P3. Consider an HTTP client that wants to retrieve a Web document at a given URL. The IP address of the HTTP server is initially unknown. What transport and application-layer protocols besides HTTP are needed in this scenario?

P7. Suppose within your Web browser you click on a link to obtain a Web page. The IP address for the associated URL is not cached in your local host, so a DNS lookup is necessary to obtain the IP address. Suppose that n DNS servers are visited before your host receives the IP address from DNS; the successive visits incur an RTT of $RTT_1, \ldots, RTT_n$. Further suppose that the Web page associated with the link contains exactly one object, consisting of a small amount of HTML text. Let RTT_0 denote the RTT between the local host and the server containing the object. Assuming zero transmission time of the object, how much time elapses from when the client clicks on the link until the client receives the object?

P10. Consider a short, 10-meter link, over which a sender can transmit at a rate of 150 bits/sec in both directions. Suppose that packets containing data are 100,000 bits long, and packets containing only control (e.g., ACK or hand-shaking) are 200 bits long. Assume that N parallel connections each get $1/N$ of the link bandwidth. Now consider the HTTP protocol, and suppose that each downloaded object is 100 Kbits long, and that the initial downloaded object contains 10 referenced objects from the same sender. Would parallel downloads via parallel instances of non-persistent HTTP make sense in this case? Now consider persistent HTTP. Do you expect significant gains over the non-persistent case? Justify and explain your answer.

P19. Consider an overlay network with N active peers, with each pair of peers having an active TCP connection. Additionally, suppose that the TCP connections pass through a total of M routers. How many nodes and edges are there in the corresponding overlay network?

P6. Consider our motivation for correcting protocol `rdt2.1`. Show that the receiver, shown in the figure on the following page, when operating with the sender shown in Figure 3.11, can lead the sender and receiver to enter into a deadlock state, where each is waiting for an event that will never occur.

P11. The sender side of `rdt3.0` simply ignores (that is, takes no action on) all received packets that are either in error or have the wrong value in the `ack-num` field of an acknowledgment packet. Suppose that in such circumstances, `rdt3.0` were simply to retransmit the current data packet. Would the proto-col still work? (*Hint:* Consider what would happen if there were only bit errors; there are no packet losses but premature timeouts can occur. Consider how many times the *n*th packet is sent, in the limit as *n* approaches infinity.)

P12. Consider the `rdt 3.0` protocol. Draw a diagram showing that if the network connection between the sender and receiver can reorder messages (that is, that two messages propagating in the medium between the sender and receiver can be reordered), then the alternating-bit protocol will not work cor-rectly (make sure you clearly identify the sense in which it will not work cor-rectly). Your diagram should have the sender on the left and the receiver on the right, with the time axis running down the page, showing data (D) and acknowledgment (A) message exchange. Make sure you indicate the sequence number associated with any data or acknowledgment segment.

P18. Consider the GBN protocol with a sender window size of 3 and a sequence number range of 1,024. Suppose that at time *t*, the next in-order packet that

P21. Answer true or false to the following questions and briefly justify your answer:

a. With the SR protocol, it is possible for the sender to receive an ACK for a packet that falls outside of its current window.

b. With GBN, it is possible for the sender to receive an ACK for a packet that falls outside of its current window.

c. The alternating-bit protocol is the same as the SR protocol with a sender and receiver window size of 1.

d. The alternating-bit protocol is the same as the GBN protocol with a sender and receiver window size of 1.

P23. Consider transferring an enormous file of L bytes from Host A to Host B. Assume an MSS of 1,460 bytes.

    a. What is the maximum value of L such that TCP sequence numbers are not exhausted? Recall that the TCP sequence number field has 4 bytes.

    b. For the L you obtain in (a), find how long it takes to transmit the file. Assume that a total of 66 bytes of transport, network, and data-link header are added to each segment before the resulting packet is sent out over a 10 Mbps link. Ignore flow control and congestion control so A can pump out the segments back to back and continuously.

P24. Host A and B are communicating over a TCP connection, and Host B has already received from A all bytes up through byte 248. Suppose Host A then sends two segments to Host B back-to-back. The first and second segments contain 40 and 60 bytes of data, respectively. In the first segment, the sequence number is 249, the source port number is 503, and the destination port number is 80. Host B sends an acknowledgement whenever it receives a segment from Host A.

    a. In the second segment sent from Host A to B, what are the sequence number, source port number, and destination port number?

    b. If the first segment arrives before the second segment, in the acknowledgement of the first arriving segment, what is the acknowledgment number, the source port number, and the destination port number?

    c. If the second segment arrives before the first segment, in the acknowledgement of the first arriving segment, what is the acknowledgment number?

    d. Suppose the two segments sent by A arrive in order at B. The first acknowledgement is lost and the second acknowledgement arrives after the first timeout interval, as shown in the diagram on the next page. Draw a timing diagram, showing these segments and all other segments and acknowledgements sent. (Assume there is no additional packet loss.) For each segment in your figure, provide the sequence number and the number of bytes of data; for each acknowledgement that you add, provide the acknowledgement number.

P33. Consider the following plot of TCP window size as a function of time.
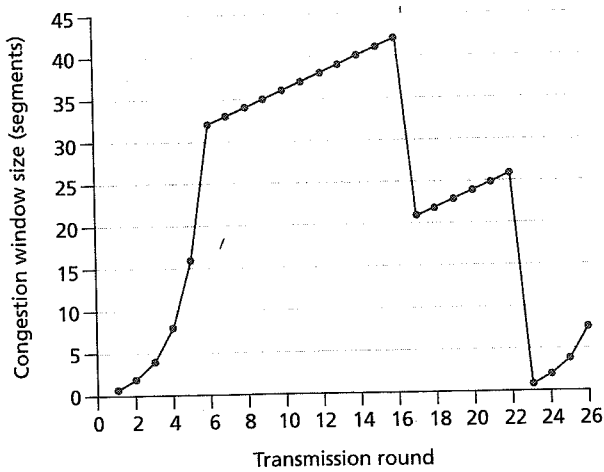
Assuming TCP Reno is the protocol experiencing the behavior shown above, answer the following questions. In all cases, you should provide a short discussion justifying your answer.

a. Identify the intervals of time when TCP slow start is operating.

b. Identify the intervals of time when TCP congestion avoidance is operating.

c. After the 16th transmission round, is segment loss detected by a triple duplicate ACK or by a timeout?

d. After the 22nd transmission round, is segment loss detected by a triple duplicate ACK or by a timeout?

e. What is the initial value of Threshold at the first transmission round?

f. What is the value of Threshold at the 18th transmission round?

g. What is the value of Threshold at the 24th transmission round?

h. During what transmission round is the 70th segment sent?

i. Assuming a packet loss is detected after the 26th round by the receipt of a triple duplicate ACK, what will be the values of the congestion window size and of Threshold?