Introduction to Computer Networks 04/14/2005 (Solutions)

1. CLOSE BOOK
2. Time& Date: 2:20 –5:20pm, April 14 2005
3. Place: BL106
4. Be sure to put your name and student ID on your answer sheets.
5. Good luck ☺

1. (25%) Define the following parameters for a switched network:

   N = number of hops between two given end systems

   L = message length in bits

   B = data rate, in bits per second (bps), on all links

   P = fixed packet size, in bits

   H = overhead (header) bits per packet

   S = call setup time (circuit switching or virtual circuit) in seconds

   D = propagation delay per hop in seconds

   a. (10%) For $N = 3$, $L = 3200$, $B = 9600$, $P = 1024$, $H = 16$, $S = 0.2$, $D = 0.001$, compute the end-to-end delay for circuit switching, virtual circuit packet switching, and datagram packet switching. Assume that there are no acknowledgements. Ignore processing delay at the nodes.

   b. (15%) Derive general expressions for the three techniques of part (a), taken two at a time (three expression in all), showing the conditions under which the delays are equal.

a. **Circuit Switching**

T = end-to-end delay = $C_1 + C_2$, where

C_1 = Call Setup Time

C_2 = Message Delivery Time

$C_1 = S = 0.2$

C_2 = Propagation Delay + Transmission Time

$= N \times D + L/B$

$= 3 \times 0.001 + 3200/9600 \approx 0.336$

$T = 0.2 + 0.336 = 0.536$ sec (3%)

Datagram Packet Switching

$T = D_1 + D_2 + D_3$ 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

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

$$D_1 = 4 \times (P/B) + D$$
$$= 4 \times (1024/9600) + 0.001$$
$$\approx 0.428$$

$$D_2 = D_3 = t + p$$
$$= (P/B) + D$$
$$= (1024/9600) + 0.001 \approx 0.108$$

$$T = 0.428 + 0.108 + 0.108$$
$$= 0.644 \text{ sec } (4\%)$$

$3D + [4 + (N-1)] \times t$

$ND + (N_p + N - 1) \times t$

Virtual Circuit Packet Switching

$T = V_1 + V_2$ where

$V_1 =$ Call Setup Time

$V_2 =$ Datagram Packet Switching Time

$$T = S + 0.644 = 0.2 + 0.644 = 0.844 \text{ sec } (3\%)$$

b.

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

$T_c = S + N \times D + L/B$ (4%)

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

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

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

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

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

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

$D_2 = P/B + D$

$D_1 + D_2 = N_p(P/B) + D + (N-1)(P/B + D)$ $\quad D \times N + (P/B)(N + N_p - 1)$

(N-1)

T_d = $(N_p + N - 1)(P/B) + N \times D$ (4%)

T_v = End-to-End Delay, Virtual Circuit Packet Switching

T_v = $S + T_d = S + (N_p + N - 1)(P/B) + N \times D$ (4%)

Circuit Switching vs. Diagram Packet Switching

Let $T_c = T_d$

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

Circuit Switching vs. Virtual Circuit Packet Switching

Let $T_c = T_v$

$L = (N_p + N - 1)P$ (1%)

Datagram vs. Virtual Circuit Packet Switching

Let $T_d = T_v$

$S = 0$ (1%)

Problem Set: 2-4

Suppose A is connected to B via an intermediate router R, as shown below. Assume A sends to B using the sliding window protocol with window size=4.

2. (10%) The A-R and R-B links each accept and transmit only one packet per second in each direction, and the two directions transmit independently. For Time=0, 1, 2, 3, 4, 5, please state what packets arrive at and leave each node, or label them on a timeline.

