This document contains 6 pages, 15 problems, maximum possible score: 170 points

14:332:423 Telecommunication Networks
Final Exam December 16, 2004

Problem 1 [6 points]

Hosts *A* and *B* send ASCII characters to each other using Block Parity Check to detect errors. The channel is almost perfect and there is at most one error in every 100 bits transmitted. Host *B* receives from *A* the binary data streams listed below. Determine whether or not these are error-free. If not, is it possible for the receiver to correct the error bit? Justify your answer.

(a) 10110010110110110011001101011011 [3 points]
(b) 11010011100010110011001011010101 [3 points]

Problem 2 [12 points]

Suppose you have an IEEE 802.11 independent BSS (IBSS) with two mobile STAs, *A* and *B*. Consider a scenario where each station has a single packet to send to the other one and show precise time diagram for each station from the start to the completion of the packet transmission. For each station, select different packet arrival time and a reasonable number of backoff slots to count down before the station commences its transmission so that no collisions occur during the entire session. Assume that both station are using the basic transmission mode and only the first data frame transmitted is received in error (due to channel noise, not collision).

Problem 3 [10 points]

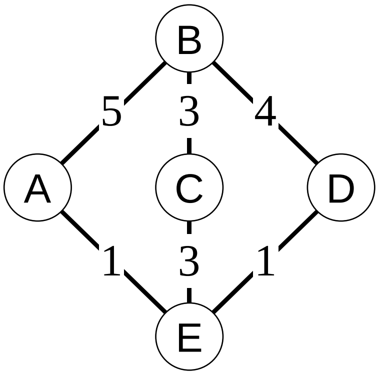
Let *G* be the total rate at which packets are transmitted in a slotted ALOHA system.

(a) What fraction of slots goes empty in this system? [3 points]
(b) What fraction of slots goes empty when the system is operation at its maximum throughput? [3 points]
(c) Can observations about channel activity be used to determine when stations should transmit? (Explain your answer.) [4 points]

Problem 4 [14 points]

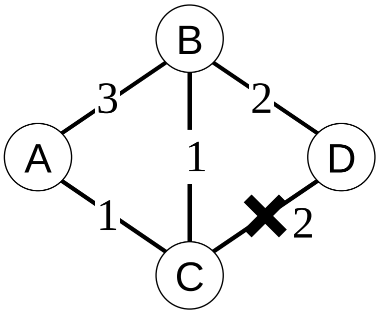
Consider the network shown in the figure. Show the successive steps, from the start until the network stabilizes and any host can act as source or destination, of the following routing algorithms:

(a) Distance vector routing (Bellman-Ford algorithm) [7 points]
(b) Link state routing (Dijkstra algorithm) [7 points]



Problem 5 [10 points]

Distance vector routing (Bellman-Ford algorithm) with poisoned reverse.
In the figure below, after the network stabilizes, when the link connecting nodes C and D is broken. Show how nodes A, B and C might experience the count-to-infinity phenomenon for their distances to node D. In demonstrating the count-to-infinity problem, show at least two updates containing distance-to-D, for each of the nodes A, B and C. For each of these updates, specify the distance-to-D advertised to the neighbors.



Problem 6 [11 points]

