Homework for Chapter 1

1. You set up a communication channel between two medieval castles by letting a trained raven repeatedly carry a scroll from the sending castle to the receiving castle, 160 kilometers away. The raven flies at an average speed of 40 km/h, and carries one scroll at a time. Each scroll contains 1.8 terabytes of data. Calculate the data rate of this channel when sending

   (i) 1.8 terabytes of data;
   (ii) 3.6 terabytes of data;
   (iii) an infinite stream of data.

   Solution:

   (i)
   $$\frac{1.8\ \text{TB}}{\frac{160\ \text{km}}{40\ \text{km/h}}} = \frac{1800 \times 8\ \text{Gb}}{4 \times 3600\ \text{s}} = 1\ \text{Gbps}.$$
   (ii)
   $$\frac{3.6\ \text{TB}}{3 \times \frac{160\ \text{km}}{40\ \text{km/h}}} = \frac{2}{3} \times \frac{1800 \times 8\ \text{Gb}}{4 \times 3600\ \text{s}} = \frac{2}{3}\ \text{Gbps}.$$
   (iii)
   $$\frac{1.8\ \text{TB}}{2 \times \frac{160\ \text{km}}{40\ \text{km/h}}} = \frac{1}{2} \times \frac{1800 \times 8\ \text{Gb}}{4 \times 3600\ \text{s}} = \frac{1}{2}\ \text{Gbps}.$$

2. A factor in the delay of a store-and-forward packet-switching system is how long it takes to store and forward a packet through a switch. If switching time is 20 µsec, is this likely to be a major factor in the response of a client-server system where the client is in New York and the server is in California? Assume the propagation speed in copper and fiber to be 2/3 the speed of light in vacuum.

   Solution:

   Assume the distance from New York to California is 5000 km.
   $$\frac{2 \times 5000\ \text{km}}{\frac{2}{3} \times 3 \times 10^8\ \text{m/s}} = \frac{2 \times 5 \times 10^6}{200 \times 10^6}\ \text{s} = 0.05\ \text{s} = 50000\ \mu\text{s} \gg 20\ \mu\text{s} \Rightarrow \text{Not a major factor.}$$

3. A client-server system uses a satellite network, with the satellite at a height of 40000 km. What is the best-case delay in response to a request?

   Solution:
   $$\frac{4 \times 40000\ \text{km}}{3 \times 10^8\ \text{m/s}} = \frac{160 \times \times 10^6 \text{m}}{300 \times 10^6\ \text{m/s}} \simeq 0.533\ \text{s}.$$

4. Five routers are to be connected in a point-to-point subnet. Between each pair of routers, the designers may put a high-speed line, a medium-speed line, a low-speed line, or no line. If it takes 50 ms of computer time to generate and inspect each topology, how long will it take to inspect all of them?

   Solution:

   5 routers: A, B, C, D, E.

   10 possible point-to-point lines: $AB, AC, AD, AE, BC, BD, BE, CD, CE, DE$.

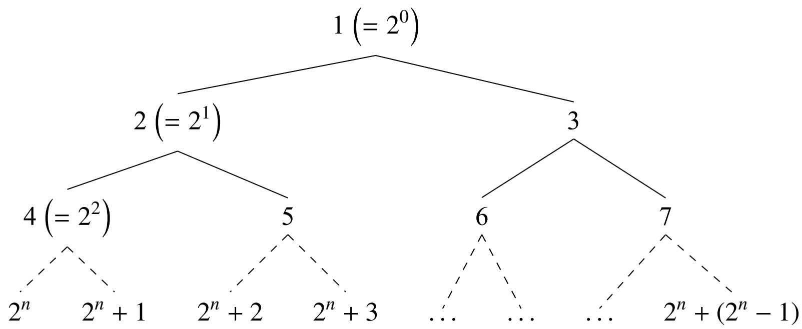
   4 possible data rate for each line: high-speed, medium-speed, low-speed, zero-speed.

