

- P5. Review the car-caravan analogy in Section 1.4. Assume a propagation speed of 100 km/hour.
- Suppose the caravan travels 150 km, beginning in front of one tollbooth, passing through a second tollbooth, and finishing just after a third tollbooth. What is the end-to-end delay?
  - Repeat (a), now assuming that there are eight cars in the caravan instead of ten.
- P6. This elementary problem begins to explore propagation delay and transmission delay, two central concepts in data networking. Consider two hosts, A and B, connected by a single link of rate  $R$  bps. Suppose that the two hosts are separated by  $m$  meters, and suppose the propagation speed along the link is  $s$  meters/sec. Host A is to send a packet of size  $L$  bits to Host B.
- Express the propagation delay,  $d_{\text{prop}}$ , in terms of  $m$  and  $s$ .
  - Determine the transmission time of the packet,  $d_{\text{trans}}$ , in terms of  $L$  and  $R$ .
  - Ignoring processing and queuing delays, obtain an expression for the end-to-end delay.
  - Suppose Host A begins to transmit the packet at time  $t = 0$ . At time  $t = d_{\text{trans}}$ , where is the last bit of the packet?
  - Suppose  $d_{\text{prop}}$  is greater than  $d_{\text{trans}}$ . At time  $t = d_{\text{trans}}$ , where is the first bit of the packet?
  - Suppose  $d_{\text{prop}}$  is less than  $d_{\text{trans}}$ . At time  $t = d_{\text{trans}}$ , where is the first bit of the packet?
  - Suppose  $s = 2.5 \cdot 10^8$ ,  $L = 120$  bits, and  $R = 56$  kbps. Find the distance  $m$  so that  $d_{\text{prop}}$  equals  $d_{\text{trans}}$ .
- P7. In this problem, we consider sending real-time voice from Host A to Host B over a packet-switched network (VoIP). Host A converts analog voice to a digital 64 kbps bit stream on the fly. Host A then groups the bits into 56-byte packets. There is one link between Hosts A and B; its transmission rate is 2 Mbps and its propagation delay is 10 msec. As soon as Host A gathers a packet, it sends it to Host B. As soon as Host B receives an entire packet, it converts the packet's bits to an analog signal. How much time elapses from the time a bit is created (from the original analog signal at Host A) until the bit is decoded (as part of the analog signal at Host B)?
- P8. Suppose users share a 3 Mbps link. Also suppose each user requires 150 kbps when transmitting, but each user transmits only 10 percent of the time. (See the discussion of packet switching versus circuit switching in Section 1.3.)
- When circuit switching is used, how many users can be supported?
  - For the remainder of this problem, suppose packet switching is used. Find the probability that a given user is transmitting.


**VideoNote**

Exploring propagation delay and transmission delay