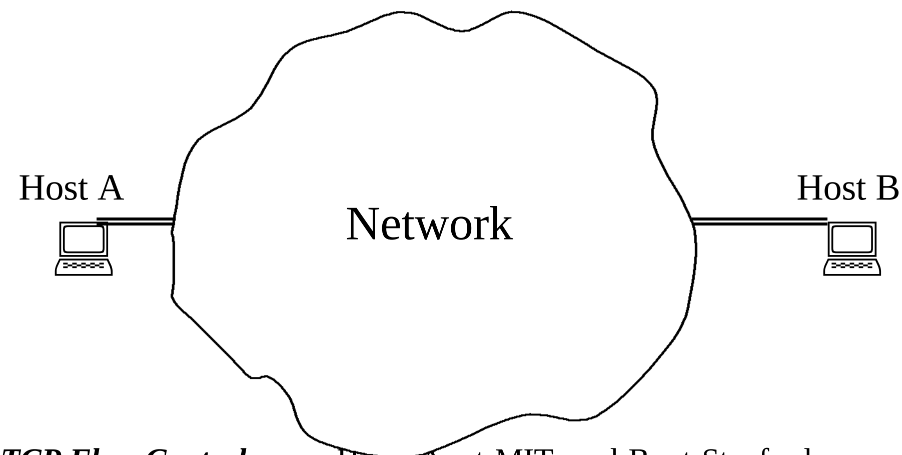
2.993: Principles of Internet Computing
Quiz 1

2–3:30 pm, March 18 Spring 1999



1. ***TCP Flow Control*** Hosts A, at MIT, and B, at Stanford are communicating to each other via links connected to the network. Both hosts communicate using TCP for flow control. Assume host A is the sender of packets and host B is the receiver. The slow-start threshold *ssthresh* for host A is 4, and the measured round-trip time *RTT* is 2. There is a bottleneck within the network with an effective throughput of 4 packets per second. The buffer size of the bottleneck is 1.

   We assume that there is no packet loss, and the packets in flight are evenly distributed in the network. Equivalently, no packet will be dropped if the number of packets in flight is not greater than the (delay × bandwidth + buffer size). The first packet to violate this condition is dropped. Also DO NOT assume that a packet transmission time is zero.

   Trace the events that take place in the TCP flow-control window at host A, and then answer the following questions. DO NOT round off the times of arrival or departure events to the closest integer, but rather use fractions. Show all work.

   [It may be helpful to trace the arrival and departure events using the following table, although you can use any method, as long as you show your work.]

time	*packet_sent*	*ack_arrived*	*snd_cwnd*
xx	xx	xx	xx
xx	xx	xx	xx
xx	xx	xx	xx

   (a) Determine the sequence number of the first packet that gets dropped.

(b) At what exact time does this occur?

(c) What is the congestion window size, *snd_cwnd*, immediately after the packet drop?

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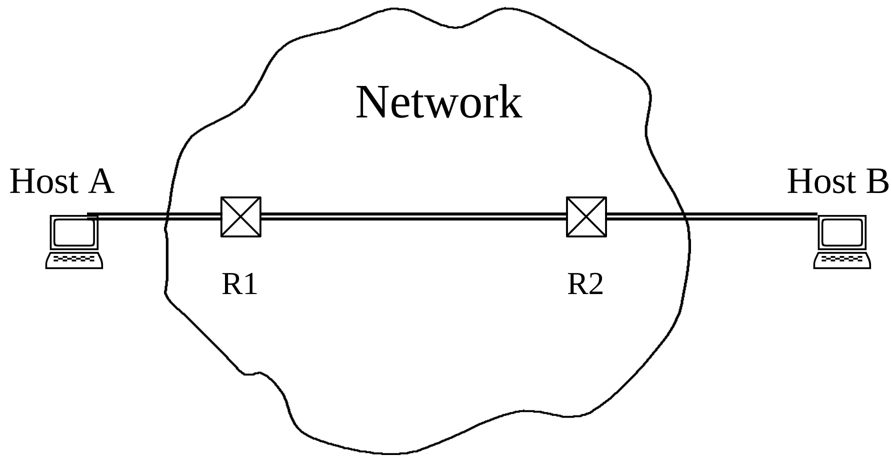
time	*packet_sent*	*ack_arrived*	*snd_cwnd*
0	(1)		1
2	(2),3	1	2
2.5	(3)		
4	(4),5	2	3
4.5	(5),6,7	3	4
5.5	(6),7		
5.6	(7)		
6	(8)	4	4 1/4
6.5	(9)	5	4 1/2
7	(10)	6	4 3/4
7.5	(11),12	7	5
8	(12),13	8	5 1/5
8.5	(13),14	9	5 2/5
9	(14),15	10	5 3/5
9.5	(15),16	11	5 4/5
10	(16), 17, 18	12	6