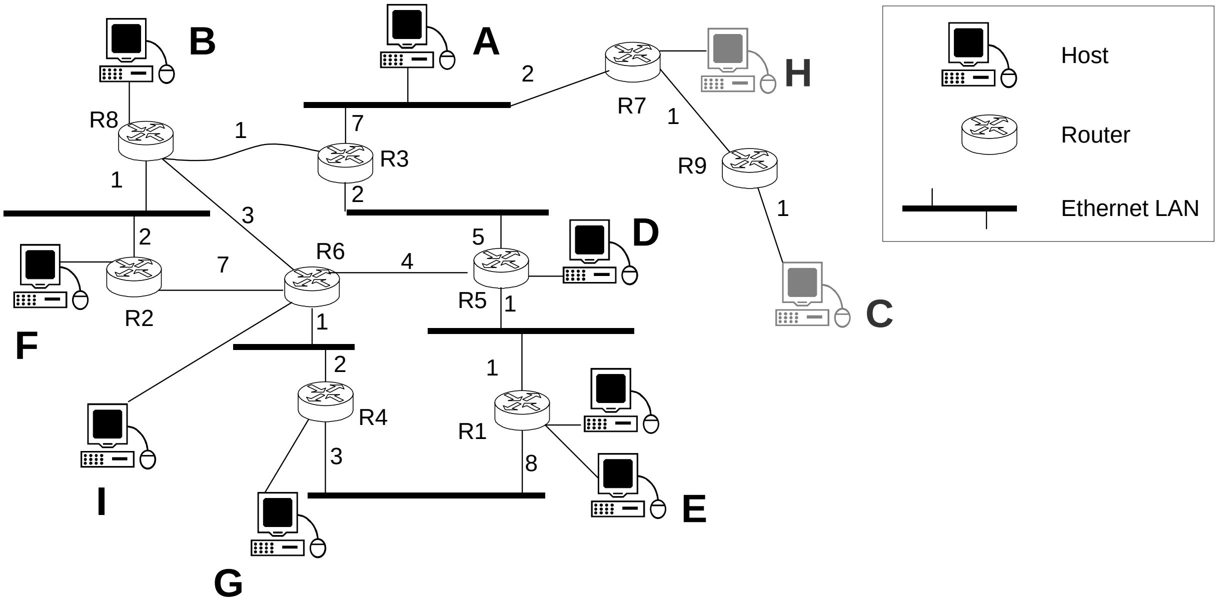
Consider the network shown in the figure below, in which source *D* sends packets to multicast group *G*, whose members are all the shown hosts, including *C*. The costs of every links are specified in the figure. Show step-by-step how to build these multicast trees:

(a) Group-shared multicast tree assuming that R6 is the center node. What is the total cost by using the multicast tree to send message to all users? [3 points]
(b) Show the source-based multicast tree for the source *I* [4 points]

After the source-based multicast tree the source *I* is already built, ***H*** leaves the group. For the multicast routing using a source-based tree, how many total packets get generated in the entire network per every packet sent by the source *I* if:

(c) RPF (reverse path forwarding) algorithm is used as in broadcast, without multicast features [2 points]
(d) RPF algorithm is used with multicast features, such as pruning [1 points]
(e) Repeat (d) if *C* also leaves. [1 points]

Show the work (tracing the packets) and the final result.

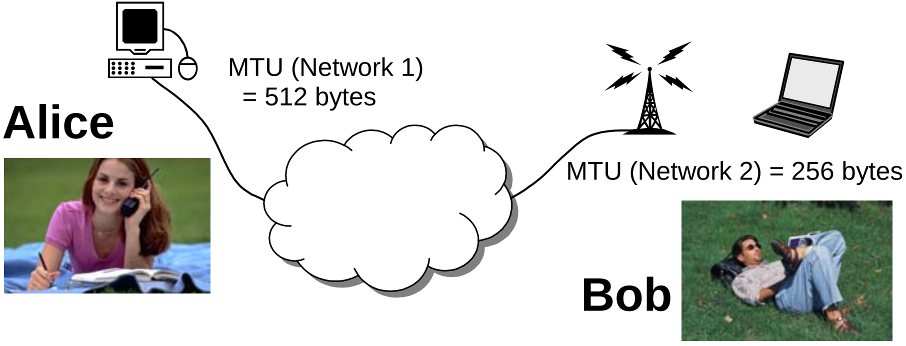


Problem 7 [15 points]

Alice is a musician and she wants to send her new song to Bob as a 2-MB MP3 file. The bottleneck link between their computers has a 10-Mbps transmission rate. Assume the overhead for link layer of both networks to be 26 bytes. TCP is used.

