_0 + P_e(t_0 + \frac{W_s t_0}{1 - P_e})$$

$$\eta_e = (1 - P_e)\frac{1 - \frac{n_0}{n_f}}{1 + (W_s - 1)P_e}$$

iii. Selective Repeat ARQ
Error-free:

$$\begin{aligned}\eta &= \frac{R_{eff}}{R} \\ &= \frac{\frac{n_f - n_0}{t_0}}{R} \\ &= 1 - \frac{n_0}{n_f}\end{aligned}$$

Errorneous:

$$t_e = \frac{1}{1 - P_e}t_0$$

$$\eta_e = (1 - P_e)(1 - \frac{n_0}{n_f})$$