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. The link can support $\frac{10 \text{ Mbps}}{1 \text{ Mbps/user}} = \boxed{10 \text{ users}}$

b. A given user has a $\boxed{0.20}$ probability of transmitting at a given moment.

c. $\boxed{\binom{100}{n}(1-0.2)^{100-n}(0.2)^n}$

d. ~~probability of 20 n~~

probability of 0-20 users: $\sum_{k=0}^{20}\binom{100}{k}(1-0.2)^{100-k}(0.2)^k$

probability of 21+ users:

$$\boxed{1-\sum_{k=0}^{20}\binom{100}{k}(1-0.2)^{100-k}(0.2)^k}$$

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. For the first packet, the queuing delay is 0.
The queuing delay for the next packet is L/R.
The queuing delay for the packet after is $2L/R$.
For the n^{th} packet, the queuing delay $(N-1)L/R$.
Average delay:

$$\frac{\left(\frac{L}{R} + \frac{2L}{R} + \dots + \frac{(N-1)L}{R}\right)}{N} = \sum_{k=1}^{N-1} \frac{kL}{NR} = \frac{L}{R}\sum_{k=1}^{N-1} k$$

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

b. N packets arrive every ~~at~~ $\frac{LN}{R}$ seconds.
The batch is transmitted ~~at a rate of~~ every $\frac{NL}{R}$ seconds, meaning after $\frac{NL}{R}$ seconds, the queue is empty. Since the packets arrive ~~at~~ to an empty queue, the average queuing delay is the ~~to~~ average queuing delay for the batch of N packets is $\boxed{L(N-1)/2R}$.

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. $\frac{12 \text{ sec}}{\text{car}} \cdot 10 \text{ cars} = 120 \text{ sec} = 2 \text{ min}$ / toll booth

$\frac{75 \text{km}}{100 \frac{\text{km}}{\text{hr}}} = \frac{3}{4} \text{hr} = 45 \text{min}$ from one toll booth to the other

$2(45 \text{min}) + 3(2 \text{min}) = \boxed{96 \text{ min}}$

b. $\frac{12 \text{ sec}}{\text{car}} \cdot 8 \text{ cars} = 96 \text{ sec}$

$\frac{75 \text{km}}{100 \frac{\text{km}}{\text{hr}}} = \frac{3}{4} \text{hr} = 45 \text{min}$

$2(45 \text{min}) + 3(96 \text{ sec})$

$= 90 + 4.8 \text{ min} = \boxed{94.8 \text{ min}}$

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

convert bytes to bits: $56 \text{ bytes} \cdot \frac{8 \text{ bits}}{1 \text{ byte}} = 448 \text{ bits}$

Waiting for Bit Stream: $448 \text{ bits} \cdot \frac{1 \text{ sec}}{64000 \text{ b}} = 0.007 \text{ sec}$

Transmission Delay: $448 \text{ bits} \cdot \frac{1 \text{ sec}}{2 \text{ Mb}} \cdot \frac{1 \text{ Mb}}{10^6 \text{ b}} = 0.000224 \text{ sec}$

Propagation Delay: 0.01 sec

Total Delay: $0.007 + 0.000224 + 0.01 = \boxed{0.017224 \text{ sec}}$

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

$$\frac{1\text{ Gb}}{\text{sec}} \times \frac{0.001\text{ Tb}}{1\text{ Gb}} = 0.001\text{ Tb/sec}$$

$$50\text{TB} \cdot \frac{8\text{ bit}}{1\text{ byte}} = 400\text{Tb}$$

$$400\text{Tb} \cdot \frac{1\text{ sec}}{0.001\text{ Tb}} = 400{,}000\text{ sec} = 111.11\text{ hours}$$

I would use FedEx overnight delivery service instead because that would take less time than ~~using~~ the link, which would take 111 hours.