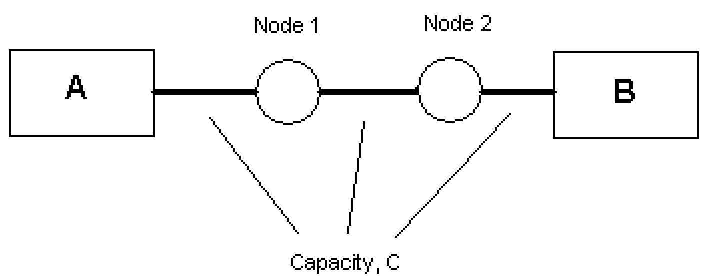
Problem Set 1
Solution

Problem 1.

Assume:

- Propagation delay is τ for each link respectively.
- No errors occur during transmission
- All nodes have the same capacity, C bits/second.
- The size of the file is M (in bits).



a) If message switching, then node 1 will only send the whole file to the next node after it has completely received it. Hence the total time needed to send the file from A to B is:

$$t_{Total} = 3 \cdot \left(\frac{M}{C} + \tau\right) \text{ seconds}$$

If we assume that τ is negligible, then t_{Total} = 30 s.

b) If the message is divided into L=1500 bits per packet, we will have M/L=12500 packets.

When the first packet leaves A, B needs to wait for $t_{First} = 3 \cdot \left(\frac{L}{C} + \tau\right)$ seconds to get it.

After the first packet was received, B will get one packet every $\frac{L}{C}$ second (parallelism effect) and there are still M/L-1 = 12499 packets to send, therefore the total time taken to receive the whole file completely is: t_{Total}

$$= 3 \cdot \left(\frac{L}{C} + \tau\right) + \left(\frac{M}{L} - 1\right) \cdot \frac{L}{C} = \left(\frac{M}{L} + 2\right) \cdot \frac{L}{C} + 3\tau \text{ seconds.}$$

Numerically, if we assume that τ is negligible, then t_{Total} = 10.008 s.

Hence we can conclude that packet switching is more efficient than message switching. Another issue not covered here is that the larger a packet is, the higher the probability it will have error(s). Moreover, it is worth noting that this study does not take into account the overhead issue. In fact each packet will need some extra overhead. See next question.

Problem 3:

1. b $\quad t_{tansmission} = \dfrac{30 \cdot 10^6\, bits}{10 \cdot 10^6\, bps} = 3\sec$
2. b $\quad t_{end\text{-}to\text{-}end} = t_{transmission} + \tau = 3 + \dfrac{10000 \cdot 10^3}{2 \cdot 10^8} = 3.05\sec$
3. d $\quad$ Total Bits Transmitted in 0.05 sec = 10Mbps * 0.05 = 500,000 bits
4. a $\quad$ Time taken from source to the router= $3 + \dfrac{5000 \cdot 10^3}{2 \cdot 10^8} = 3.025\sec$

   Time taken from router to destination is the same, hence total time =6.05sec
5. b $\quad$ When source starts to send the first packet, the destination needs to wait for: $2 \cdot (\dfrac{10 \cdot 10^6}{10 \cdot 10^6} + \dfrac{5000000}{200000000}) = 2 \cdot (1.025) = 2.05\sec$ to get it, after that it will need to wait additional 2*(1.0)=2 sec to get the remaining 2 packets. The total time is : 2.05+2 = 4.05sec
6. a $\quad$ 10Mbps/10 channels = 1 Mbps/channel.

Problem 4:

a. $d_{prop} = \dfrac{m}{s}\sec$

b. $d_{trans} = \dfrac{L}{R}\sec$

c. End-to-end delay = $d_{prop} + d_{trans}$

d. At t= d_{trans} , the last bit just leaves the source.

e. At t= d_{trans} , if d_{prop} is greater than d_{trans} , the first bit is still on the link.

f. At t= d_{trans} , since d_{prop} is less than d_{trans} , the first bit has already been received by the destination.

g. Given:

L =1000 bits

s = 2.5 10^8 meters

R=284 kbps

m=?

To get $d_{trans} = d_{prop}$, we set:

$$\frac{L}{R} = \frac{m}{s} \Rightarrow m = s \cdot \frac{L}{R} = 2.5 \cdot 10^8 \cdot (\frac{1000}{284 \cdot 10^3}) \approx 880.28Km$$

R19

a) 500 kbps
b) 64 seconds
c) 100kbps; 320 seconds

P6

Consider the first bit in a packet. Before this bit can be transmitted, all of the bits in the packet must be generated. This requires

$$\frac{48 \cdot 8}{64 \times 10^3} \text{ sec=6msec.}$$

The time required to transmit the packet is

$$\frac{48 \cdot 8}{1 \times 10^6} \text{ sec=} 384\mu \text{ sec.}$$

Propagation delay = 2 msec.
The delay until decoding is

$$6\text{msec} + 384\mu \text{ sec} + 2\text{msec} = 8.384\text{msec}$$

A similar analysis shows that all bits experience a delay of 8.384 msec.

P8

a) 10,000

b) $\sum_{n=N+1}^{M} \binom{M}{n} p^n (1-p)^{M-n}$

P9

The first end system requires L/R_1 to transmit the packet onto the first link; the packet propagates over the first link in d_1/s_1; the packet switch adds a processing delay of d_{proc}; after receiving the entire packet, the packet switch requires L/R_2 to transmit the packet onto the second link; the packet propagates over the second link in d_2/s_2. Adding these five delays gives

$$d_{end\text{-}end} = L/R_1 + L/R_2 + d_1/s_1 + d_2/s_2 + d_{proc}$$

To answer the second question, we simply plug the values into the equation to get 8 + 8 + 16 + 4 + 1 = 37 msec.

P18

a) 40,000 bits
b) 40,000 bits
c) The bandwidth-delay product of a link is the maximum number of bits that can be in the link
d) 1 bit is 250 meters long, which is longer than a football field
e) *s/R*

P19

25 bps

P21

a) $t_{trans} + t_{prop}$ = 400 msec + 40 msec = 440 msec
b) 10 * ($t_{trans} + 2\, t_{prop}$) = 10*(40 msec + 80 msec) = 1.2 sec

P24

a) Time to send message from source host to first packet switch = $\frac{7.5\times 10^6}{1.5\times 10^6}\sec = 5\sec$. With store-and-forward switching, the total time to move message from source host to destination host = $5\sec\times 3\ hops = 15\sec$
b) Time to send 1st packet from source host to first packet switch = . $\frac{1.5\times 10^3}{1.5\times 10^6}\sec = 1\ m\sec$. Time at which 2nd packet is received at the first switch = time at which 1st packet is received at the second switch = $2\times 1\ m\sec = 2\ m\sec$
c) Time at which 1st packet is received at the destination host = . $1\ m\sec\times 3\ hops = 3\ m\sec$. After this, every 1msec one packet will be received; thus time at which last (5000th) packet is received =

$3\ m\sec + 4999 * 1 m\sec = 5.002\sec$. It can be seen that delay in using message segmentation is significantly less (almost 1/3rd).

d) Drawbacks:

   i. Packets have to be put in sequence at the destination.
   ii. Message segmentation results in many smaller packets. Since header size is usually the same for all packets regardless of their size, with message segmentation the total amount of header bytes is more.