Massachusetts Institute of Technology
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6.02 Fall 2011 **Solutions to Chapter 17** Updated November 2011

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1. When the different conversations have the same, known, constant bit rates. That situation occurs rarely in modern data networks.

2. Statements (a), (b), and (c) are correct. (d) is not true; switches in a circuit-switched network do need to know about the topology, not to forward each frame, but to establish the right state during connection establishment.

3. (a) Using Little's law, the average queue lengths are 2, 2, 0.5, 0.5.

   (b) B, C, and D remain unchanged because of the isolation provided by time division multiplexing. A's queue grows to infinity because its arrival rate is larger than the service rate of $1/4 = 0.25$ packets per time slot.

4. Rate $= 19000/(0.1 \cdot 1 + .9 \cdot 0.1) = 19000/(0.19) = 100000$ packets/s.

5. (a) The offered load presented to the network is 8 Megabits/s in aggregate. The throughput of the protocol is $0.75 \cdot 10 = 7.5$ Megabits/s. The packet collision rate is therefore equal to $1 - 7.5/8 = 1/16 = 6.25\%$.

   (b) Apply Little's law, noting that the average queue size per node is 5 packets. The rate at which the network processes each node's packets is $10^6/10^4 = 100$ packets/s. The average queueing delay is therefore equal to 5/100 seconds, or 50 milliseconds.

6. This problem is essentially the same as one on PSet #9.

7. (a) Suppose the fraction of students doing an MEng is m. The average time spent in the system (i.e., at MIT) is equal to $4(1-m)+5m$. Since nobody drops out, the departure rate and arrival rate are equal, both F students per year. By Little's law,

   $$N = F\{4(1-m)+5m\},$$

   which gives us $m = \frac{N}{F} - 4$.

   (b) Let the elapsed time between invoicing and payment be D years. Then, 300×10^6 dollars/year $\cdot$ D years $= 45 \times 10^6$, giving us $D = 0.15$ years $= 54.75$ days (54.9 days in a leap year!).

   (c) I would disagree. Suppose the total population is N and d people die every year on average. Then, if the average life expectancy is L years, by Little's law, $N = dL$. That means that the average life expectancy, L, is equal to N/d, which is the reciprocal of the fraction of people who die every year. Since L is less than 100 years (it's between 75 and 80 or so), more than 1% of the population dies each year. In fact, one can estimate that about $100/L$ percent of the population, alas, dies annually.

   (d) For the first part, using Little's law, 100 emails / 50 emails/day = 2 days.

   For the second part, let x be the desired average time to reply to a non-6.02 email. Then, x satisfies the equation 48 hours $= 0.25 \times 1$ hour $+ 0.75x \Rightarrow x = 63.67$ hours.

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8. (a) The average queueing delay of the network path is $75-50 = 25$ ms. The rate is 1 Mbit/s, which is 125 packets/s (each packet is 1000 bytes in size). Hence, the average number of packets in the queue is equal to $25 \cdot 10^{-3} \cdot 125 = 3.125$.

   (b) The packet loss rate is $1 - 1.6/2 = 20\%$.

   (c) We said to assume that the queue size does not change appreciably from before, so we can assume it is 3.125 packets, or 3,125 bytes on average. With a delivery rate of 1.6 Mbits/s, the average one-way queueing delay is equal to 3125×8 bits/1600 Kbits/s = 15.625 ms. Hence, the average one-way delay = 50 + 15.625 = 65.625 ms. (It is unlikely that the three decimal places are actually significant!)

9. (a) The time delay between the arrival of the first bit of each packet is equal to the *transmission delay* of a packet, since packets are sent back-to-back. The transmission delay of the first hop is much smaller than the second, so we can safely ignore it (the second packet will arrive at the Switch before hardly any bits of the second packet are sent on the second link). The transmission delay over the second hop is 1000 bytes/10^6 bytes/s = 1 millisecond.

   (b) The round-trip time is equal to the time it takes for 1000 bytes to go from the Sender to the Receiver plus the time it takes for 100 bytes to go from the Receiver to the Sender. Again, we can safely ignore the transmission time on the Sender-Switch link. The desired time is equal to $1 + \approx 0 + 10 + 1 + 10 + 0.1 + 1 + \approx 0$ ms = 23.1 ms. The first term is the propagation time on the first link, the second term is the transmission time, which we ignore, the third term is the propagation time on the second link, the fourth term is the transmission time on the second link. The last four terms are the corresponding times for the reverse path from Receiver to Sender.

10. Let λ be the rate when we have N concurrent requests. By Little's Law, $N = (a + bN^2)\lambda$, or $\lambda = \frac{N}{a+bN^2}$. Maximizing λ is equivalent to minimizing $1/\lambda = \frac{a}{N} + bN$. The minimum of $1/\lambda$ occurs when the derivative of $\frac{a}{N} + bN$ with respect to N is 0, which happens when $N = \sqrt{\frac{a}{b}}$. The maximum value of λ is therefore equal to $\frac{\sqrt{a/b}}{(a+a)} = \frac{1}{2\sqrt{ab}}$.