(a) How many packets does Alice's computer send? [3 points]
(b) How many fragments Bob's computer receive? [3 points]
(c) How long time it takes to complete the transmission? (Assume transmission-, queuing-, and processing delay all equal to zero, and RTT = 1.) [3 points]
(d) Show the first four and the last one IP fragments that Bob's computer receives and specify the values of all relevant parameters in the fragment headers (by last fragment is meant the very last one that Bob sees). Assume the first packet ID = 54321 [4 points]
(e) How many datagrams are generated if UDP is used? [2 points]

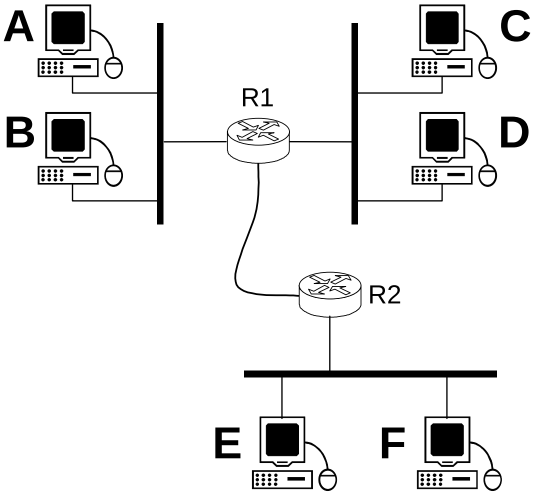
(Show your work.)



Problem 8 [10 points]

You are hired as a network administrator for the network of sub-networks shown in the figure. Assume that the network will use CIDR.

(a) Assign meaningfully the IP addresses to all hosts on the network. Allocate the minimum possible block of addresses for your network, assuming that no new hosts will be added to the current configuration.
(b) Show how should routing/forwarding tables look at the routers after the network stabilizes.



Problem 9 [6 points]

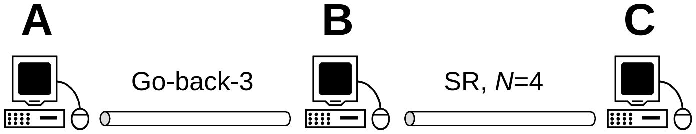
Optimal window size for Go-back-*N* protocol is defined as the window size *N* for which the source transmits packets exactly as fast as the network bottleneck can handle them without loss.

(a) Compute the optimal window size *N* when packet size is 53 bytes, the propagation time is 30 ms, and bottleneck bandwidth is 1.5 Mbps. [3 points]
(b) Suppose now that data flow is bi-directional (i.e., receiver is also a source, rather than only sending ACK's). Is the optimal window size for each host equal to ½ *N* from part (a)? Explain your answer. [3 points]

Problem 10 [10 points]

Suppose three hosts are connected as shown in the figure. Host *A* sends packets to host *C* and host *B* serves merely as a relay. However, as indicated in the figure, they use different ARQ's for reliable communication (Go-back-*N* vs. Selective Repeat). Notice that *B* is *not* a router; it is a regular host running both receiver (to receive packets from *A*) and sender (to forward *A*'s packets to *C*). *B*'s receiver immediately relays in-order packets to *B*'s sender.

Draw side-by-side the timing diagrams for A→B and B→C transmissions up to the time where the first seven packets from *A* show up on *C*. Assume that the 2nd and 5th packets arrive in error to host *B* on their first transmission, and the 5th packet arrives in error to host *C* on its first transmission.



