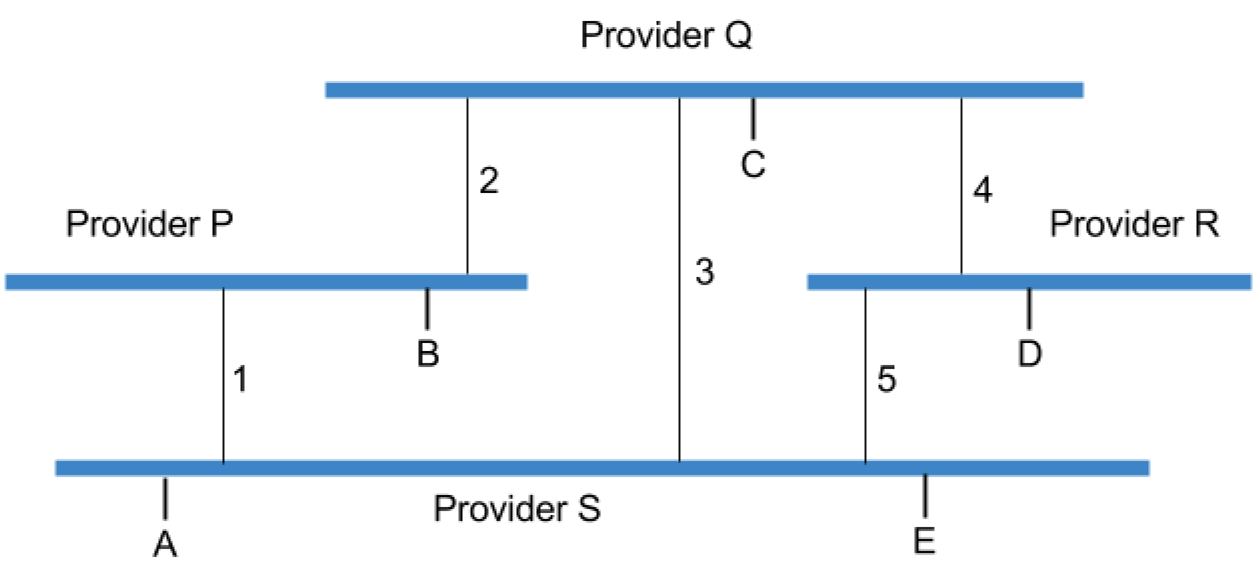
CSE 123: Computer Networks

Homework 3 Solutions

Total points = 50

Problems

1. **BGP Routing [10 points]**
   Consider the network shown below, in which horizontal lines represent Autonomous Systems (AS), and numbered vertical lines are inter-provider links. A, B, C, D, and E are networks connected to a particular provider below (customers within an AS). The numbered links 1, 2, 3, 4 and 5 show the peering links between the providers. For the purposes of this problem, a route can be written as a comma separated path from one provider to another. Ie. the route from C to A through Provider P would be "<Q, P, S>." Take note that in an all-knowing sense there are actually two other routes from C to A, namely <Q,S> and <Q,R,S>, but depending on the business relationships between the providers, only certain routes will be advertised.



a. Suppose that P, Q, R, and S are peer autonomous systems to the other autonomous systems to which they have direct links. Ie. S has a peer relationship to P, Q, and R, but R only has peer relationships to Q and S because it has no direct link to P. Remember, a route can only be used if network's attached provider has received an advertisement for the destination network. If there is no route that would be used, say so.

    i. What route would D use to send traffic to network C?

        <R, Q> only because an AS only advertises its customers to its peers, it doesn't share routes to another peer's customers

    ii. What route would B use to send traffic to network D?

        There is none for basically the same reason as above

b. Now suppose providers P, Q, R, and S adopt the policy that outbound traffic is routed to the "closest" inter-provider link that it knows is on a route to the destination, thus minimizing their own cost (e.g., S would prefer to use link 1 for any outbound traffic from network A because link 1 is closest to A, but it can only use link 1 if there is a known route to the destination that has P next in the route). Assume that relationships are different from part a, so now P, R, and S are all customers of Q. Additionally, P and S are peers, and S and R are peers. If there is no route that would be used, say so.

    i. What route would B use to send traffic to network A?

        <P, Q, S>

    ii. What route would A use to send traffic to network B?

        <S, P>

    iii. What route would D use to send traffic to network E?

        <R, Q, S>

    iv. What route would E use to send traffic to network C?

        <S, Q>

c. Suppose the same as part b above in choosing the “closest” link, except the autonomous system relationships have changed again. Now R is a customer of S and S is a customer of P. Also, Q has peer relationships with P, R, and S. If there is no route that would be used, say so.

   i. What route would C use to send traffic to network B?

      <Q, P>

   ii. What route would C use to send traffic to network D?

      <Q, S, R>

   iii. What route would A use to send traffic to network C?