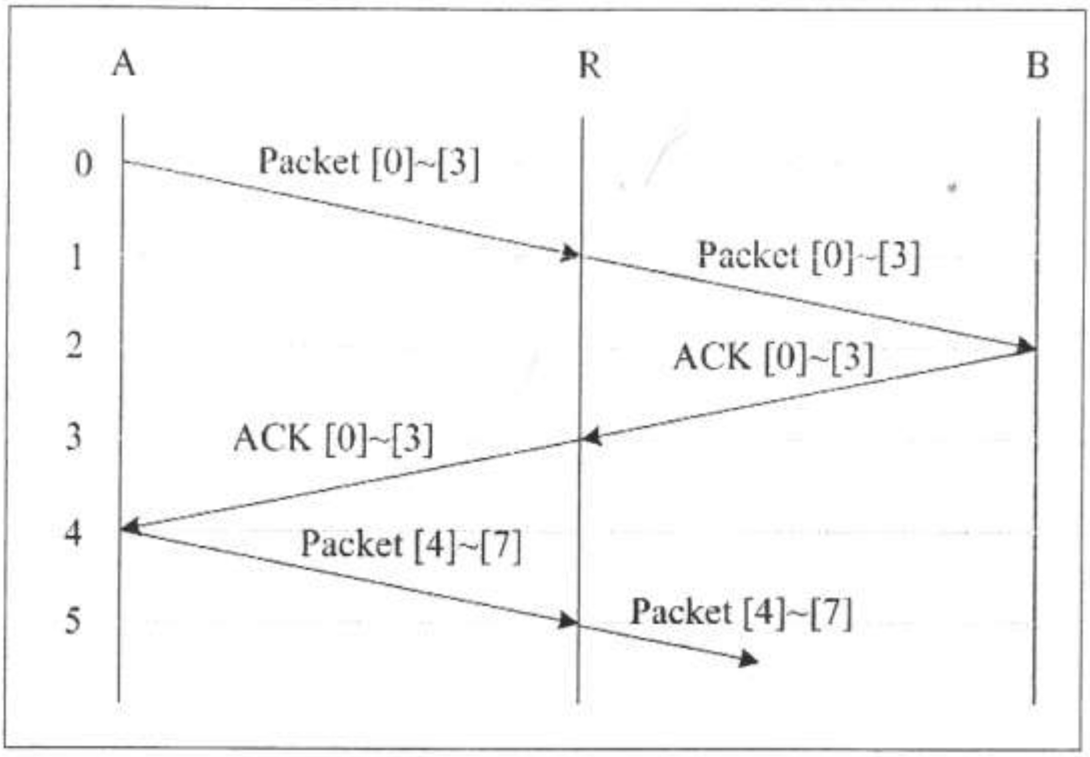
(10%)

Propagation delay of A-R = 1 s

Transmission time of A-R = 0

Propagation delay of R-B =1 s

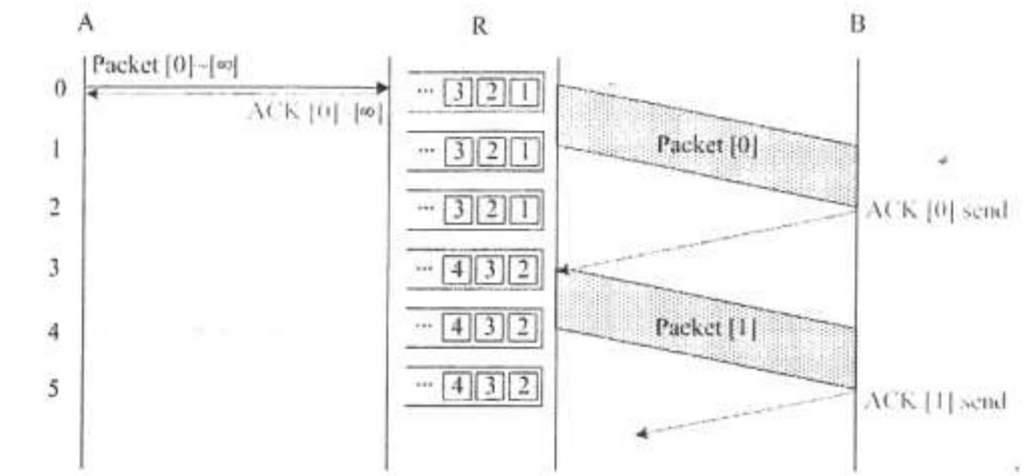
Transmission time of R-B = 0



3. (10%) Now let the A-R link be instantaneous (i.e., accept and transmit immediately as many packets as are offered), but the R-B link transmit only one packet each second, one at a time. For Time=0,1,2,3,4 please state what packets arrive at and are sent from A and B. How large does the queue at R grow in the steady state?