Problem 11 [12 points]

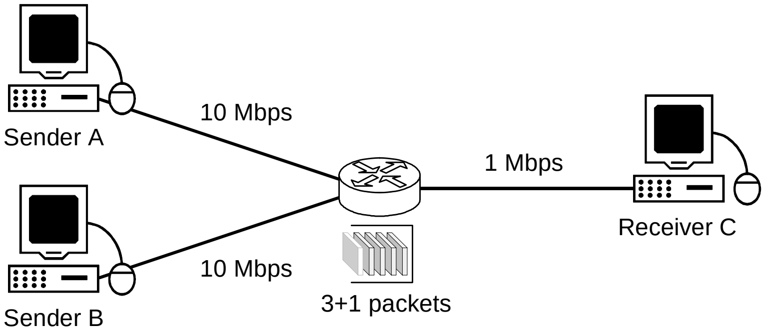
Consider two hosts directly connected and communicating using Stop-and-wait ARQ in the presence of channel errors. Assume that all packets are of the same size, the transmission time T_{xmit} per packet, one-way propagation time T_{prop}, and the probability of error is equal to p, same in both directions (i.e., for packets as well as for ACK). Also assume that the error probabilities are independent of each other. Find the expected time per packet transmission.

Assume that the duration of the timeout T_{out} is just large enough that the source gets ACK before the timer times out, when both a packet and its ACK are correctly transmitted.

Problem 12 [14 points]

Consider the network shown in the figure. TCP senders at hosts A and B have 3.6 KB of data each to send to TCP receiver at host C. Assume MTU = 512 bytes for all the links and `TimeoutInterval` = 2×RTT = 2×1 sec. The router buffer size is 3 packets in addition to the packet currently being transmitted; should the router need to drop a packet, it drops the last arrived from the host which currently sent more packets. Sender A runs TCP Tahoe and sender B runs TCP Reno and assume that sender B starts transmission 2×RTTs after sender A. Trace the evolution of the congestion window sizes on both senders until all packets are successfully transmitted.

Assume a large `RcvWindow` and error-free transmission on all the links. Finally, to simplify the graphs, assume that all ACK arrivals occur exactly at unit increments of RTT and that the associated `CongWindow` update occurs exactly at that time, too.



Problem 13 [14 points]

Consider a TCP Tahoe sender which always detects a packet loss (via duplicate ACK's) when its congestion window size reaches `CongWindow` = 16 MSS. Assume RTT = 1 sec, MSS = 1 KB, and the bottleneck link bandwidth equal to 128 Kbps.

(a) What is the min/max range in which the window size oscillates? [2 points]
(b) What will be the average rate at which this sender sends data? [8 points]
(c) What is the utilization of the bottleneck if it only carries this single sender?

[Note: When computing the average rate, draw the evolution of the congestion window. To simplify the calculation you can ignore the first part of the diagram, up to the point when the first loss is detected.] [4 points]

Problem 14 [14 points]

Consider two hosts communicating by TCP-Tahoe protocol. Assume RTT = 1, MSS = 512 bytes, `TimeoutInterval` = 3×RTT, `Threshold` = 3×MSS to start with, and `RcvBuffer` = 2 KB. Also assume that the bottleneck router has available buffer size of 1 packet in addition to the packet currently being transmitted.

(a) Starting with `CongWindow` = 1×MSS, determine the congestion window size when the first packet loss will happen.

(b) What will be the amount of unacknowledged data at the sender at the time the sender detects the loss?

Problem 15 [12 points]

Calculate the total time required to transfer a 1-MB file from server to client in the following cases, assuming an RTT of 100 ms, a packet size of 1 KB, and an initial 2 × RTT of "handshaking" before data is sent. Assume error-free transmission.

(a) The bottleneck bandwidth is 1.5 Mbps, and data packets can be sent continuously (i.e., without waiting for ACK's) [1 point]

(b) The bottleneck bandwidth is 1.5 Mbps, but Stop-and-wait ARQ is employed [2 points]

(c) The bandwidth is infinite, meaning that we take transmission time to be zero, and Go-back-20 is employed [3 points]

(d) The bandwidth is infinite, and TCP Tahoe is employed [6 points]