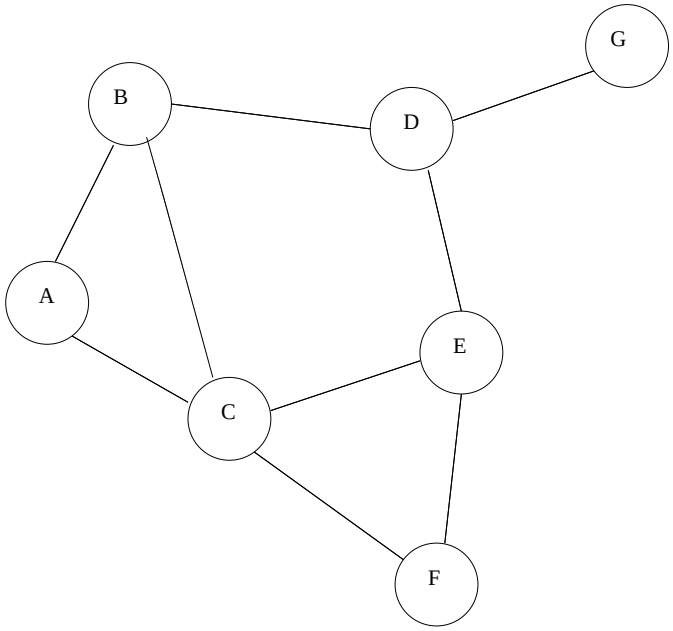
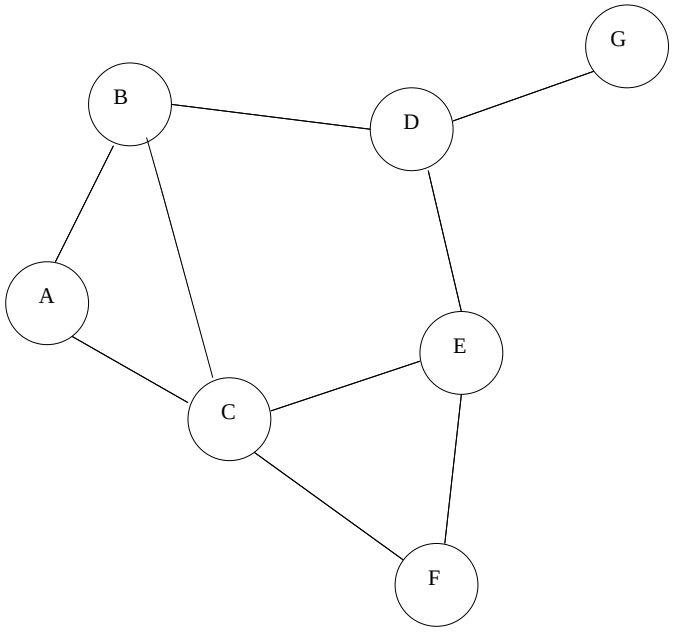
1. Consider the operation of reverse path forwarding. Using the same topology shown below, find a set of paths from all nodes to the source node A, such that if these paths were the least-cost paths, then node B would receive a copy of A's broadcast message from nodes A, C, and D under RPF.



2. Consider the topology below, and assume each link has unit cost. Suppose node C is chosen as the center in a center-based multicast routing algorithm.



   (a) Assuming that each attached router uses its least-cost path to node C to send join messages to C, draw the resulting center-based routing tree.

   (b) Is the resulting tree a minimum cost tree? Justify your answer.

3. Dijkstra's link state algorithm is for computing the unicast paths that are individually the least-cost paths from the source to all destinations. The union of these paths might be thought of as forming a **least-unicast-cost path tree** (or shortest unicast path tree, if all link costs are identical). Buy constructing a counterexample, show that the least-cost path tree is *not* always the same as a minimum spanning tree

4. Consider multicasting.

   (a) What is the size of the multicast address space?

   (b) Suppose now that two multicast groups randomly choose a multicast address. What is the probability that they choose the same address?

