CSE 434 – TTh 9:15 AM
Homework #1 Sample Solution
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Please email Catherine (cwen@asu.edu) if you have questions about the sample solution.

1. *(1.1)* **Imagine that you have trained your St. Bernard, Bernie, to carry a box of three 8mm tapes instead of a flask of brandy. (When your disk fills up, you consider that an emergency.) These tapes each contain 7 gigabytes. The dog can travel to your side, wherever you may be, at 18 km/hour. For what range of distances does Bernie have a higher data rate than a transmission line whose data rate (excluding overhead) is 150 Mbps?**

1 gigabyte = 2^{30} byte = 1 073 741 824 byte

A data tape carries 7 GB. Since a dog can carry 3 tapes at a time, he can carry $3*7*(8*2^{30})$ bits per load, at a rate of 18 km / hour (or 0.005 km / second). Let x be the distance Bernie travels. We need to determine for what range of distances Bernie have a data rate higher than 150 Mbps (or $150*10^6$ bps), that is,

$$\frac{3 \times 7 \times \left(8 \times 2^{30}\right) bits \times 0.005 km \,/\, \sec}{x km} \rangle 150 \times 10^6 \, bits / \sec$$

Solve to obtain

x < 6.01km

(1.5) **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 10 microseconds, 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 a vacuum (3 x 10^8 m/sec).**

The distance between SJC airport (San Jose, CA) and JFK airport (New York, NY) is 2968.2 miles (or 4749.1 km). So the time for a signal from client to server (without switching) is

$$4749.1 * 1000 / (\frac{2}{3} * 300000000) = 0.09498s = 95ms$$

10 microsecond : 95ms is approximately 1 : 10^4, so the 10 microsecond switching time to store and forward packets is unlikely to have a significant effect on the response of the client-server system unless thousands of switches occur along the way. The more significant factor in the response delay is the propagation speed and distance between the client and server.

2. ***(1.8)*** **A collection of five routers is 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 100 ms of computer time to generate and inspect each topology, how long will it take to inspect all of them?**

Each router can connect with potentially 4 other routers in the subnet. Each of these offers 4 connection options: high, medium, low, or none.

There are five routers, and the designers must make a decision about the connection between each pair of routers. That means there are $\binom{5}{2} = 10$ decisions to make. Each decision is assumed to be independent, so there are 4 independent possible outcomes for each of the 10 decisions; therefore, there are 4^{10} = 1,048,576 topologies that the designers could choose from. If it takes 100ms to inspect each topology (top), it will take $1048576 tops * \frac{100ms}{top} * \frac{1\sec}{1000ms} = 104{,}857.6$ seconds, or about 29.13 hours to inspect all of the topologies.

(1.10) **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 are wasted due to collisions?**

The probability that a time slot is wasted is equal to the probability that more than one host tries to use the channel during that time slot. That equals 1 – (probability that one or zero hosts try to use the channel during the time slot). Call f(x) the probability that x hosts try to use the channel during the time slot. If p is the probability that a host tries to use the channel, and there are n hosts, then,

