EECS 122: Introduction to Communication Networks
Homework 1 Solutions

Solution 1.

$$rate = data/time$$

$$time = data\frac{1}{rate} = 15 \cdot 2^{10} \text{ bytes} \cdot \frac{\text{second}}{1.5 \cdot 10^6 \text{ bits}} \cdot \frac{8 \text{ bits}}{\text{byte}} \cdot \frac{1000 \text{ ms}}{\text{second}} = 81.92 \text{ ms}$$

Solution 2.

$$\text{user data rate} = \frac{400 \text{ characters}}{\text{minute}} \cdot \frac{8 \text{ bits}}{\text{character}} \cdot \frac{\text{minute}}{60 \text{ seconds}} = \frac{160}{3} \text{ bps}$$

$$\text{fraction of modem capacity} = \frac{\frac{160}{3} \text{ bps}}{9600 \text{ bps}} = \frac{1}{180}$$

Solution 3. Each user produces (by typing) $\frac{160}{3}$ bps (from solution 2), but the average message is 6 times larger than what the user typed, so each user causes 320 bps to be sent on the network. The maximum number of users that can share the 38.4 kbps link is therefore

$$\frac{38400 \text{ bps}}{320 \text{ bps}} = 120$$

Solution 4.

a) Since the propagation delay is zero, the time for a packet to traverse one link is the transmission time $(H+S)/C$. Because a router first receives a packet entirely before sending it back out again, the time for the packet to traverse n links from A to B is simply n times as much: $n \cdot (H+S)/C$.

b) Using too many very small packets causes too much data to be sent, because of the per-packet overhead H, leading to a large delay. On the other hand, using only one large packet prevents any parallelism—with multiple packets, one packet can be using the j^{th} link at the same time the next packet is using the $j+1^{\text{st}}$ link, and so on.

Observe from part (a) that larger packets take longer to get from A to B, so the time for all the packets to reach B is limited by the size of the largest packet. When dividing a given amount of data among a given number of packets, the size of the largest packet is minimized when all packets are the same size.

Suppose we use k packets. Each has size $H+\frac{S}{k}$. After the first packet is received by B, the rest will immediately follow. From part (a), the time for the first packet to get from A to B is $n \cdot \left(H+\frac{S}{k}\right)/C$. The time for the remaining $k-1$ packets to be arrive is simply $(k-1)\left(H+\frac{S}{k}\right)/C$, for a total of $(n+k-1)\left(H+\frac{S}{k}\right)/C$. To find the k that minimizes the delay, we set the derivative with respect to k to zero:

$$\begin{aligned}
\frac{d}{dk}\left[(n+k-1)\frac{\left(H+\frac{S}{k}\right)}{C}\right] &= 0 \\
\frac{d}{dk}\left[(n+k-1)\left(H+\frac{S}{k}\right)\right] &= 0 \\
(n+k-1)\left(\frac{-S}{k^2}\right)+\left(H+\frac{S}{k}\right)(1) &= 0 \\
(n+k-1)(-S)+(Hk^2+Sk) &= 0 \\
Hk^2 &= (n-1)S \\
k &= \sqrt{(n-1)\frac{S}{H}}
\end{aligned}$$

Of course, in general k will not be an integer, so given actual numbers for S, H, and n, we would need to evaluate the total delay for $\lfloor k \rfloor$ packets and $\lceil k \rceil$ packets, and use whichever was better.

Solution 5. Circuit-switched networks (like the telephone network) can guarantee a certain bandwidth and maximum delay, because there is a dedicated connection between parties. In packet-switched networks many connections share the same resources (links, buffers in routers), so there are no guarantees on bandwidth and delay. On the other hand, in packet-switched networks there is better utilization of resources due to sharing: when a connection in a circuit-switched network is used intermittently, the unused capacity is wasted, while in a packet-switched network it is available for other users. Also, in a packet-switched network, when a router or link fails, subsequent packets can take a different path, whereas in a circuit-switched network the connection is broken and must be set up again by the end nodes.

Solution 6. [not yet]