1. R4. Suppose two nodes start to transmit at the same time a packet of length L over a broadcast channel of rate R. Denote the propagation delay between the two nodes as d_{prop}. Will there be a collision if $d_{prop} < L/R$? Why or why not?

   If the propagation delay is less than the transmission delay, then there will be a collision since both nodes will be receiving the packet sent by the other node at the time it is transmitting its own packet.

2. R11. Why is an ARP query sent within a broadcast frame? Why is an ARP response sent within a frame with a specific destination MAC address?

   An ARP query is sent within a broadcast frame because the host making the query does not know where to find the IP address it is looking for. An ARP response is sent within a frame with a specific destination MAC address because the sender knows where the response should be sent.

3. P18. Suppose nodes A and B are on the same 10 Mbps broadcast channel, and the propagation delay between the two nodes is 325 bit times. Suppose CSMA/CD and Ethernet packets are used for this broadcast channel. Suppose node A begins transmitting a frame and, before it finishes, node B begins transmitting a frame. Can A finish transmitting before it detects that B has transmitted? Why or why not? If the answer is yes, then A incorrectly believes that its frame was successfully transmitted without a collision. Hint: Suppose at time t = 0 bits, A begins transmitting a frame. In the worst case, A transmits a minimum-sized frame of 512 + 64 bit times. So A would finish transmitting the frame at t = 512 + 64 bit times. Thus, the answer is no, if B's signal reaches A before bit time t = 512 + 64 bits. In the worst case, when does B's signal reach A?

   When t = 0, node A begins to transmit a frame. At t = 512 + 64 = 576, A would finish transmitting the frame. In the worst-case scenario, B begins transmitting just before the first bit of the frame from node A arrives at node B, or t = 324. At t = 324 + 325 = 649, the first bit of the frame from node B arrives at node A. Since 576 < 649, node A finishes transmitting its frame before it detects that node B has transmitted a frame, thus A incorrectly believes that its frame was successfully transmitted without a collision.

4. Consider a point-to-point link between nodes A and B with the following measured values:

   i. Link length = 2000 kilometers = 2×10^6 meters
   ii. Signal propagation speed = 5 meters/nanosecond = 5 meters/1×10^{-9} seconds
   iii. Link speed = 1 Mbps = 1×10^6 bits per second
   iv. ACK processing time at node A = 10 milliseconds = 1×10^{-2} seconds
   v. Packet processing time at node B = 20 milliseconds = 2×10^{-2} seconds
   vi. Packet size = 1500 bytes = 12,000 bits
   vii. ACK size = 64 bytes = 512 bits

   Assume the node A is sending to node B and permits (acks) are granted after each packet is received. Compute the network utilization for the following cases:

   a. Stop-and-Wait with no channel errors.

   $$d_{prop} = \frac{\text{link length}}{\text{propagation speed}} = \frac{2\times10^6 \text{ meters}}{5 \text{ meters}/1\times10^{-9} \text{ seconds}} = 4 \times 10^{-4} \text{ seconds}$$

   $$d_{trans\ (pkt)} = \frac{\text{packet size}}{\text{link bandwidth}} = \frac{12{,}000 \text{ bits}}{1\times10^6 \text{ bits per second}} = 1.2 \times 10^{-2} \text{ seconds}$$

$$\mathrm{d}_{\text{trans (ack)}} = \frac{\text{acknowledgement size}}{\text{link bandwidth}} = \frac{512 \text{ bits}}{1 \times 10^6 \text{ bits per second}} = 5.12 \times 10^{-4} \text{ seconds}$$

$$U = \frac{\mathrm{d}_{\text{trans (pkt)}}}{(2 \cdot \mathrm{d}_{\text{prop}}) + \mathrm{d}_{\text{trans (pkt)}} + \mathrm{d}_{\text{proc (pkt)}} + \mathrm{d}_{\text{trans (ack)}} + \mathrm{d}_{\text{proc (ack)}}}$$

$$U = \frac{1.2 \times 10^{-2} \text{ s}}{(2 \cdot 4 \times 10^{-4} \text{ s}) + (1.2 \times 10^{-2} \text{ s}) + (2 \times 10^{-2} \text{ s}) + (5.12 \times 10^{-4} \text{ s}) + (1 \times 10^{-2} \text{ s})}$$

$$U = 0.277 = 27.7\%$$

b. Sliding Window with no channel errors and W=10 (W is the window size)

$$U = \frac{W \cdot \mathrm{d}_{\text{trans (pkt)}}}{(2 \cdot \mathrm{d}_{\text{prop}}) + \mathrm{d}_{\text{trans (pkt)}}} = \frac{10 \cdot 1.2 \times 10^{-2} \text{ s}}{(2 \cdot 4 \times 10^{-4} \text{ s}) + (10 \cdot 1.2 \times 10^{-2} \text{ s})} = 0.993 = 99.3\%$$

c. Stop-and-Wait with Prob[bit in error] = 0.0001

$$U = 0.277 + \frac{1.2 \times 10^{-2} \text{ s}}{10{,}000 \times (2 \cdot 4 \times 10^{-4} \text{ s}) + (1.2 \times 10^{-2} \text{ s}) + (2 \times 10^{-2} \text{ s}) + (5.12 \times 10^{-4} \text{ s}) + (1 \times 10^{-2} \text{ s})} = 0.2770277$$