CSE 123: Computer Networks

Homework 4

Out: 11/27, Due: 12/4

Total – 48.5 points

Question 1

Assume that we have a token bucket shaper that has a replenishment rate r = 10 KBps, an infinite maximum rate R, a bucket size b = 50 KB, and that the bucket starts off full. Also assume that a sender emits 15KB-packets every 0.5 seconds in a periodic manner, starting at t=0.5 seconds. For the purposes of this question you can assume that if sufficient tokens are available, packets pass through the token bucket instantaneously, otherwise they are queued until there are.

i. How many tokens are left in the bucket after 1.5 seconds? **(3 points)**

ii. How long will it take until packets start to be queued or dropped? **(2 points)**

iii. Now, presume the sender can send as much as they want, whenever they want. If the token bucket is changed to enforce a maximum rate R of 20 KBps, what would the maximum possible burst size be? **(3 points)**

```
i.   At t = 0.5s, the number of tokens in the bucket is
                         (50 - 15) = 35 KB.
     At t = 1.0s, the number of tokens in the bucket is
                   (35 - 15) + (10*0.5) = 25 KB.
     At t = 1.5s, the number of tokens in the bucket is
                   (25 - 15) + (10*0.5) = 15 KB.
     Therefore, after 1.5 seconds, 15KB worth of tokens are
     left in the bucket. (Note here we equate KBps with KB,
     contrary to earlier in the term.  Answers assuming the
     packet size unit KB = 2^1024 bytes while the
     replenishment rate unit, KBps = 10^10 bytes per second,
     are also accepted.)

ii.  Since this is a token bucket shaper, packets will only be
     queued, not dropped. Tracing the sequence of steps as
     mentioned in part (a), packets will start queuing at t =
```

2.5s, as the number of tokens in the bucket at that point in time will not be able to handle the incoming flow.

iii. The maximum possible burst size would be given by

b*R/(R-r)

After simple substitution, we get (50*20)/(20-10), which is 100KB.

Question 2

Suppose a router has three input flows and one output. It receives the packets listed in the following table all at the same time, in the order listed, during a period in which the output port is busy but all queues are otherwise empty. Give the order in which the packets are transmitted, assuming

a. Fair queuing **(5 points in total; 0.5 points for calculation of each F_i, 1 point for final transmitted sequence)**
b. Weighted fair queuing**(7 points in total; 0.75 points for calculation of each F_i, 1 point for final transmitted sequence)**

You should assume that the link rate is 1 byte per second.

Packet	Packet size (in Bytes)	Flow	Weight
1	100	1	1
2	100	1	1
3	100	1	1
4	100	1	1
5	190	2	4
6	200	2	4
7	110	3	1
8	50	3	1

a. First we calculate the finishing times Fi. Fi is calculated as Fi = Fi-1 + Pi (Ai=0 here as all packets arrive at the router at the same time)

Packet	Size	Flow	Fi
1	100	1	100
2	100	1	200
3	100	1	300
4	100	1	400
5	190	2	190
6	200	2	390
7	110	3	110
8	50	3	160

We send packets in increasing order of Fi, the order being

<1, 7, 8, 5, 2, 3, 6, 4>

b. Dividing the flows by their weights, we get the following table

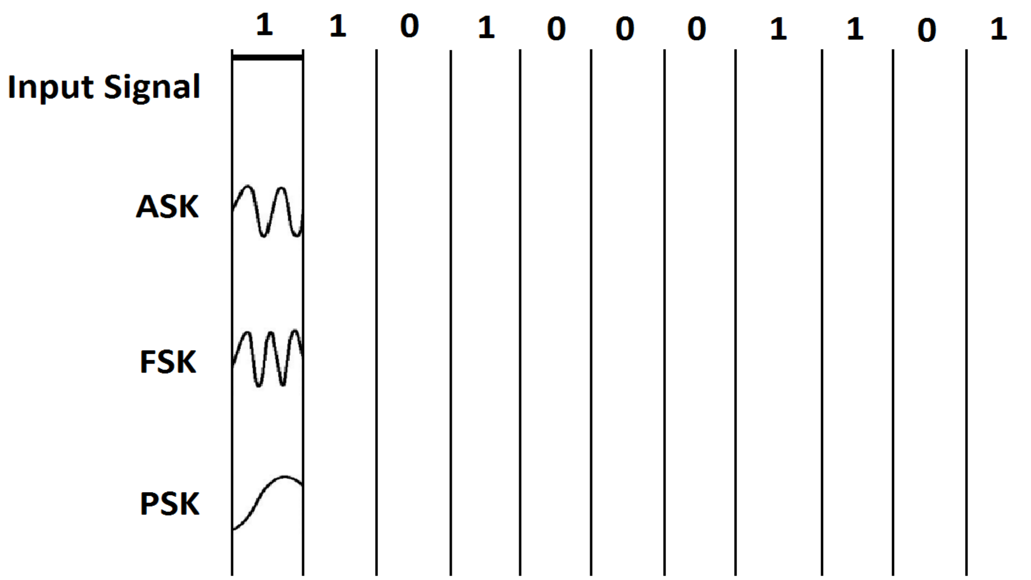
Packet	Size	Flow	Weights	Weighted Fi
1	100	1	1	100
2	100	1	1	200
3	100	1	1	300
4	100	1	1	400
5	190	2	4	47.5
6	200	2	4	97.5
7	110	3	1	110
8	50	3	1	160