(10%)
Propagation delay of A-R = 0
Transmission time of A-R =0
Propagation delay of R-B =1 s
Transmission time of R-B =1 s (Assume the transmission time of an ACK packet is zero)

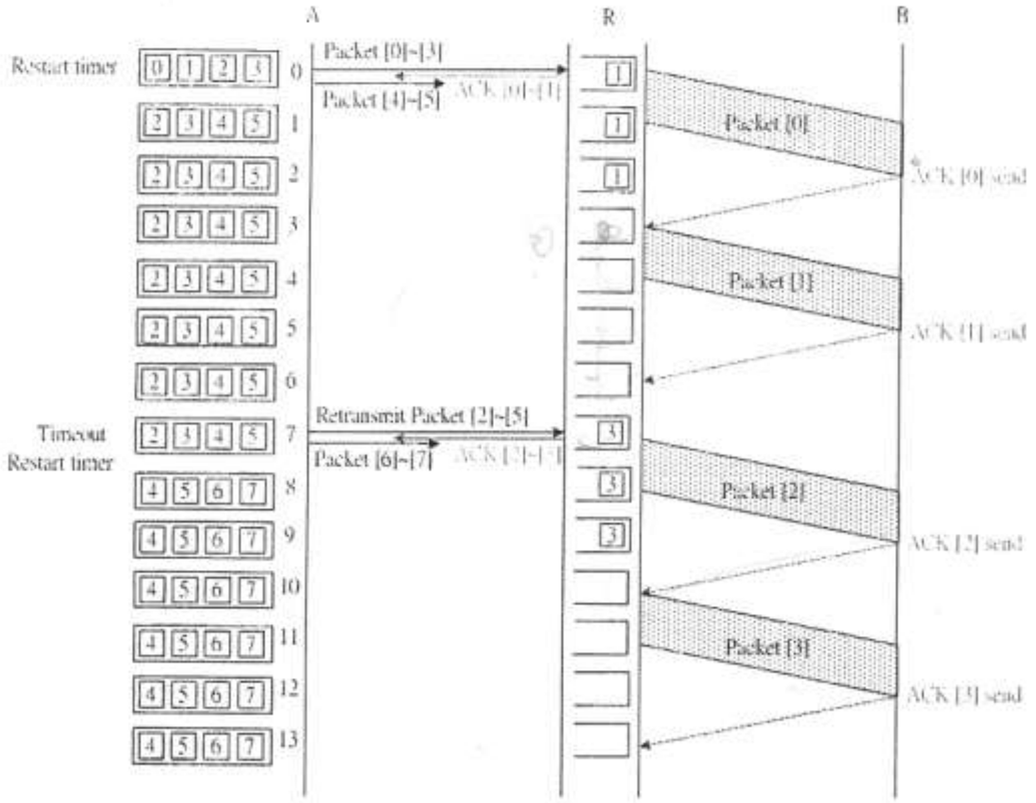
(A-R: Go Back to N; R-B: Stop and Wait)



In the steady state, the queue size at R is ∞ (or overflow).

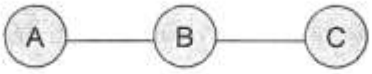
4. (10%) Consider the same situation as in (3), except that this time assume that the router has a queue size of 1; that is, it can hold one packet in addition to the one it is sending (in each direction). Let A's timeout be 7 seconds. Show what happens at each second from T=0 until all four packets from the first window are successfully delivered.

(10%)
Propagation delay of A-R = 0
Transmission time of A-R = 0
Propagation delay of R-B =1 s
Transmission time of R-B =1 s (Assume the transmission time of an ACK packet is zero)
A's timeout is 7 seconds.



At T=7, all four packets from the first window (i.e., packet [0]~[3]) are successfully ACK'd (At T=12, the first four packets are completely received by B).

