Problem 1

Suppose users share a 100 Mbps link. Also suppose each user requires 10 Mbps when transmitting, but each user transmits only 25% 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 (Hint: only the formula is required).

(a) $\because \frac{100 \text{ Mbps}}{10 \text{ Mbps}} = 10$

$\therefore$ There are 10 users can be supported.

(b) The probability that a given user is transmitted is $p = 25\%$.

(c) According to Binomial Theorem, the probability is:

$$P_n = \binom{100}{n} 0.25^n (1-0.25)^{100-n} = \frac{100!}{n!(100-n)!} \cdot 0.25^n \cdot 0.75^{100-n}.$$

(d) The probability is 1 minus the probability of 20 or less users are simultaneously transmitting, which is:

$$P_{(n \geq 21)} = 1 - \sum_{i=0}^{20} \binom{100}{i} 0.25^i (1-0.25)^{100-i}$$

Given that the users are either transmitting or not transmitting, we can say that the probability is basically normal distributed.

Therefore, $\text{z-score} = \frac{20 - 100 \times 0.25}{\sqrt{100 \times 0.25 \times (1-0.25)}} = \frac{-5}{4.33} = -1.15$

$$P_{(n>20)} = P(z > -1.15) = 0.845$$

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 N packets?

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

(a) Since all packets arrive simultaneously, they are put in a queue and are processed one at a time. Then for each packet, the wait time is:

$1^{st}: L/R, \quad 2^{nd}: 2L/R, \quad 3^{rd}: 3L/R, \ldots \quad N^{th}: N\cdot L/R.$

Therefore, the total queuing delay is $(1+2+3+\cdots+N)L/R = \frac{(1+N)\cdot N\cdot L}{2R}$.

So the average queuing delay is $\frac{(1+N)\cdot N\cdot L}{2R\cdot N} = \frac{(N+1)\cdot L}{2R}$

(b) The total time for each batch's queuing delay is $\frac{N\cdot L}{R}$, which is exactly the same of the time each batch arrives.

So each time a batch arrives, the previous batch has just already done the transmitting. Therefore, the average queuing delay is the same as the previous one: $\frac{(N+1)\cdot L}{2R}$.

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 (5 cars) travels 100 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 50 km. Each car takes 12 sec to serve. The caravan can only dispatch a tollbooth after all cars in the caravan are served. What is the end-to-end delay (from when the caravan is lined up before 1st tollbooth till the caravan is served by the 3rd tollbooth)?

(b) Repeat (a), now assuming that there are 8 cars in the caravan instead of 5.

(a) The propagation time is 100km/(100km/hr) = 1 hr = 60 min.
The total dispatch time for the 3 tollbooths is 3×5×12 sec = 180 sec = 3 min
So in all, the end-to-end delay is 60 min + 3 min = 63 min

(b) The propagation time is 100km/(100km/hr) = 1 hr = 60 min.
The total dispatch time for the 3 tollbooths is
3×8×12 sec = 288 sec = 4 min 48 sec. So in all, the end-to-end delay is
60 min + 4 min 48 sec = 64 min 48 sec

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, which means it take 1 second to create 64K bits from the analog signal. 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 56-byte 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 the first bit of one packet is created (from the original analog signal at Host A) until the packet is received at Host B)?

First, we need to convert the 56-byte $= 56 \times 8$ bits $= 448$ bits large packet in 64000 bits / second rate, so the time is

$\frac{448 \text{ bits}}{64000 \text{ bits/sec}} = 0.007 \text{ sec} = 7 \text{ msec}$

Then, we need to propagate the packet in 2Mbps $= 2 \times 10^6$ bits/sec.

So the time it takes is $\frac{448 \text{ bits}}{2 \times 10^6 \text{ bits/sec}} = 2.24 \times 10^{-4} \text{ sec} = 0.224 \text{ msec}$.

In addition, there are 10 msec delay.

Thus, the total time elapses is $7 + 0.224 + 10 = 17.224$ msec.

Problem 5

Suppose you would like to urgently deliver 50 terabytes data from Boston to Los Angeles. You have available a 2 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.

I prefer the FedEx overnight delivery.
First, the data size is 50 terabytes $= 50 \times 8 \times 10^{12}$ bits.
The data transfer rate is 2 Gbps $= 2 \times 10^{9}$ bits/sec.
Therefore, the time for transferring data via the link is
$\frac{50 \times 8 \times 10^{12} \text{ bits}}{2 \times 10^{9} \text{ bits/sec}} = 2 \times 10^{5} \text{ sec} = \frac{2 \times 10^{5}}{60 \times 60} \text{ hr} = 55 \text{ hr} = 2 \text{ days } 7 \text{ hrs}$,
which is much slower than using the FedEx overnight delivery.
Thus, besides the financial cost of the FedEx delivery, the time cost is much lower for FedEx overnight delivery, so I prefer the FedEx delivery.