We send the packets in increasing order of weighted Fi, the order being

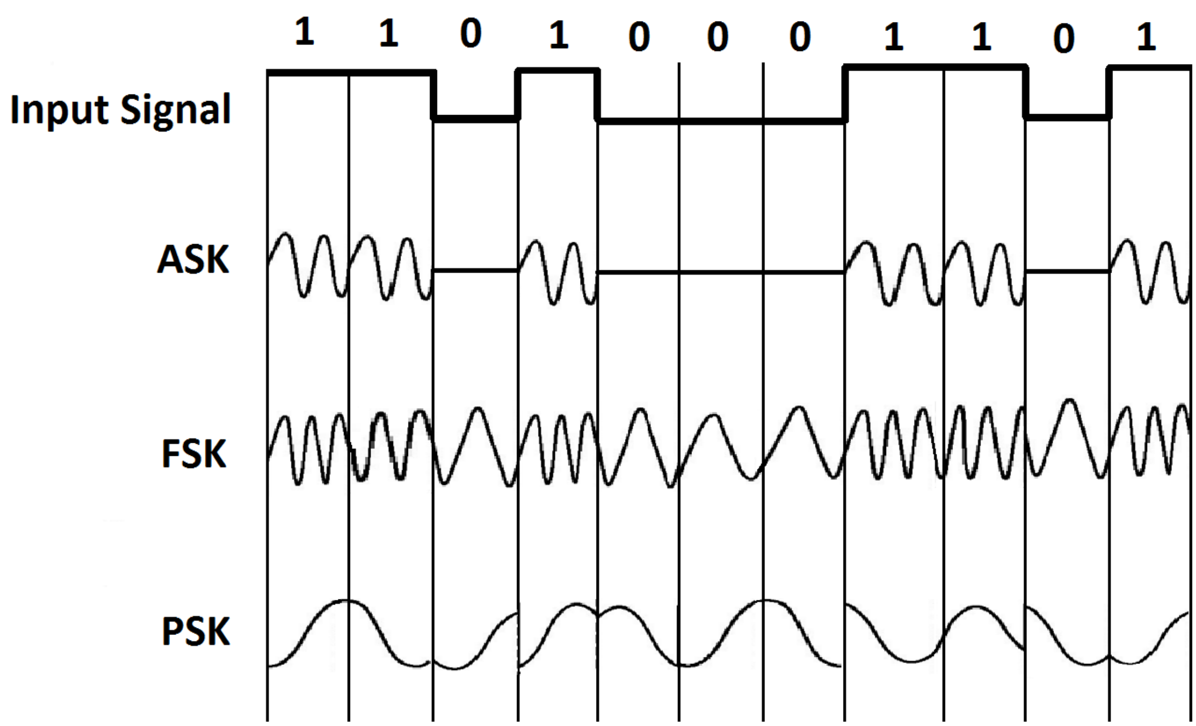
<5, 6, 1, 7, 8, 2, 3, 4>

Question 3

Draw the waveforms of the input signal, and the amplitude shift, frequency shift, and phase shift keying of the input for the input bit sequence that's provided at the top. The waveforms have been provided for the first bit of the sequence, to help you get started. **(8 points in total; 0.2 points for the correct waveform for each symbol, for the input signal and for each type of keying)**

