INST346 HW01 Solutions

Introduction and Basics

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0 Introduce Yourself

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1 Accessing the Internet

1. Computers communicate according to *protocols* that govern how they exchange information. Give an example of a protocol from your day-to-day life that governs your interactions with someone or something.

   Solution Examples include food recipes, the process of ordering food at a restaurant, wedding ceremonies, etc.

2. Why do you think two computers might require a predefined protocol to communicate over a network?

   Solution The rigid nature of computers requires specific instructions on how to read data out of a signal, so hardware/software can be pre-programmed accordingly. Hardware is an especially good example of the value of pre-defined protocols since a networking device has hard-coded locations for where to look for addressing or error detection information. This isn't to say communication via unknown protocols is not impossible as research exists into automatically learning new protocols. Such a process is complex and slow though, and networks value speed.

3. Why are *standards* important for these communication protocols? Do you think it possible for two computers to implement a standard protocol differently and still communicate?

   Solution Standardized protocols are important to ensure networks can be composed of heterogeneous (i.e., many different kinds of) devices regardless of manufacture. Cisco, Apple, HP, and whomever else can implement the same standardized protocol and be sure they can communicate. It is also possible for two computers with different implementations of the same standard to communicate. We see this effect in Windows vs. Linux networking stacks, in which slight differences can identify the type of operating system, but the two can still communicate without issue.

4. List the available residential access technologies in your neighborhood. For each type of access, what is its advertised downstream rate, upstream rate, and monthly price?

Solution Comcast's Xfinity with various bandwidth offerings: Plus at 25 Mbps downstream, unpublished upstream, and 39.99/month. Pro at 45 Mbps downstream, unpublished upstream, and 49.99/month. Performance at 25 Mbps downstream, unpublished upstream, and 29.99/month. Performance Pro at 75 Mbps downstream, unpublished upstream, and 76.95/month. Performance Starter at 6 Mbps downstream, unpublished upstream, and 49.95/month. Blast! at 150 Mbps downstream, unpublished upstream, and 78.95/month. Extreme 505 at 505 Mbps downstream, unpublished upstream, and 399.95/month. Economy Plus at 3 Mbps downstream, unpublished upstream, and 34.99/month.

5. Dial-up, cable modems, DSL, fiber, and cellular networks are all used for residential access. For each of these technologies, what is the range of transmission rates they provide? Are these rates shared or dedicated? Is the downstream/upstream symmetric or asymmetric?

   Solution Dial up modems: up to 56 Kbps, bandwidth is dedicated. ADSL: up to 24 Mbps downstream and 2.5 Mbps upstream, bandwidth is dedicated. Hybird-Coax-Fiber: DOCSIS 3.1 specifications support up to 10 Gbps downstream and 1 Gbps upstream of network capacity with shared bandwidth. Fiber-to-the-Home: gigabit downstream is common with 100s of megabits upstream; bandwidth is not shared with "active" optical networks but is with "passive" networks.

6. Describe a situation in which a *symmetric* upstream/downstream access technology might be desired. When might *asymmetric* upstream/downstream access be acceptable?

   Solution The typical example for symmetric use cases are for data centers or network service providers who need to ship large amounts of data. Asymmetric rates are often used and economical for residential access in which a typical user downloads much more data than uploads. For example, a typical home may spend many megabits per second downloading shows from Netflix but only a few hundred kilobits per second sending requests for the next episode of Narcos.

2 Moving Data Between Systems

1. What advantages does circuit switching have over packet switching?

   Solution Simple sharing rules, guaranteed bandwidth, and no congestion issues.

2. Suppose users share a 3 Mbps link, and each user requires 150 kbps when transmitting. Each user, however, only transmits 10 percent of the time.

   a) If circuit switching is used, what is the maximum number of users N the link can support?

      Solution $N = \frac{150kbps \text{ per user}}{3Mbps} = \frac{150kbps \text{ per user}}{3000kbps} = 20$ users.

   b) For the remainder of this problem, suppose packet switching is used. What is the probability that a given user is transmitting?

      Solution $p = 0.1$

   c) Suppose the network contains 120 users. What is the probability that, at any given time, exactly n users are transmitting simultaneously? (*Hint:* Use the binomial distribution.)

Solution $P(X=n) = \binom{120}{n}(0.1)^n(1-0.1)^{(120-n)}$

d) What is the probability that 21 or more users are transmitting simultaneously?