(a) packet 18 is dropped
(b) at the end of 5^{th} RTT or start of 6^{th} RTT
(c) window size is 6

Grading: 8 pts. for each RTT.



2. ***Stop-and-Wait*** Assume that hosts A and B are connected to each other via routers R1 and R2. All the links are full-duplex; i.e., the capacity is the same in both directions.

The bandwidth and propagation delay in each link are as follows:

host A ↔ R1	10 Mbps	5 ms
host B ↔ R2	10 Mbps	5 ms
R1 ↔ R2	2 Mbps	30 ms

Each router uses a store-and-forward mechanism; i.e., a packet is not forwarded until the whole packet is received. Host A, the sender, uses *Stop-and-Wait* transmission scheme. Assume no packet loss and infinite buffer size.

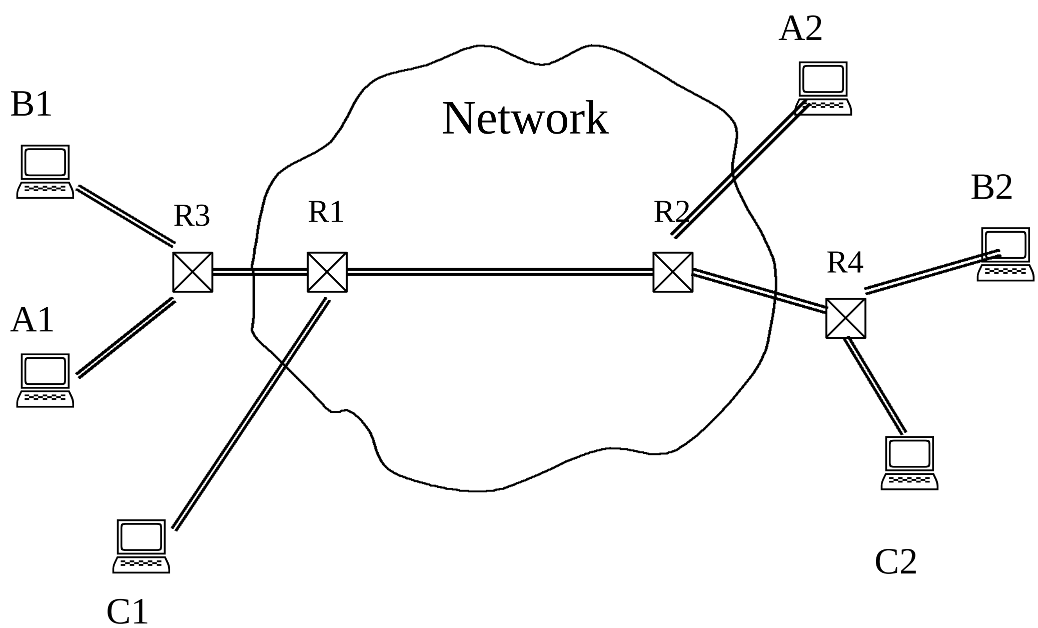
(a) If host A sends a packet of size 10,000 bits to host B at time 0, when will B receive the whole packet, assuming no transmission error?

(b) Assuming host B replies by sending a 1,000 bit acknowledgment immediately after it receives the whole packet, what is the round-trip time?

(The round-trip time, *RTT*, is defined as the time from the transmission of the first bit of a packet to the reception of the last bit of an acknowledgment.)

