

1. A system has an  $n$ -layer protocol hierarchy. Applications generate messages of length  $M$  bytes. At each of the layers, an  $b$ -byte header is added. What fraction of the network bandwidth is filled with headers?
2. **What metrics are used to assess the performance of a network?** Calculate the latency (from first bit sent to last bit received) for a 100-Mbps Ethernet with a single store-and-forward switch in the path and a packet size of 12,000 bits. Assume that each link introduces a propagation delay of  $10\ \mu\text{s}$  and that the switch begins retransmitting immediately after it has finished receiving the packet.
3. Consider a source computer (S) transmitting a file of size 106 bits to a destination computer (D) over a network of two routers (R1 and R2) and three links (L1, L2, and L3). L1 connects S to R1; L2 connects R1 to R2; and L3 connects R2 to D. Let each link be of length 100km. Assume signals travel over each link at a speed of  $10^8$  meters per second. Assume that the link bandwidth on each link is 1Mbps. Let the file be broken down into 1000 packets each of size 1000 bits. Find the total sum of transmission and propagation delays in transmitting the file from S to D.
4. Given a network with a bandwidth of 100 Mbps and an average latency of 50 ms. Calculate the throughput if the network experiences a packet loss rate of 2%. Explain the impact of packet loss on overall network performance.
5. Consider a network with a mix of PCs, switches, and routers. Explain how data is transmitted from a PC in one LAN to a PC in another LAN. Illustrate the path taken by the data packet and the role of each device in the process.