Solution $P(X>20) = \sum_{n=21}^{120}\binom{120}{n}(0.1)^n(1-0.1)^{(120-n)} \approx 0.0079$

3. Consider an application that transmits data at a steady rate (for example, the sender generates an N-bit unit of data every k unites of time, where k is small and fixed). Also, when such an application starts, it will continue running for a relatively long period of time. Answer the following questions, briefly justifying your answer:

a) Would a packet-switched network or a circuit-switched network be more appropriate for this application? Why?

Solution A circuit-switched network would be well suited to the application, because the application involves long sessions with predictable smooth bandwidth requirements. Since the transmission rate is known and not bursty, bandwidth can be reserved for each application session without significant waste. In addition, the overhead costs of setting up and tearing down connections are amortized over the lengthy duration of a typical application session.

b) Suppose a packet-switched network is used and the only traffic in this network comes from applications like that describe above. Furthermore, assume the sum of the application data rates is less than the capacities of each and every link. Is some form of congestion control needed? Why?

Solution In the worst case, all the applications simultaneously transmit over one or more network links. However, since each link has sufficient bandwidth to handle the sum of all of the applications' data rates, no congestion (very little queuing) will occur. Given such generous link capacities, the network does not need congestion control mechanisms.

4. What advantages does packet switching have over circuit switching?

Solution Much better resource sharing, accounts for idle users, and can support many more users on the same infrastructure.

5. Why do you think the store-and-forward packet switching method might be more common in routers than continuous transmission?

Solution Continuous transmission would be much more difficult since packet-switched networks do **not** know where packets are to be routed beforehand. As a result, a switch needs to be able to inspect the packet to determine which link on which to send it.

6. Suppose there is exactly one packet switch between a sender and receiver. The transmission rates between the sender and the switch and between the switch and receiver are R_1 and R_2 respectively. Assuming the switch uses store-and-forward packet switching, what is the total end-to-end delay to send a packet of length L (ignoring queueing, propagation, and processing delays)?

Solution delay $= \frac{L}{R_1} + \frac{L}{R_2}$

7. We saw that Equation 1 gives the formula for the end-to-end delay of sending one packet of length L over N links of transmission rate R. Generalize this formula for sending P such packets back-to-back over the N links.

$$d_{end-to-end} = N\frac{L}{R} \tag{1}$$

Solution $d_{end-to-end} = (P - 1 + N)\frac{L}{R}$

8. Suppose you need to deliver a 40-terabyte data set from Boston to Los Angeles. You have available a 100 Mbps dedicated link for data transfer. Would you prefer to transmit the data via this link or instead use FedEx over-night delivery? Explain.

Solution 40 terabytes = $40 * 10^{12} * 8$ bits. So, if using the dedicated link, it will take $40 * 10^{12} * 8/(100 * 10^6) = 3200000$ seconds = 37 days. But with FedEx overnight delivery, you can guarantee the data arrives in one day, and it should cost less than $100.

"Never underestimate the bandwidth of a station wagon full of tapes hurtling down the highway." – Tannenbaum

3 The Layered Internet

1. What are the five layers of the Internet protocol stack? What are the principal responsibilities of each of these layers?

Solution Physical → pushing bits on the wire. Link → protocols for sending data between adjacent devices. Network → routing data between remote networks. Transport → providing a "direct connection" between network applications. Application → user-facing applications.

2. What are the seven layers of the OSI model? How do these layers differ from those in the Internet protocol stack?

Solution Five layers of the TCP/IP stack plus session and presentation between transport and application. These additional layers break out responsibility for "episodes of interaction" and mechanics for changing how data is presented. The TCP/IP stack combines these additional layers into the application layer.

3. What is an application-layer message? A transport-layer segment? A network-layer datagram? A link-layer frame?

Solution An application-layer message is the data to be communicated between applications (e.g., web pages). A transport segment contains the app-layer message plus port information and optional control data (e.g., checksums and message IDs). Network datagrams encapsulate the segment within a larger packet augmented with source and destination information. The link-layer frame contains data from all other layers as well as physical addressing information (e.g., hardware addresses).

4. Which layers in the Internet protocol stack does a router process? Which layers does a host process?

Solution The router processes the physical, link, and network layers. Some routers that support firewalls or network address translation (NAT) also process the transport layer. Hosts process all layers from physical up to application.