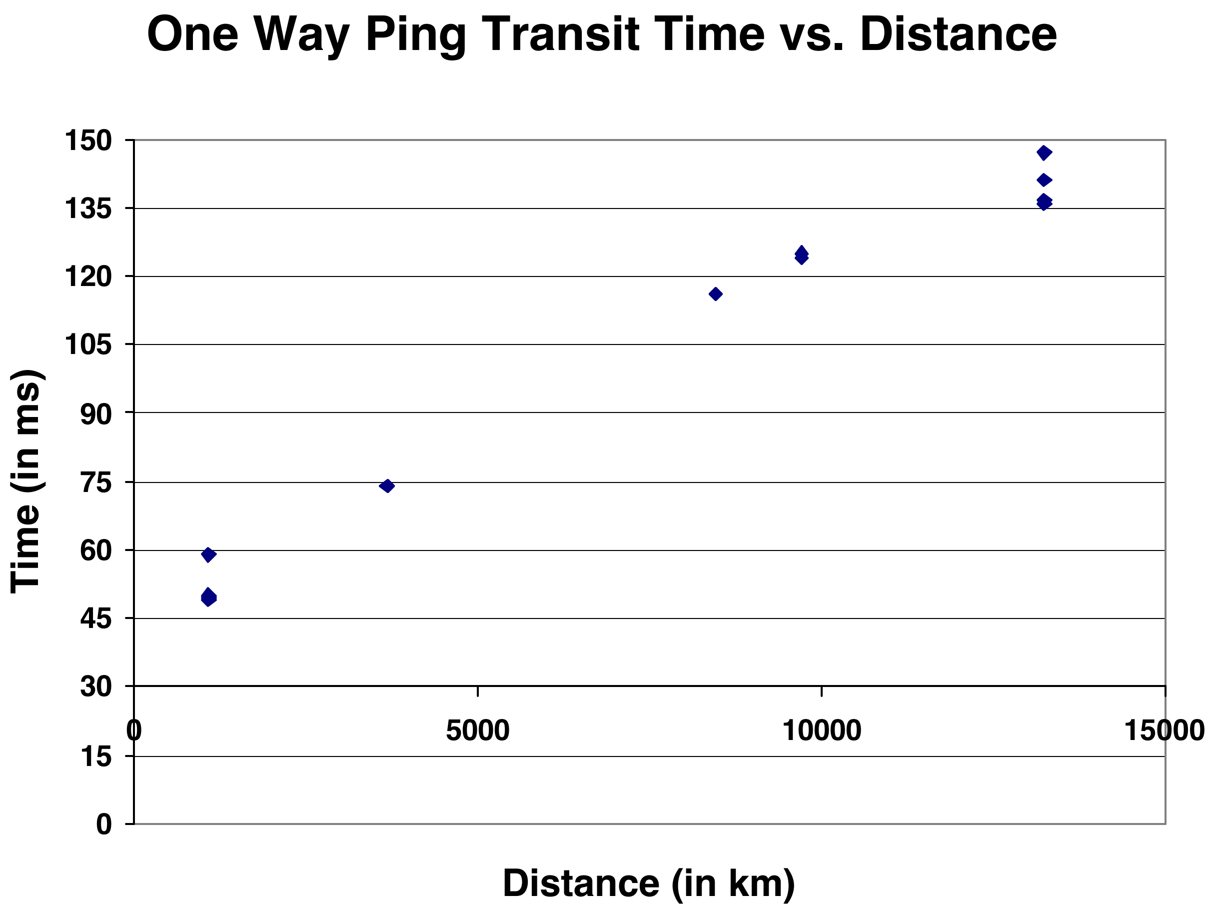
f(x) = $\binom{n}{x} p^x (1-p)^{n-x}$

So f(0) = $\binom{n}{0} p^0 (1-p)^{n-0} = (1-p)^n$ and f(1) = $\binom{n}{1} p^1 (1-p)^{n-1} = np(1-p)^{n-1}$

The probability that one or zero hosts try to use the channel during the time slot, then, is f(0) + f(1) = $(1-p)^n + np(1-p)^{n-1}$. The problem that more than one host tries to use the channel during the time slot is 1 – [f(0) + f(1)] = 1 – $[(1-p)^n + np(1-p)^{n-1}]$. The result represents the probability that one slot is wasted. It also represents the fraction of time slots that are wasted on collisions.

3. *(1.35)* **The *ping* program allows you to send a test packet to a given data location and see how long it takes to get there and back. Try using *ping* to see how long it takes to get from your location to several known locations. From this data, plot the one-way transit time over the Internet as a function of distance. It is best to use universities since the location of their servers is known very accurately. *Berkely.edu* is in Berkeley, California, *mit.edu* is in Cambridge, Massachusetts, v*u.nl* is in Amsterdam, The Netherlands, *www.usyd.edu.au* is in Sydney, Australia, and *www.uct.ac.za* is in Cape Town, South Africa.**

Location	Distance (in km)	Time (in ms)
Berkeley, Cal.	1075	49
(Berkeley.edu)	1075	50
	1075	49.5
	1075	49
MIT – Cambridge, Mass.	3671	74
(mit.edu)	3671	74
	3671	74
	3671	74
University of Cambridge	8456	116
(www.cam.ac.uk)	8456	116
	8456	116
	8456	116
Moscow State University	9705	124
(www.msu.ru)	9705	125
	9705	125
	9705	124
Melbourne, Australia	13245	141
(www.unimelb.edu.au)	13245	136
	13245	147
	13245	136.5



4. *(1.28)* **An image is 1024 x 768 pixels with 3 bytes/pixel. Assume the image is uncompressed. How long does it take to transmit it over a 56-kbps modem channel?**

The image is comprised of 1024x768 = 786432 pixels, each pixel composed of 3 bytes, or 24 bits. Then the image's total size is 786432 x 3 = 18874368 bits.

Then the image takes $\frac{18874368 bits}{56000\, bits/_{\sec}} = 337 \sec$ to send over a 56-kbps modem channel.

Over a 1-Mbps cable modem?

The image takes $\frac{18874368 bits}{10^6\, bits/_{\sec}} = 18.874$ seconds to send over a 1-Mbps cable modem.

Over a 10-Mbps Ethernet?

The image takes $\frac{18874368 bits}{10^7 \ bits/_{\text{sec}}} = 1.8874$ seconds to send over a 10-Mbps Ethernet.

Over 100-Mbps Ethernet?

The image takes $\frac{18874368 bits}{10^8 \ bits/_{\text{sec}}} = 188.74$ milliseconds to send over a 100-Mbps Ethernet.

5. ***(2.4)* If a binary signal is sent over a 3-kHz channel whose signal-to-noise ratio is 20 dB, what is the maximum achievable data rate?**

According to Shannon's Theorem on page 90 of the textbook, the maximum number of bits/sec $= H \log_2 (1 + S/N)$ where H is the bandwidth is H Hz, and the signal-to-noise ratio is S/N.
The ratio S/N can be found by the function that determines decibels: $dB = 10 \log_{10} S/N$
$20 dB = 10 \log_{10} S/N \rightarrow 2 dB = \log_{10} S/N \rightarrow 100 = S/N$
So the maximum achievable data rate here is $= (3000\ Hz) \log_2 (1 + 2)$
$= (3000 Hz) * \frac{\log 21}{\log 2}$
$= 19.974 kbps$. This upper limit is the maximum transmission rate no matter how many signal levels are used, or how frequently samples are taken.

Since we know the signal is binary, we can use Nyquist's theorem on page 89 to check the upper bounds of the transmission rate on a perfect channel at 3-kHz. According to Nyqust's theorem, the maximum achievable data rate on a channel with no noise is:

$= 2H * \log_2 V$ bits/sec
$= 2(3000 Hz) * \log_2 2$
=6000 bps

Nyquist's theorem appears to say that even on a flawless channel with no noise, the maximum rate at which a binary signal can be sent is 6000 bps. This is a much lower bound than the limit given by Shannon's theorem, giving a max data rate of 6 kbps for this channel.