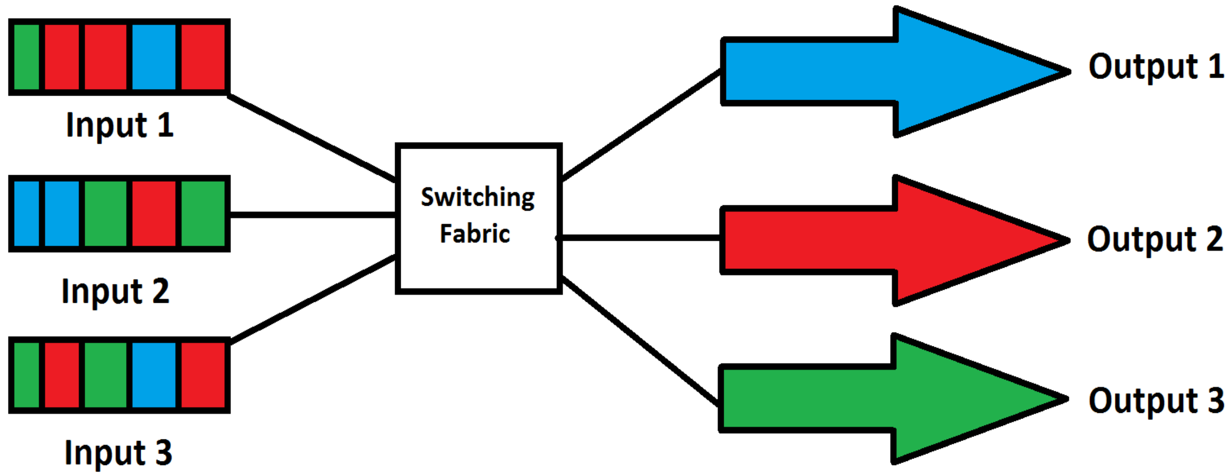


The solution is provided below



Question 4

Suppose we have a router with three input ports and three output ports. Assume all of the output ports operate at the same speed Assume that the blue-colored packets go out on Output 1, red-colored packets go out on Output 2, and green-colored packets go out on Output 3.



a. Assume that the switching fabric works fast enough such that it is able to take a packet from **each** input queue and transfer it to the output in one clock cycle. Also assume the scheduling time to be trivial. Assume a simple scheduling algorithm, wherein:-

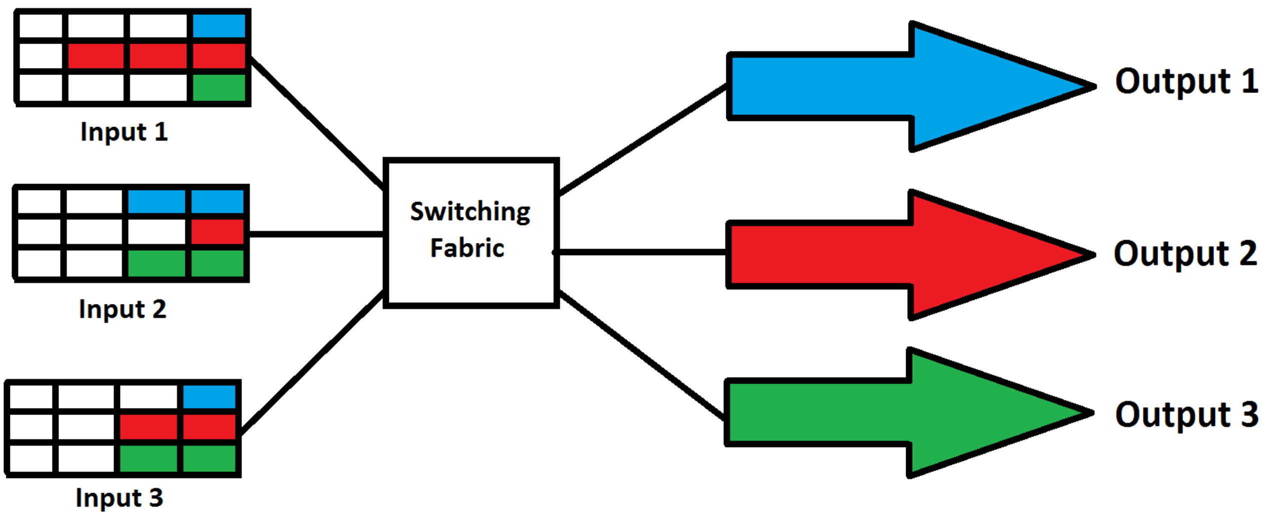
1. If input queue 1 is not empty, send packet at the head
2. If input queue 2 is not empty, send packet at the head unless the packet's corresponding output port is being used at that current clock cycle.
3. If input queue 3 is not empty, send packet at the head unless the packet's corresponding output port is being used at that current clock cycle.