      <S, P, Q>

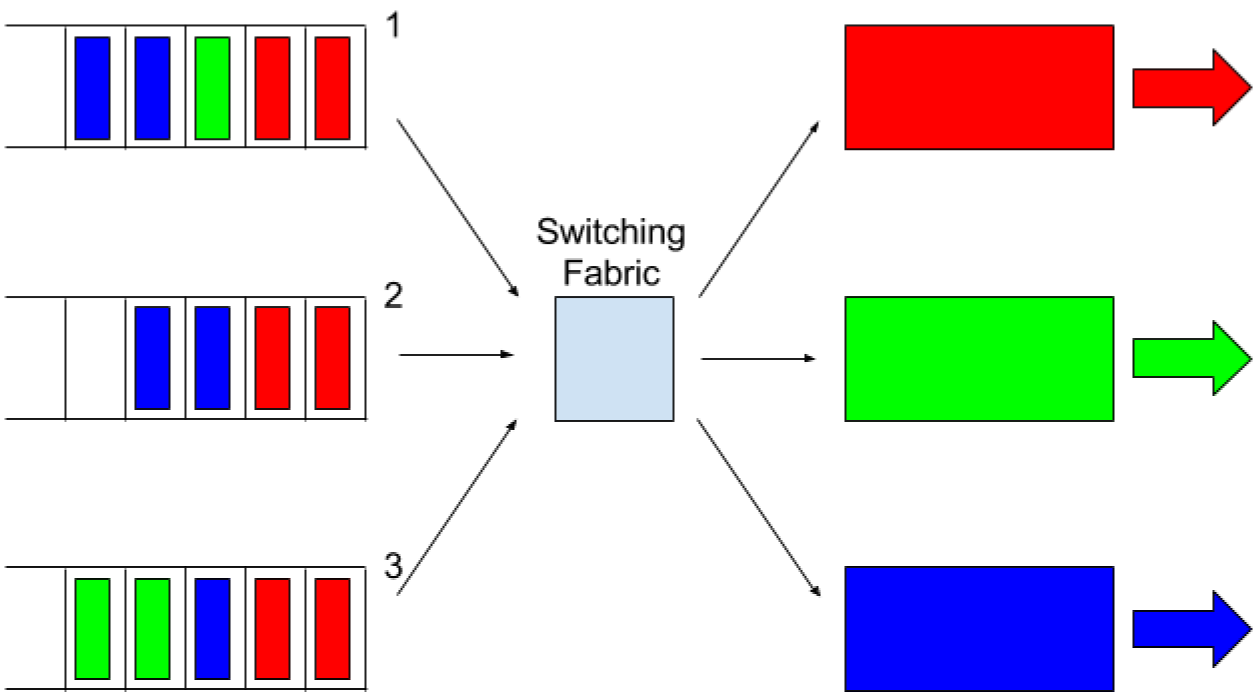
   iv. What route would D use to send traffic to network A?

      <R, S>

10 points total

- 1 point for each answer

2. **Input Queueing and Virtual Output Queueing [8 points]**
   Suppose we have a router with three input ports and three output ports. We will consider one implementation that uses only input queueing for part a and then another implementation that uses input queueing with virtual output queueing for part b. No more packets are entering the input queues. All of the output ports run at the same speed.