(c) Host A has been approached by a representative from a long-haul trunk link provider. He claims that by replacing the 2 Mbps link between R1 and R2 with a high-speed fiber link of 100 Mbps, the throughput can be increased significantly. As a network engineer, argue whether his claim is true or false. Give quantitative results.

(a) 47 ms
(b) 87.7 ms
(c) Not so. Because of Stop-and-Wait transmission, the rate increase is small, since the propagation delay (30ms) is much larger than transmission time.



3. ***Max-Min Fairness*** The link capacities between pairs of routers (in units of Mbps) are as follows:

R1 - R2	=	10
R1 - R3	=	6
R2 - R4	=	8

Each host is connected to a router using a 10 Mbps link.

(a) Allocate bandwidth to each flow such that the rate assignments meet the max-min fairness criterion. Indicate the bottleneck link(s) in each flow.

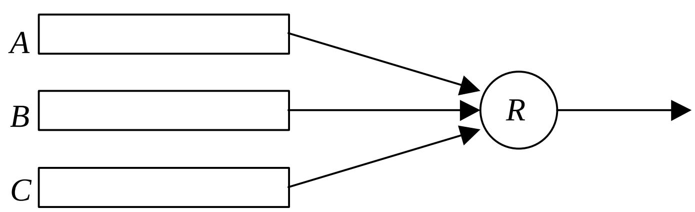
(b) If flows between hosts A1↔A2 and C1↔C2 have reserved 2 and 3 Mbps, respectively, what are the new rate assignments if the leftover capacity assignment is based on max-min fairness criterion. Indicate the bottleneck link(s) for each flow with respect to the leftover capacity.

(c) In part (b), suppose you are allowed to increase the capacity of the link between R1 and R2 only, what is the largest rate achievable for flow C1↔C2, while maintaining max-min fairness? What is the minimum link capacity required between R1 and R2 to achieve this rate?

(a)	B = 3	R1 - R3
	A = 3	R1 - R3
	C = 4	R1 - R2
(b)	2 + 5/3	R1 - R2
	5/3	R1 - R2
	3 + 5/3	R1 - R2
(c)	A = 2 + 2	R1 - R3
	B = 2	R1 - R3
	C = 3 + 3	R2 - R4
	Link capacity = 7 + 5	

Grading: 10 pts each

4. ***Fair Queuing*** There are three sessions, *A*, *B*, and *C* which share the same router *R*. Router *R* will use a fair queuing policy similar to the one described in the textbook in order to decide which packet it should transmit next. Assume all packets have the same fixed size 1.



During a given time slot *j*, a packet may arrive at the router from any of the three sessions. During the same time slot *j*, one of the packets in *R* (those arrived in time slot *j* or earlier) will be transmitted by the router using the following queuing policy.

The time-stamp formula is: $F_i = max(F_{i-1}, A_i) + P_i$
where

F_i = time-stamp of packet *i*
F_{i-1} = time-stamp of packet belonging to the same session as *i* that has arrived before *i*
A_i = arrival time slot of *i*
P_i = time needed to transmit *i* if the router's output rate were evenly divided among all sessions (in this case, $P_i = 3$).

The router will always transmit the packet with the smallest time-stamp. If two packets have the same time-stamp, priority is given to session *A* over session *B* over session *C*. The left side of the table below illustrates a sequence of arrivals into router *R*. An 'X' indicates that a packet belonging to a particular session has arrived during the corresponding time-slot.

	Input			Output			
Time-slot	*A*	*B*	*C*	*A*	*B*	*C*	F_i
1		X	X		X		4
2		X	X			X	4
3		X	X		X		7
4			X			X	7
5			X		X		10
6	X		X	X			9
7	X		X			X	10
8	X			X			12
9	X					X	13
10	X			X			15
11	X					X	16
12				X			18
13						X	19

For this problem, you are asked to compute which packets are being transmitted by *R* at every time-slot. Complete the table on the right by inserting 'X' at the box corresponding to the session being serviced in each time-slot. In the last column, indicate the time-stamp of the packet that is being transmitted.

Grading: some part correct = 5
More than some = 10
All correct = 30