1

1. \( \frac{2 \text{ Mbps}}{200 \text{ Kbps}} = 10 \text{ users} \)

2. \( {50 \choose 5} \cdot 0.01^5 \cdot 0.99^{45} \)

3. \( 1 - {50 \choose n} \sum_{n=0}^{20} 0.01^n \cdot 0.99^{50-n} \)

2

1. \( R \times d_{\text{drop}} = 110^6 \left( \frac{500010^3}{2.710^8} \right) = 1.8510^4 \text{ bits} \)

2. As \( 1.85 \times 10^4 \text{ bits} < 50000 \), then the maximum number of bits is \( 1.85 \times 10^4 \text{ bits} \).

3. \( \frac{\text{linkLength}}{d_{\text{prop}}/d_{\text{trans}}(1\text{ bit})} = 5 \times 10^6 / (1.85 \times 10^4) = 270 \text{ m} \)

4. \( \frac{\text{linkLength}}{d_{\text{prop}}/d_{\text{trans}}(1\text{ bit})} = \frac{(m/1)}{R} = \frac{s}{R} \)

3

- \( P_0 = (1 - P)^N \)
- \( P_m = {N \choose m} p^m (1 - p)^{N-m} \)
- \( P_{tr} = \sum_{n=0}^{m} \frac{N!}{n!} p^n (1 - p)^{N-n} \)
- \( P_k = (1 - P_{tr})^{k-1} P_{tr} \)
- Let random variable \( T \) represent the number of times that A has to send the file to get it accepted at B. We have, \( E[T] = \sum_{k=1}^{\infty} k P_k = \sum_{k=1}^{\infty} k (1 - P_{tr})^{k-1} P_{tr} = \frac{1}{r_{tr}}. \)

4

Figure 1: part 1
• We are in state $S_0$ at time $k = 1$, when there is no arrival in the first transition step, and it follows that: $P_{(1)}^0 = 1 - P_a$

• We are in state $S_1$ at time $k = 1$, when there is an arrival in the first transition step, and it follows that: $P_{(1)}^1 = P_a$

• We can not reach state $S_2$ from $S_0$ in 1 transition step, and it follows that: $P_{(1)}^2 = 0$

• We have:

$$P_{(1)}^0 = (1 - P_a)P_0 + P_lP_1$$

$$P_{(1)}^1 = P_aP_0 + (1 - P_a - P_l)P_1 + P_lP_2$$

$$P_{(1)}^2 = P_aP_1 + (1 - P_l)P_2$$

• We have to solve the system of equation:

$$P_{(1)}^0 = (1 - P_a)P_0 + P_lP_1$$

$$P_{(1)}^1 = P_aP_0 + (1 - P_a - P_l)P_1 + P_lP_2$$

$$P_{(1)}^2 = P_aP_1 + (1 - P_l)P_2$$

Under the condition that:

$$P_0 + P_l + P_2 = 1$$

Using the equation

$$P_0 = (1 - P_a)P_0 + P_lP_1$$

We obtain that:

$$P_1 = \frac{P_a}{P_l}P_0 = \rho P_0$$

For $\rho = \frac{P_a}{P_l}$ Using this result in the equation

$$P_1 = P_aP_0 + (1 - P_a - P_l)P_1 + P_lP_2$$

we obtain that

$$P_2 = \rho^2 P_0$$

Finally, using the condition that

$$P_0 = (1 - P_a)P_0 + P_lP_1$$

We get that

$$P_0 = \frac{1}{1 + \rho + \rho^2} = \frac{1 - \rho}{1 - \rho^3}$$

• Using results of (f), the steady state probabilities are:

$$P_0 = \frac{1}{1 + \rho + \rho^2} = \frac{1 - \rho}{1 - \rho^3}$$

$$P_1 = \rho \frac{1}{1 + \rho + \rho^2} = \frac{1 - \rho}{1 - \rho^3}$$

$$P_1 = \rho^2 \frac{1}{1 + \rho + \rho^2} = \frac{1 - \rho}{1 - \rho^3}$$
• processing delay, transmission delay, propagation delay and queuing delay. All of these delays are
fixed, except for the queuing delays, which are variable according to the pressure of the packets on
link.

• (1) $64\text{kbps}/8 = 8\text{frames/s}$

(2) $192 \times 10^6 / 8 = 24 \times 10^6 \text{frames/s}$

(3) $24 \times 10^3 / (8 \times 10^3) = 3000$

(4) processing delay. Or time used to switch packages.