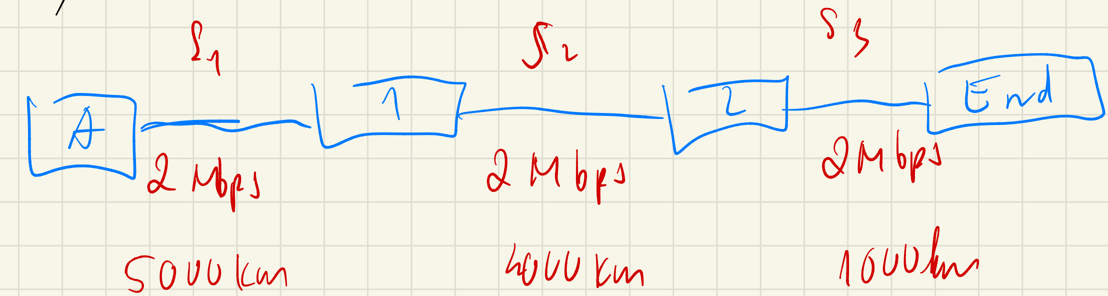
P9. Consider the discussion in Section 1.3 of packet switching versus circuit switching in which an example is provided with a 1 Mbps link. Users are generating data at a rate of 100 kbps when busy, but are busy generating data only with probability $p = 0.1$. Suppose that the 1 Mbps link is replaced 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 a packet of length L which begins at end system A and travels over three links to a destination end system. These three links are connected by two packet switches. Let d_i, s_i, and R_i denote the length, propagation speed, and the transmission rate of link i, for $i = 1, 2, 3$. The packet switch delays each packet by d_{proc}. Assuming no queuing delays, in terms of d_i, s_i, R_i, ($i = 1,2,3$), and L, what is the total end-to-end delay for the packet? Suppose now the packet is 1,500 bytes, the propagation speed on all three links is $2.5 \cdot 10^8$ m/s, the transmission rates of all three links are 2 Mbps, the packet switch processing delay is 3 msec, the length of the first link is 5,000 km, the length of the second link is 4,000 km, and the length of the last link is 1,000 km. For these values, what is the end-to-end delay?

10/



Solve

S_1 : Transmission Delay : $\frac{L}{R} = \frac{1500\,B}{2M\,bps} = 6ms$

Propagation Delay:

$$\frac{D}{S} = \frac{5000\,km}{2{,}5 \cdot 10^8\, ms} = 20ms$$

$\Rightarrow S_1$ delay: $20 + 6 = 26ms$

S_2: Transmission delay: $\frac{L}{R} = \frac{1500B}{2Mbps} = 6ms$

Propagation Delay: $\frac{D}{S} = \frac{4000\,km}{2{,}5 \cdot 10^8\, ms} = 16\,ms$

$\Rightarrow S_2$ delay $= 16 + 6 = 22ms$

S_3: Transmission Delay $= S_2$'s TD $= 6ms$

Propagation Delay: $\frac{D}{S} = \frac{1000\,km}{2{,}5 \cdot 10^8\, ms} = 4ms$

$\Rightarrow S_3$ delay $= 4 + 6 = 10ms$

Packet switch processing delay: 3ms

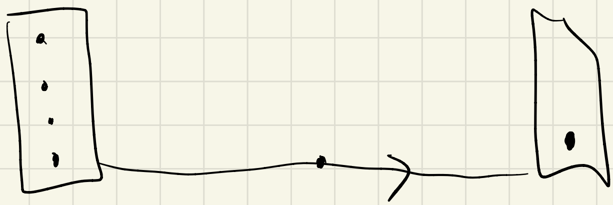
we have $\underline{2}$ packet switches

$\Rightarrow$ PS delay: $3 \cdot 2 = 6ms$

$\Rightarrow$ End-to-End delay $= 26 + 22 + 10 + 6 = \boxed{64ms}$

P12. A packet switch receives a packet and determines the outbound link to which the packet should be forwarded. When the packet arrives, one other packet is halfway done being transmitted on this outbound link and four other packets are waiting to be transmitted. Packets are transmitted in order of arrival. Suppose all packets are 1,500 bytes and the link rate is 2 Mbps. What is the queuing delay for the packet? More generally, what is the queuing delay when all packets have length *L*, the transmission rate is *R*, *x* bits of the currently-being-transmitted packet have been transmitted, and *n* packets are already in the queue?

12/ Solve:



Intensity $I = L \cdot a / R$

- L: packet length
- a: average rate of packets / sec
- R: Transmission rate

Queing Delay $= I(L/R)(1 - I)$ for $I < 1$

$L = 1500$ Bytes $= 12\,000$ bits

$\Rightarrow x = 12000/2 = 6000$ bits

$n = 4$ $\quad R = 2$ Mbps $\quad a = \frac{x}{n} = 1500$ b/s

$$I = \frac{12000 \cdot 1500}{2 \cdot 10^6} = 9$$

$I = 9 > 1 \Rightarrow$ Queing delay $= +\infty$