c. Suppose there are 120 users. Find the probability that at any given time, exactly n users are transmitting simultaneously. (*Hint*: Use the binomial distribution.)

d. Find the probability that there are 21 or more users transmitting simultaneously.

P9. Consider the discussion in Section 1.3 of packet switching versus circuit switching in which an example is provided with a 1 Mbps link. Users are generating data at a rate of 100 kbps when busy, but are busy generating data only with probability $p = 0.1$. Suppose that the 1 Mbps link is replaced by a 1 Gbps link.

a. What is N, the maximum number of users that can be supported simultaneously under circuit switching?

b. Now consider packet switching and a user population of M users. Give a formula (in terms of p, M, N) for the probability that more than N users are sending data.

P10. Consider the network illustrated in Figure 1.16. Assume the two hosts on the left of the figure start transmitting packets of 1500 bytes at the same time towards Router B. Suppose the link rates between the hosts and Router A is 4-Mbps. One link has a 6-ms propagation delay and the other has a 2-ms propagation delay. Will queuing delay occur at Router A?

P11. Consider the scenario in Problem P10 again, but now assume the links between the hosts and Router A have different rates R_1 and R_2 byte/s in addition to different propagation delays d_1 and d_2. Assume the packet lengths for the two hosts are of L bytes. For what values of the propagation delay will no queuing delay occur at Router A?

P12. Consider a client and a server connected through one router. Assume the router can start transmitting an incoming packet after receiving its first h bytes instead of the whole packet. Suppose that the link rates are R byte/s and that the client transmits one packet with a size of L bytes to the server. What is the end-to-end delay? Assume the propagation, processing, and queuing delays are negligible. Generalize the previous result to a scenario where the client and the server are interconnected by N routers.

P13. (a) Suppose N packets arrive simultaneously to a link at which no packets are currently being transmitted or queued. Each packet is of length L and the link has transmission rate R. What is the average queuing delay for the N packets?