5. (30%) The figure below shows that frames are generated at node A and sent to node C through node B.



a. (15%) Determine the minimum transmission rate required between nodes B and C so that the buffers of node B are not overflow, based on the following:
   i. The data rate between A and B is 100Kbps
   ii. The propagation delay is 5 us/km
   iii. There are full duplex lines between the nodes
   iv. All data frames are 1000 bits long
   v. ACK frames are separate frames of negligible length
   vi. Between A and B, a sliding window with a window size of 3 is used. Between B and C, stop and wait is used
   vii. There are no errors
   viii. The link distance: A – B: 4000km and B – C: 1000km

b. (15%) Now consider that nodes A and C are two nodes attached to the opposite ends of a 1000m cable, i.e., (A – B: 500m and B – C: 500 m). Suppose nodes A and C attempt to send a frame of 1000 bits (including the header) to each other. Node B is a repeater which inserts a 25-bit delay. Assume that the transmission rate is 10Mbps and a CSMA/CD with backoff intervals of multiple 512 bits is used. The backoff sequences of A and C for the first three collisions are {0,2,5} and {1,2,7}, respectively. Ignore the jam signal and the 96-bit time delay. The signal propagation speed is 2x10^8. At what time, in second, is A's packet arrives at C?

(a)

$A \rightarrow B$: Propagation time = $4000 \times 5\ \mu\text{sec} = 20$ msec

Transmission time per frame $= \dfrac{1000}{100 \times 10^3} = 10$ msec

$B \rightarrow C$: Propagation time = $1000 \times 5\ \mu\text{sec} = 5$ msec

Transmission time per frame = x = 1000/R

R = data rate between B and C (unknown)

A can transmit three frames to B and then must wait for the acknowledgment of the first frame before transmitting additional frames. The first frame takes 10 msec to transmit; the last bit of the first frame arrives at B 20 msec after it was transmitted, and therefore 30 msec after the frame transmission began. It will take an additional 20 msec for B's acknowledgment to return to A. Thus, A can transmit 3 frames in 50 msec.

B can transmit one frame to C at a time. It takes 5 + x msec for the frame to be received at C and an additional 5 msec for C's acknowledgment to return to A. Thus, B can transmit one frame every 10 + x msec, or 3 frames every 30 + 3x msec. Thus

30 + 3x = 50

x = 6.66 msec

R = 1000/x = 150 kbps

(b)

The one-way propagation delay (including the repeater delay) between A and C is

$$\frac{1000m}{2 \cdot 10^8\, m/\sec} + \frac{25 bits}{10 \times 10^6\, bps}$$

$$= (5\times10^{-6} + 2.5\times10^{-6})\,\text{sec}$$
$$= 7.5\mu\,\text{sec}$$

- At time $t=0$, both A and C transmit.
- At time $t=7.5\mu\,\text{sec}$, A detects a collision.
- At time $t=15\mu\,\text{sec}$ last bit of C's aborted transmission arrives at A.
- At time $t=22.5\mu\,\text{sec}$ first bit of A's retransmission arrives at B.
- At time $t=22.5\mu\,\text{sec}+\dfrac{1000bits}{10\times10^6\,bps}$ =122.5 μ sec. A 's packet is completely delivered at B.

6. (5%) Please generate the CRC code for the data of 11111000 using the four-bit generator 1011.

001

7. (10%) Ethernet frames must be at least 64 bytes long to ensure that the transmitter is still going in the event of a collision at the far end of the cable. Fast Ethernet has the same 64-byte minimum frame size but can get the bits out ten times faster. How is it possible to maintain the same minimum frame size?

For the 100 Mbps Ethernet standard, the maximum distance between two hosts is 200 m. For transmitting station A to detect whether any other station transmitted during A's interval, the minimal transmission time must be greater than $2t_{prop}$ = (400m $/1.8\times10^8$ m/sec) sec $=2.22\mu$ sec. Because the minimal frame size is 64 bytes, the minimal transmission time = $64\times8\,bits/(100\times10^6\,bps)=5.12\mu\,\text{sec} > 2t_{prop} = 2.22\mu\,\text{sec}$. Thus it is possible to maintain the same minimum frame size as 64 bytes in Fast Ethernet.