**Solution to HW4**

**7.6 (10 pt)**

Round trip propagation delay of the link = 2 x L x t
Time to transmit a frame = B/R
To reach 100% utilization, the transmitter should be able to transmit frames continuously during a round trip propagation time. Thus, the total number of frames transmitted without an ACK is:

$N = \left\lceil \frac{2 \times L \times t}{B/R} + 1 \right\rceil$, where $\lceil X \rceil$ is the smallest integer greater than or equal to X

This number can be accommodated by an M-bit sequence number with:

$$M = \lceil \log_2(N) \rceil$$

**7.9 (17 pts)**

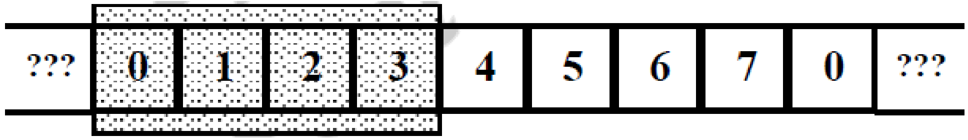
| a | 0.1 | 1 | 10 | 100 |
|---|---|---|---|---|
| S & W | (1 –P)/1.2 | (1 – P)/3 | (1 – P)/21 | (1 – P)/201 |
| GBN (7) | (1–P)/<br>(1+0.2P) | (1–P)/(1+2P) | 7(1–P)/<br>21(1+6P) | 7(1 –P)/<br>201(1+6P) |
| GBN (127) | (1–P)/<br>(1+0.2P) | (1–P)/(1+2P) | (1 –P)/<br>(1+20P) | 127(1–P)/<br>201(1+126P) |
| SREJ (7) | 1 – P | 1 – P | 7(1 – P)/21 | 7(1 – P)/201 |
| SREJ (127) | 1 – P | 1 – P | 1 – P | 127(1 –P)/<br>201 |

For a given value of *a*, the utilization values change very little as a function of P over a reasonable range (say $10^{-3}$ to $10^{-12}$). We have the following approximate values for $P = 10^{-6}$:

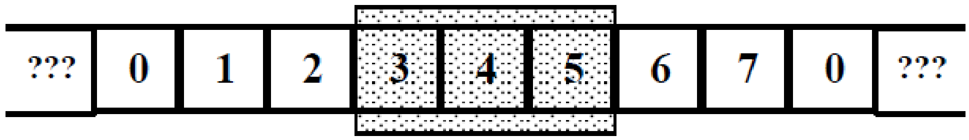
| a | 0.1 | 1 | 10 | 100 |
|---|---|---|---|---|
| S & W | 0.83 | 0.33 | 0.05 | 0.005 |
| GBN (7) | 1.0 | 1.0 | 0.33 | 0.035 |
| GBN (127) | 1.0 | 1.0 | 1.0 | 0.63 |
| SREJ (7) | 1.0 | 1.0 | 0.33 | 0.035 |
| SREJ (127) | 1.0 | 1.0 | 1.0 | 0.63 |

**7.10 (12 pts)**

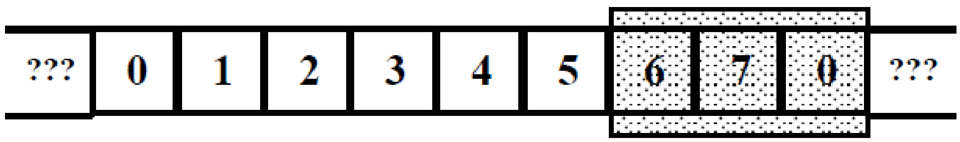
**a.**




**b.**




**c.**




**7.13 (8 pts)**

Let $t_1$ = time to transmit a single frame

$t_1 = 1024 \text{ bits}/10^6 \text{ bps} = 1.024$ msec

The transmitting station can send 7 frames without an acknowledgment. From the beginning of the transmission of the first frame, the time to receive the acknowledgment of that frame is:

$t_2 = 270 + t_1 + 270 = 541.024$ msec

During the time $t_2$, 7 frames are sent.

Data per frame = 1024 – 48 = 976

Throughput = $7 \times 976$ bits /($541.024 \times 10^{-3}$ sec) = 12.6 kbps

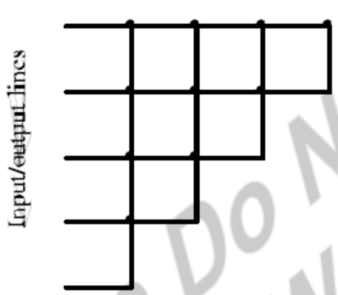
**10.1 (8 pts)** Each telephone makes 0.5 calls/hour at 6 minutes each. Thus a telephone occupies a circuit for 3 minutes per hour. Twenty telephones can share a circuit (although this 100% utilization implies long queuing delays). Since 10% of the calls are long distance, it takes 200 telephones to occupy a long distance (4 kHz) channel full time. The interoffice trunk has $10^6/(4 \times 10^3) = 250$ channels. With 200 telephones per channel, an end office can support $200 \times 250 = 50{,}000$ telephones.

