Problem 1

Suppose users share a 10 Mbps link. Also suppose each user requires 1 Mbps when transmitting, but each user transmits only 20 percent of the time.

(a) When circuit switching is used, how many users can be supported?

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

(c) Suppose there are 100 users. Find the probability that at any given time, exactly n users are transmitting simultaneously. (Hint: Use the binomial distribution)

(d) Find the probability that there are 21 or more users transmitting simultaneously.

Write your solution to Problem 1 in this box

a) 10 users can be supported because circuit switching requires a dedicated communication channel for each user

$$\frac{10 \text{ Mbps}}{1 \text{ Mbps/user}} = \boxed{10 \text{ users}}$$

b) The probability that a given user is transmitting is $\boxed{.2}$ b/c each user transmits 20% of the time

c) $\boxed{P(n) = \binom{100}{n}(.2)^n(.8)^{100-n}}$

This is a binomial PMF with parameters n and p

This is Binom(100, .2)

d) $P(n \geq 21) = 1 - P(n < 21)$

$$= 1 - \sum_{n=0}^{20} \binom{100}{n}(.2)^n(.8)^{100-n}$$

$$= 1 - .55946 = \boxed{.4405}$$

This number was calculated using an online calculator for binomial distributions found at:

http://stattrek.com/online-calculator/binomial.aspx

Problem 2

Queuing delay.

(a) Suppose N packets arrive simultaneously to a link at which no packets are currently being transmitted or queued. Each packet is of length L and the link has transmission rate R. What is the average queuing delay for the N packets?

(b) Now suppose that N such packets arrive to the link every $\frac{LN}{R}$ seconds. What is the average queuing delay of a packet?

Write your solution to Problem 2 in this box

a) The first packet will have a queueing delay of 0 b/c it can be transmitted immediately

The 2nd packet will have a queueing delay of $\frac{L}{R}$ because it must wait for the 1st packet to send before it can be sent

Here, we note the fact that $\frac{L}{R}$ is the transmission delay for 1 packet

For the 3rd packet we have a queueing delay of $2\left(\frac{L}{R}\right)$ since we have to wait for the transmission delay of 2 packets in front of this one

In general, average queueing delay will be

$$\frac{\frac{L}{R}\left(1+2+\ldots+(N-1)\right)}{N} = \frac{L}{RN}\left(\frac{N(N-1)}{2}\right)$$

$$\boxed{= \frac{L(N-1)}{2R}}$$

Note: $(1+2+\ldots+(n-1)) = \frac{n(n-1)}{2}$

b) Note that N such packets takes $\frac{LN}{R}$ to transmit, and so the queue is empty every time a new batch of N packets arrives. Therefore, the average queueing delay over all packets is actually the same as the average queueing delay for a group of N packets arriving simultaneously. From the previous question, the queueing delay will be $\boxed{\frac{L(N-1)}{2R}}$

Problem 3

Review the car-caravan analogy in lecture #1 slides (for Chapter 1). Assume a propagation speed of 100 km/h.

(a) Suppose the caravan (10 cars) travels 150 km, beginning in front of one tollbooth, passing through a second tollbooth, and finishing just after a third tollbooth. The distance between two tollbooths is 75 km. Each car takes 12 sec to serve. What is the end-to-end delay?

(b) Repeat (a), now assuming that there are 8 cars in the caravan instead of 10.

Write your solution to Problem 3 in this box

a) First, we find the delay to service all cars, this is analogous to the transmission delay:

(10 cars) (12 seconds/car) = 120 seconds = 2 min

Then, the propagation delay for the cars to line up behind the second toll booth is:

$$\frac{75 \text{ km}}{100 \text{ km/h}} = .75 \text{ h} = 45 \text{ min}$$

Taking into account the three tollbooths and the two propagations, we have: (2 min/booth)(3 toll booths) + (45 min/prop)(2 props)

$\boxed{= 96 \text{ min}}$

b) Repeating the above with 8 cars in the caravan yields:

(8 cars) (12 seconds/car) = 96 seconds

(45 min/prop)(2 props) + (96 seconds/booth) (3 booths)

= 90 min + 288 seconds = 94.8 min

$\boxed{= 94 \text{ min } 48 \text{ seconds}}$

Problem 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 (as part of the analog signal at Host B)?

Write your solution to Problem 4 in this box

For the first bit to be sent along communication channel, we must first wait for an entire packet to be created. this takes:

$$\frac{(56 \text{ bytes})(8 \text{ bits / byte})}{64000 \text{ bits / sec}} = .007 \text{ sec} = 7 \text{ms}$$

Then, the time required to transmit the packet, or the transmission delay, can be calculated as follows:

$$\frac{(56 \text{ bytes})(8 \text{ bits / byte})}{2000000 \text{ bits / sec}} = .000224 \text{ sec} = .224 \text{ ms}$$

Then, the propagation delay for the link is 10 ms

Adding these values together we find that the elapsed time from when a bit is created until the bit is decoded is:

$$10 \text{ms} + 7 \text{ms} + .224 \text{ms} = \boxed{17.224 \text{ms}}$$

Problem 5

Suppose you would like to urgently deliver 50 terabytes data from Boston to Los Angeles. You have available a 1 Gbps dedicated link for date transfer. Would you prefer to transmit the data via this link or to use FedEx overnight delivery instead? Explain your choice.

Write your solution to Problem 5 in this box

We need to compare the time it takes to transmit the data under both scenarios.

1. FedEx - presumably 1 day
2. 1 Gbps Link

50 terabytes (10^{12} bytes/terabyte) (8 bits/byte) = $400 \cdot 10^{12}$ bits

$$\frac{50\,(10^{12})(8)}{1 \cdot 10^{9}} = \frac{400 \cdot 10^{12}}{10^{9}} = 400 \cdot 10^{3} \text{ seconds}$$

$$\frac{400000 \text{ seconds}}{86400 \text{ sec/day}} = 4.629 \text{ days}$$

Therefore, it would make sense to choose $\boxed{\text{overnight delivery}}$ if all you care about is the time for delivery.