Identify which packet(s) will be transferred at each clock cycle, and in the process, compute the total number of clock cycles needed to output all the packets. **(4.5 points in total; 0.5 points for the correct packets that are sent in each clock cycle)**

```
CC 1 - Input 1 sends red, Input 2 sends green
CC 2 - Input 1 sends blue, Input 2 sends red
CC 3 - Input 1 sends red, Input 2 sends green
CC 4 - Input 1 sends red, Input 2 sends blue
CC 5 - Input 1 sends green, Input 2 sends blue, Input 3 sends red
CC 6 - Input 3 sends blue
CC 7 - Input 3 sends green
CC 8 - Input 3 sends red
```

```
CC 9 - Input 3 sends green
Hence, it takes a total of 9 clock cycles to send the packets
```

b. Now assume that the input queues make use of a virtual output queue. What problem that is faced in part (a) of the problem does this solve? A one line answer would do. Also, assume the same scheduling algorithm as mentioned before, except that each input queue has a virtual output queue that will be scheduled in the preference order of blue, red,and green. Identify which packet(s) will be transferred at each clock cycle, and in the process, compute the total number of clock cycles needed to output all the packets. **(7 points in total; 1 point for the correct packets that are sent in each clock cycle, 1 point for mentioning head-of-line blocking)**



This solution solves the **head-of-line** blocking problem.

```
CC 1 - Input 1 sends blue, Input 2 sends red, Input 3 sends green
CC 2 - Input 1 sends red, Input 2 sends blue, Input 3 sends green
CC 3 - Input 1 sends red, Input 2 sends blue
CC 4 - Input 1 sends red, Input 2 sends green, Input 3 sends blue
CC 5 - Input 1 sends green, Input 3 sends red
CC 6 – Input 2 sends green, Input 3 sends red

It takes a total of 6 clock cycles to send all the packets.
```

Question 5

Consider a RED gateway, where the probability that a packet is dropped when the average queue size is equal to the maximum threshold size of the queue is 10%. Also assume that at the moment the average queue length is a quarter of the distance between the minimum threshold and the maximum threshold.

Now, calculate the following:-

a. The drop probability if the number of newly arrived packets in the queue is
   i. 1
   ii. 30
   (5 points each; 3 points for arriving at the expression for P_{count}, 1 point each for substituting the value of count)
b. The probability that none of the first 10 packets are dropped **(4 points; 2 points for arriving at the telescopic product, 2 points for the final answer)**

For the purposes of simplicity, you don't have to compute the decimal value of the fraction, i.e, find the answer as a fraction.

a. To calculate TempP, the following formula is used:-

$$TempP = MaxP \times \frac{(AvgLen - MinThreshold)}{(MaxThreshold - MinThreshold)}$$

Since AvgLen is a quarter of the distance from the minimum threshold (i.e, at the first quartile), the fraction in the above equation will be 1/4, or 0.25. Multiplying that with MaxP which is 10% will give a value of 0.025.
The drop probability is given by

$$\Rightarrow P_{count} = TempP/(1 - count*TempP)$$
$$\Rightarrow P_{count} = 0.025/(1 - count/0.025)$$
$$\Rightarrow 1/(40 - count)$$

i. Since count = 1, $P_{count} = 1/(40 - 1) = 1/39$
ii. Since count = 30, $P_{count} = 1/(40 - 30) = 1/10$

b. To find the probability that none of the first 10 packets are dropped, we need to find the telescopic product

$$(1-P_1) * (1-P_2) \dots * (1-P_{10})$$

Where P_{count} is calculated as above, i.e.

$$\Rightarrow P_{count} = 1/(40 - count)$$
$$\Rightarrow 1-P_{count} = (39 - count) / (40 - count)$$

Which is given by:-

(38*39) * (37/38) * (36/37) * ……… * (29/30)

This is simplified to get the final fraction 29/39.