Instructions

Read Chapter 1 in your textbook and the relevant lecture slides. Answer the questions below *individually*. The goal is to have you think about the problems, not cover every eventuality. Shoot for short, succinct answers that address the root of the question. Please, submit your **typed** answers into the Dropbox on D2L into the "Homework Assignment 1" folder.

Questions

1. Why are Internet standards important?

   Solution: Bradley Adams: Standardization of protocols allows for communication between different networks to occur. If there were no standards then each network would have it's own way of communicating within itself that may not be compatible with other networks and thus would not allow for a very large network such as the Internet to exist.

2. What are the five layers of the Internet protocol stack discussed in class? What are the principal responsibilities for each of these layers?

   Solution: Sarah Morrison-Smith:

   - Application layer: contains network applications and application-layer protocols. Applications use the protocol to exchange messages (packets of information) with other applications.
   - Transport layer: transports messages between application endpoints (end to end communication). Transport-layer data packets are called segments. Depending on hether or not TCP is used as the transport protocol (as opposed to UDP), the transport layer guarantees delivery of messages and congestion-control.
   - Network layer: transports segments from source hosts to destination hosts. The network-layer is passed the segment and destination address from the transport-layer. Network-layer data packets are called datagrams. The IP protocol (located in the network layer) defines datagram fields and defines how end routers and systems will end on the fields. Routing protocols (also in the network layer) specify routes between sources and destinations for datagrams.
   - Link layer: moves datagrams from one host or router (node) to the next done in the route. Network-layer data packets are called frames. Additional services provided by the link layer, such as reliability, depend on the specific protocol used.
   - Physical layer: moves the individual bits within a frame from one node to the next. Protocols used depend on the link and transmission medium (twisted copper wire, coaxial cable etc).

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

4. In this problem, we consider sending real-time voice from Host A to Host B over a packet-switched network (VoIP). Host A converts analog voice to a digital 64 kbps bit stream on the fly. Host A then groups the bits into 56-byte packets. There is one link between Hosts A and B; its transmission rate is 2 Mbps and its propagation delay is 10 msec. As soon as Host A gathers a packet, it sends it to Host B. As soon as Host B receives an entire packet, it converts the packet's bits to an analog signal. How much time elapses from the time a bit is created (from the original analog signal at Host A) until the bit is decoded and played back as part of the analog signal at Host B?

Solution: Consider the first bit in a packet. Before this bit can be transmitted, all of the bits in the packet must be generated. This requires

`56*8bits/64kbps = 7ms`

The time required to transmit the packet is:

`56*8bits/2Mbps = .224ms`

Propagation delay = `10ms`. The delay until decoding is

`7ms + .224ms + 10ms = 17.224 ms`

5. Suppose there are M disjoint paths between client and server. Path $k \in [1, M]$ consists of N links with capacities $r_1^k, r_2^k, \ldots, r_N^k$. What is the achievable download rate (formula) if the client can:

   (a) Use one path at a time?

   Solution: The download rate on path k is the the rate of its bottleneck link, or

   $$\min_{i \in [N]} r_i^k$$

   However, the achievable rate on any one path is the maximum of all bottleneck links, or

   $$\max_{k \in [M]} \min_{i \in [N]} r_i^k$$

   (b) Use K paths in parallel?

   Solution: To find the achievable rate for K parallel paths, we need to chose a set of paths with the highest sum of download rates, or

   $$\max_{I \in \binom{M}{K}} \sum_{k \in I} \min_{i \in [N]} r_i^k$$

6. Consider a path of L links each with loss probability p due to interference.

   (a) What is the probability that a packet transmitted by the client does not reach the server?

Solution: Alexander Henning: Let P(fail) = probability that packet does not reach the server. We can represent P(fail) as 1 - P(success). P(success) or the probability that the packet reaches the server would be $(1-p)^L$. Therefore we have P(fail) $= 1 - ((1-p)^L)$.

(b) Assume that a client sends a message segmented into four packets. What is the probability the message will get through to the server without any retransmissions?

Solution: Alexander Henning: Using our equation from part (a) for the probability of success, P(success) $= (1-p)^L$, we now must consider that each of the four packets must arrive for the message to be received. Therefore we have P(success)^4 or $((1-p)^L)^4$.