1) Stop-and-Wait ARQ, Sliding Window

Sender
- Send frame 0
- waits for ACK
- Send ACK for frame 0
- wait for ACK

Receiver
- sends ACK for frame 0
- Waits for frame 1
- Send ACK for frame 1
- Wait for frame 0

2) With $P = 0$ (no errors)

\[ D_{0} = \frac{t_{L}}{t_{L} + t_{2a}} \approx 0 \]

\[ D_{0} = \frac{1}{1 + 2a} \quad \text{with} \quad a = \frac{t_{error}}{t_{L}} \]

With $P \neq 0$, a frame is transmitted on average $N$ times

\[ N = \left( \frac{1}{1 - P} \right) \]

\[ D_{0} = \frac{t_{L}}{N(t_{L} + 2t_{prop})} = \frac{1}{N(t_{L} + 2t_{prop})} = \frac{1 - P}{N + 2a} \]

3) $P = 0$ (no errors)

Case 1:
- ACK frame 0 is received before $k$
- $U_{p=0} = 1$

Case 2:
- the ACK for frame 0 is received at $t > t_{0}$
- $U_{p=0} < 1$

\[ U_{p=0} = \frac{k \cdot t_{L}}{t_{a}} = \frac{\text{time for transmission of frames}}{t_{a}} \quad \text{time until next ACK frame 0 is received} \]
\[ t_p = t_k + t_{\text{prop}} + t_{\text{ack}} + t_{\text{prop}} = t_k + 2t_{\text{prop}} \]

\[ U_{\rho=0} = \frac{Kt_k}{t_k + 2t_{\text{prop}}} \Rightarrow t_p = \frac{20}{K-U} \text{sec} \]

\[ t_p = \frac{5}{R} \Rightarrow L = (1.36 \times 10^{-6})(10 \times 10^{-6}) = 73.63 \text{ bits} \geq 74 \text{ bits} \]

4.) a) Selective Repeat Protocol

\[ t_p = \frac{3500}{3 \times 10^8} = 11.67 \mu \text{sec} \]

Time needed for the ack of first frame to be received +

\[ T = t_p + t_{\text{prop}} + t_{\text{prop}} + t_p + t_{\text{prop}} + t_{\text{prop}} \]

\[ K \text{ frames} = 0.64 \mu \text{sec} \]

\[ \Rightarrow Kt_p > T \Rightarrow K > \frac{T}{t_p} \Rightarrow K > 41.84 \approx 42 \]

5) \[ P_e = 0.01 \]

\[ N = \frac{1}{1-P_e} \]

\[ U = \frac{U_{\rho=0}}{C(1-P_e)} = 1 \times (0.99) = 0.99 \]

\[ R = 64 \times 10^3 \frac{\text{bit}}{\text{sec}} = 64 \times \frac{\text{bit}}{\text{sec}} \Rightarrow \text{(For successful delivery)} = 64.099 = 63.36 \frac{\text{bit}}{f} \]

\[ p_{\text{succ}} = 1 \]

\[ p_{\text{trans.}} \]