   (c) Suppose now that 1,000 multicast groups ongoing at the same time and choose their multicast group addresses at random. What is the probability that they interfere with each other?

5. In RIP, distances to subnets are advertised. What is advertised in BGP?

6. How does RIP, OSPF and BGP ensure reliability of the routing information they send over the network?

7. Why do Link State Advertisements have sequence numbers and Distance Vectors do not?

8. What is the method used to distribute Link State Advertisements?

9. Consider a 4 bit generator 1001. Find the value of R for the following values of D

   (a) 10010011

   (b) 10110010

   (c) 10101001

   (d) 11101101

10. Recall that when there are N active nodes, the efficiency of slotted ALOHA is $Np(1-p)^{N-1}$.

    (a) Find the value of p that maximizes the above expression.

    (b) Using the value of P you have found above, find the efficiency of slotted ALOHA.

    (c) Show that the maximum efficiency of *pure* ALOHA is $1/(2e)$

11. Suppose three active nodes – nodes A, B, and C – are competing for access to a channel using slotted ALOHA. Assume that each node has an infinite number of packets to send. Each node attempts to transmit in each slot with probability p. The first slot is numbered slot 1, the second slot is numbered slot 2, and so on.

    (a) What is the probability that the first success occurs in slot 2?

    (b) What is the probability that node B succeeds for the first time in slot 3?

    (c) What is the probability that some node (either A, B, or C) succeeds in slot 4?

    (d) What is the efficiency of this three-node system?

12. Recall that with the CSMA/CD protocol, the adapter waits $K \cdot 512$ bit times after a collision, where K is drawn randomly.

    (a) How long does the adapter wait until returning to step 2 in a 100Mbps Ethernet?

    (b) How long does the adapter wait until returning to step 2 in a 10Mbps Ethernet?

13. Suppose nodes A and B are on the same 10 Mbps Ethernet bus, and the propagation delay between the two nodes is 225 bit times. Suppose both A and B send frames at the same time, the frames collide, and then A and B choose different values of K in the CSMA/CD algorithm.

    (a) Assuming no other nodes are active, can the retransmissions of A and B collide?

    (b) Suppose A and B begin transmitting at $t = 0$. Both frames collide and the stations transmit a jam signal. The values $K_A = 0$ and $K_B = 1$ are chosen.

        i. At what time does A begin its retransmission?

ii. At what time does B schedule its retransmission?

iii. At what time does A's signal reach B?

iv. Does B refrain from transmitting at its scheduled time?

14. Consider a 100Mbps 100BASE-T Ethernet with all nodes directly connected to a hub.

    (a) To have an efficiency of 0.70, what should be the maximum distance between a node and the hub?

    (b) Assume a frame length of 64 bytes and no repeaters. Does this maximum distance also ensure that a transmitting node A will be able to detect whether any other node transmitted while A was transmitting?

    (c) How is the maximum distance you derived compare to the actual 100Mbps standard?

15. Suppose two nodes, A and B, are attached to opposite ends of a 1,000m cable, and they each have one frame of 1,500 bits (including all headers and preambles) to send to each other. Both nodes attempt to transmit at time $t = 0$ Suppose there are 4 repeaters between A and B, each inserting a 20-bit delay. Assume the transmission rate is 10Mbps, and CSMA/CD with backoff intervals of multiples of 512 bits is used. After the first collision, A draws $K = 0$ and B draws $K = 1$ in the exponential backoff protocol. Ignore the jam signal and the 96-bit time delay.

    (a) What is the one-way propagation delay (including repeater delays) between A and B in seconds? Assume that the signal propagation speed is $2 \cdot 10^8$m/sec.

    (b) At what time (in seconds) is A's packet completely delivered to B?

    (c) Now suppose that only A has a packet to send and that the repeaters are replaced with switches. Suppose that each switch has a 20-bit processing delay in addition to a store-and-forward delay. At what time, in seconds, is A's packet delivered at B?