**10.2 (10 pts.)**

**a.** $n \times m$

**b.** $n(n - 1)/2$

**c.**



**10.3 (15 pts.)**

**a.** Each first stage matrix has n input lines and $(2n - 1)$ output lines, so it has $n(2n - 1)$ crosspoints. There a $N/n$ first stage matrices, so there are a total of $(N/n)n(2n - 1) = N(2n - 1)$ crosspoints in the first stage. By the same argument, there are $N(2n - 1)$ crosspoints in the third stage. Each second stage matrix has $(N/n)$ inputs and $(N/n)$ outputs, for a total of $(N/n)^2$ crosspoints. So there are a total of $(2n - 1)(N/n)^2$ crosspoints in the second stage. Therefore, the total number of crosspoints is $C = (2n - 1)[2N + (N/n)^2]$.

**b.** For large $n$, we can approximate $(2n - 1)$ by $2n$. Thus we have

$C = 2n[2N + (N/n)^2] = 4nN + (2N^2)/n$

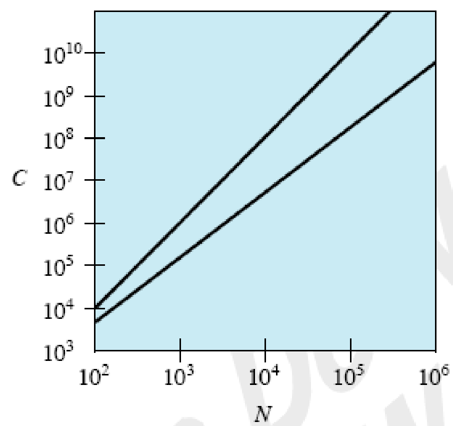
To find the minimum, set the derivative of $C$ with respect to $n$ equal to 0.

$$\frac{dC}{dn} = 0 = 4N - \frac{2N^2}{n^2}$$

$$n = \sqrt{N/2}$$

$$C_{\min} = 4N\sqrt{N/2} + \frac{2N^2}{\sqrt{N/2}} = 2N\sqrt{2N} + \frac{2N^2\sqrt{N/2}}{N/2} = 4N\sqrt{2N}$$

**c.**




**10.5 (15 pts.)**

**a. Circuit Switching**

$T = C_1 + C_2$ where

$C_1$ = Call Setup Time

$C_2$ = Message Delivery Time

$C_1 = S = 0.2$

$C_2$ = Propagation Delay + Transmission Time

$= N \times D + L/B$

$= 4 \times 0.001 + 3200/9600 = 0.337$

$T = 0.2 + 0.337 = 0.537$ sec

**Datagram Packet Switching**

$T = D_1 + D_2 + D_3 + D_4$ where

$D_1$ = Time to Transmit and Deliver all packets through first hop

$D_2$ = Time to Deliver last packet across second hop

$D_3$ = Time to Deliver last packet across third hop

$D_4$ = Time to Deliver last packet across forth hop

There are P – H = 1024 – 16 = 1008 data bits per packet. A message of 3200 bits requires four packets (3200 bits/1008 bits/packet = 3.17 packets which we round up to 4 packets).

$D_1 = 4 \times t + p$ where

t = transmission time for one packet

p = propagation delay for one hop

$D_1 = 4 \times (P/B) + D$

$= 4 \times (1024/9600) + 0.001$

$= 0.428$

$D_2 = D_3 = D_4 = t + p$

$= (P/B) + D$

$= (1024/9600) + 0.001 = 0.108$

$T = 0.428 + 0.108 + 0.108 + 0.108$

$= 0.752$ sec

**Virtual Circuit Packet Switching**

$T = V_1 + V_2$ where

$V_1$ = Call Setup Time

$V_2$ = Datagram Packet Switching Time

$T = S + 0.752 = 0.2 + 0.752 = 0.952$ sec

**b. Circuit Switching vs. Diagram Packet Switching**

$T_c$ = End-to-End Delay, Circuit Switching

$T_c = S + N \times D + L/B$

$T_d$ = End-to-End Delay, Datagram Packet Switching

$N_p$ = Number of packets = $\left\lceil \frac{L}{P-H} \right\rceil$

$T_d = D_1 + (N - 1)D_2$

$D_1$ = Time to Transmit and Deliver all packets through first hop

$D_2$ = Time to Deliver last packet through a hop

$D_1 = N_p(P/B) + D$

$D_2 = P/B + D$

$T = (N_p + N - 1)(P/B) + N \text{ x } D$

$T = T_d$

$S + L/B = (N_p + N - 1)(P/B)$

**Circuit Switching vs. Virtual Circuit Packet Switching**

$T_V$ = End-to-End Delay, Virtual Circuit Packet Switching

$T_V = S + T_d$

$T_C = T_V$

$L/B = (N_p + N - 1)(P/B)$

**Datagram vs. Virtual Circuit Packet Switching**

$T_d = T_V - S$

**10.6 (10 pts.)**

From Problem 10.5, we have

$T_d = (N_p + N - 1)(P/B) + N \times D$

For maximum efficiency, we assume that $N_p = L/(P - H)$ is an integer. Also, it is assumed that $D = 0$. Thus

$T_d = (L/(P - H) + N - 1)(P/B)$

To minimize as a function of P, take the derivative:

$0 = dT_d/(dP)$

$0 = (1/B)(L/(P – H) + N – 1) - (P/B)L/(P – H)^2$

$0 = L(P – H) + (N – 1) (P – H)^2 - LP$

$0 = –LH + (N – 1)(P – H)^2$

$(P - H)^2 = LH/(N – 1)$

$P = H + \sqrt{\frac{LH}{N-1}}$