   4^{10} possible topologies.

   Total time to inspect all the topologies:
   $$4^{10} \times 50\ \text{ms} = 52428800\ \text{ms} = 52428.8\ \text{s} \simeq 14.563\ \text{h}.$$

5. A group of $2^n - 1$ routers are interconnected in a centralized binary tree, with a router at each tree node. Router i communicates with router j by sending a message to the root of the tree. The root then sends the message back down to j. Derive an approximate expression for the mean number of hops per message for large n, assuming that all router pairs are equally likely.

   Solution:



$$\begin{aligned}
& \text{Mean router-to-router hops} \\
= \;& (\text{Mean router-to-root hops}) \times 2 \\
= \;& \left(\left(\frac{1}{2}\right)(n-1) + \left(\frac{1}{2}\right)^2 (n-2) + \left(\frac{1}{2}\right)^3 (n-3) + \cdots\right) \times 2 \\
= \;& (n-2) \times 2 \\
= \;& 2n - 4.
\end{aligned}$$

6. A disadvantage of a broadcast subnet is the capacity wasted when multiple hosts attempt to access the channel at the same time. As a simplistic example, suppose that time is divided into discrete slots, with each of the n hosts attempting to use the channel with probability p during each slot. What fraction of the slots will be wasted due to collisions?

   Solution:

$$\begin{aligned}
\text{The sample space } S &= \{\text{No host active}\} + \{\text{1 host active}\} + \{\text{2 or more hosts active}\} \\
&= E_0 + E_1 + E_{\geq 2} \\
1 &= P(E_0) + P(E_1) + P(E_{\geq 2}) \\
&= (1-p)^n + np(1-p)^{n-1} + P(E_{\geq 2}) \\
\\
P(E_{\geq 2}) &= 1 - (1-p)^n - np(1-p)^{n-1}.
\end{aligned}$$

7. In some networks, the data link layer handles transmission errors by requesting that damaged frames be retransmitted. If the probability of a frame's being damaged is p, what is the mean number of transmissions required to send a frame? Assume that acknowledgements are never lost.

   Solution:

$$\begin{aligned}
\text{Mean number of transmissions} &= 1(1-p) + 2p(1-p) + 3p^2(1-p) + \cdots \\
&= \sum_{k=1}^{\infty} kp^{k-1}(1-p) \\
&= \frac{1}{1-p}.
\end{aligned}$$

8. How long was a bit in the original 802.3 standard in meters? Use a transmission speed of 10 Mbps and assume the propagation speed of the signal in coax is 2/3 the speed of light in vacuum.

   Solution:

$$\frac{1 \text{ b}}{10 \text{ Mbps}} \times \frac{2}{3} \times 3 \times 10^8 \text{ m/s} = \frac{1}{10^7} \times 2 \times 10^8 \text{ m} = 20 \text{ m}.$$

9. Ethernet and wireless networks have some similarities and some differences. One property of Ethernet is that only one frame at a time can be transmitted on an Ethernet. Does 802.11 share this property with Ethernet? Discuss your answer.

   Solution: Think about the hidden terminal problem.

   Imagine a wireless network of five stations, A through E, such that each one is in range of only its immediate neighbors. Then A can talk to B at the same time D is talking to E. Wireless networks have potential parallelism, and in this way differ from Ethernet.

10. List two advantages and two disadvantages of having international standards for network protocols.

    Solution:

    Advantages:

    Interoperable.

    Cheap.

    Disadvantages:

    Not so efficient.

    Too long to be standardized.

11. Suppose the algorithms used to implement the operations at layer k is changed. How does this impact operations at layers $k1$ and $k + 1$?

    Solution:

    No impact on layer $k + 1$.

    No impact on layer $k - 1$.

12. Suppose there is a change in the service (set of operations) provided by layer k. How does this impact services at layers $k - 1$ and $k + 1$?

    Solution:

    Yes impact on layer $k + 1$.

    No impact on layer $k - 1$.