Error and Flow Control

Performance

- Definition for average channel utilization

$$U = \frac{\text{Time to transfer information given no protocol}}{\text{Time to transfer information given the protocol}} = \frac{T_D}{T_P}$$

Error and Flow Control

Performance

- Utilization for simplex stop-and-wait protocol

$$T_p = \underbrace{\frac{D+H}{C}}_{\text{frame + overhead}} + \underbrace{\tau}_{\text{propagation}} + \underbrace{i}_{\text{interrupt \& service}} + \underbrace{\frac{A}{C}}_{\text{transmit ack}} + \tau + i$$

$$T_D = \frac{D}{C}$$

Error and Flow Control

Performance

$$U = \frac{D}{D + H + A + 2C(\tau + i)}$$

Note that $2C\tau$

= the number of bits in a round trip time.

Example:

D+H = 10,000 bits, C= 100 Mb/s,

2τ = 250 ms

U = 4 x 10^{-7}

Error and Flow Control

Performance

- Performance including errors

R = Average Number of retransmissions
T = Timeout period

$$T_p = \frac{R(D+H)}{C} + RT + (\frac{D+H}{C} + 2(\tau + i))$$

Time to transmit bad frames

Time to transmit good frame

Error and Flow Control

Performance

- Both the original frame and the acknowledgment must be error free for a successful transmission.
- Let P_1 = Probability of a frame error

  and P_2 = Probability of an ack error
- Assume frame and ack errors are statistically independent

Error and Flow Control

Performance

Probability of retransmission $= L$

$$L = 1 - (1 - P_1)(1 - P_2)$$

and

Probability of K transmission attempts $= \mathrm{Prob}[\mathrm{K} = \mathrm{k}]$

$$\mathrm{Prob}[\mathrm{K} = \mathrm{k}] = (1 - L)L^{k-1}$$

then $\mathrm{E}[\mathrm{K}] = \sum_{\mathrm{k}=1}^{\infty} \mathrm{k}(1 - L)L^{k-1} = \frac{1}{(1 - L)}$

and

$$R = \frac{1}{(1 - L)} - 1 = \frac{L}{(1 - L)}$$

Error and Flow Control

Performance

Example:

D = 1024 bits H = 48 bits $P_e = 10^{-5}$

$P_x = nP_e(1 - P_e)^{n-1}$ where n = # bits and x = 1,2

so

$P_1 = 0.01$

$P_2 = 0.0005 \longrightarrow$ has little effect

$$R = \frac{1}{94}$$

Error and Flow Control

Performance of Sliding Window Protocols

- Case 1: Large Windows
  - Transmit at full speed because ack arrives just as the window closes.

Transmit $\frac{W(D+H)}{C}$ sec and wait for ack.

First ack arrives at transmitter at time $2\tau + \frac{(D+H)}{C}$

If $\frac{W(D+H)}{C} \geq 2\tau + \frac{(D+H)}{C}$

or W > $1 + \frac{2C\tau}{(D+H)}$ and there are no errors

then $U = \frac{D}{D+H}$

If errors and selective repeat then

$$U = \frac{D}{(D+H)(\frac{1}{1-L})} = \frac{D(1-L)}{(D+H)}$$

Error and Flow Control

Performance of Sliding Window Protocols

- Case 2: Small Windows
  - Small window means that the window closes before the ack returns.

In this case $W < 1 + \frac{2C\tau}{F}$

The time to transmit a frame is $\frac{D+H}{C} + 2\tau$

and

$$U = \frac{\frac{WD}{D+H}}{\frac{D+H}{C} + 2\tau} = \frac{WD}{(D+H) + 2C\tau} = \left(\frac{D}{D+H}\right)\left(\frac{W}{1 + \frac{2C\tau}{D+H}}\right)$$

Note $1 + \frac{2C\tau}{D+H}$ is the number of frames in transit

With errors

$$U = \left(\frac{D}{D+H}\right)\left(\frac{W}{1 + \frac{2C\tau}{D+H}}\right)(1 - L)$$