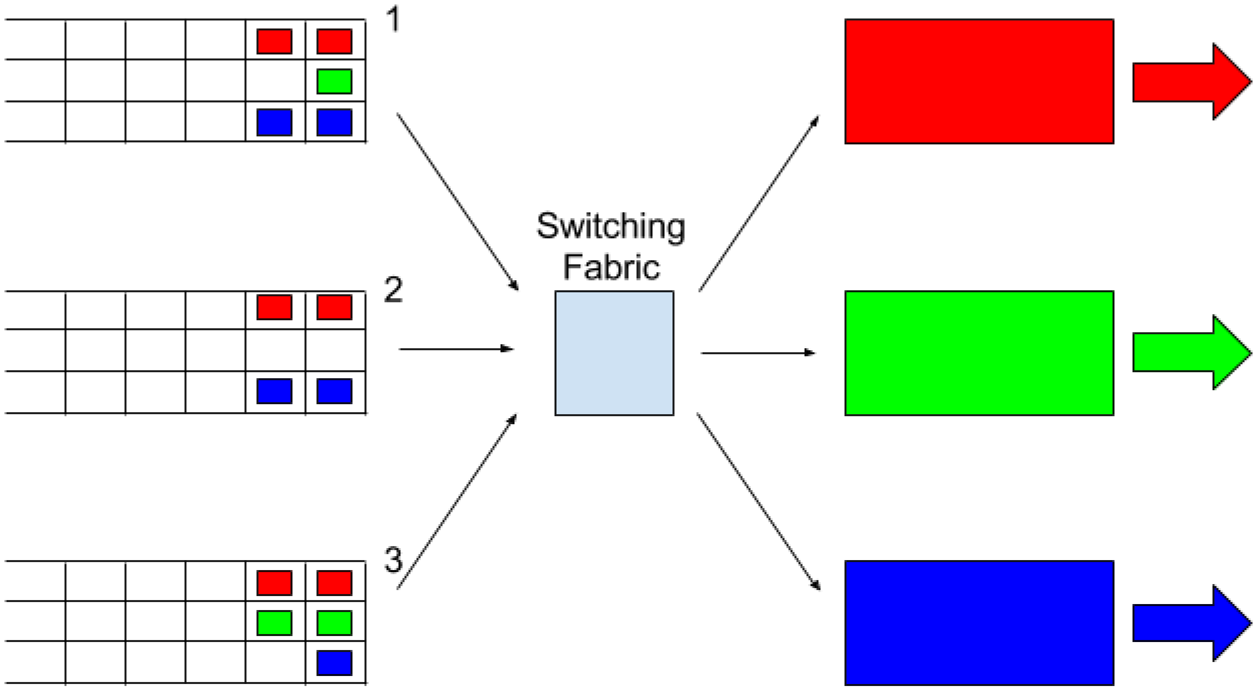
   a. Let's say the switching fabric in the illustration above runs fast enough to take a single packet from each input queue and put it onto each output queue in one "period". For this problem a period will be the time it takes to take a packet from the input queue and finish sending it out of an output queue. Consider scheduling time to be trivial. Assume the scheduling algorithm is as follows for each period (it is unfair, but simple):
      - If input queue 1 is not empty, send whatever is at the head
      - If input queue 2 is not empty, send whatever is at the head unless the output port corresponding to the packet at the head is already being used this period
      - If input queue 3 is not empty, send whatever is at the head unless the output port corresponding to the packet at the head is already being used this period

i. How many periods will it take to empty all of the input queues? Please mention what packets are sent in each period. As an example, in the first period a packet from the red flow is sent from input queue 1 while no packets from input queues 2 and 3 can be sent yet. Thus, you could write, “P1 - 1 sends red”. This signifies that in the first period, P1, input queue 1 has a packet from the red flow sent and nothing is sent from input queues 2 and 3.

Input Queue = IQ, P# = period number

P1- 1 sends red
P2- 1 sends red
P3- 1 sends green, 2 sends red
P4- 1 sends blue, 2 sends red
P5- 1 sends blue, 3 sends red
P6- 2 sends blue, 3 sends red
P7- 2 sends blue
P8- 3 sends blue
P9- 3 sends green
P10- 3 sends green

So it would take 10 periods to empty all of the input queues.



b. Take a moment to realize that the illustration above starts with the same packets in the input queues as in part a except now we are also using virtual output queueing (pay no attention to the change in scale of the packets). Treat everything the same as part a except now each input queue has three virtual output queues that will scheduled in the preference of red, green, then blue.

   i. Now how many periods will it take to empty all of the input queues? Please mention what packets are sent in each period like in part a.

      P1- 1 sends red, 2 sends blue, 3 sends green
      P2- 1 sends red, 2 sends blue, 3 sends green
      P3- 1 sends green, 2 sends red, 3 sends blue
      P4- 1 sends blue, 2 sends red
      P5- 1 sends blue, 3 sends red
      P6- 3 sends red

      So it would take 6 periods to empty all of the queues.

8 points total

- 4 points for part a
- 4 points for part b
- -1 point total if no work
- -1 point if answers are almost right

3. **Scheduling and QoS [8 points]**

Packet #	**Size**	**Flow**
1	100	1
2	140	1
3	180	2
4	120	2
5	60	2
6	110	3
7	80	3
8	90	3

Suppose a router has three input flows and one output. It receives the packets listed in the table above all at about 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 for

a. Fair Queueing.

   Within a given flow we still want to make sure that we send the packets in order. This allows things like TCP to perform best because out of order packets can cause duplicate acknowledgements to be sent unnecessarily.

   Flow 1: 1- 100, 2- 240
   Flow 2: 3- 180, 4- 300, 5- 360
   Flow 3: 6- 110, 7- 190, 8- 280

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

b. Weighted fair queuing with flow 1 having twice as much share as flow 3, and flow 2 having three times as much share as flow 3.

   We can rewrite the table given using the weights for each flow and the size of each packet. The “weighted size” is relative to the amount of weight that flow 3 gets. So packets from flow 1 will have a weighted size of “packet size/ 2” and flow 2 will have a weighted size of “packet size/ 3”.

Packet #	**Weighted Size**	**Flow**
1	50	1
2	70	1
3	60	2
4	40	2
5	20	2
6	110	3
7	80	3
8	90	3

From this, we can use the weighted size to solve the problem

Flow 1: 1- 50, 2- 120
Flow 2: 3- 60, 4- 100, 5- 120
Flow 3: 6- 110, 7- 190, 8- 280

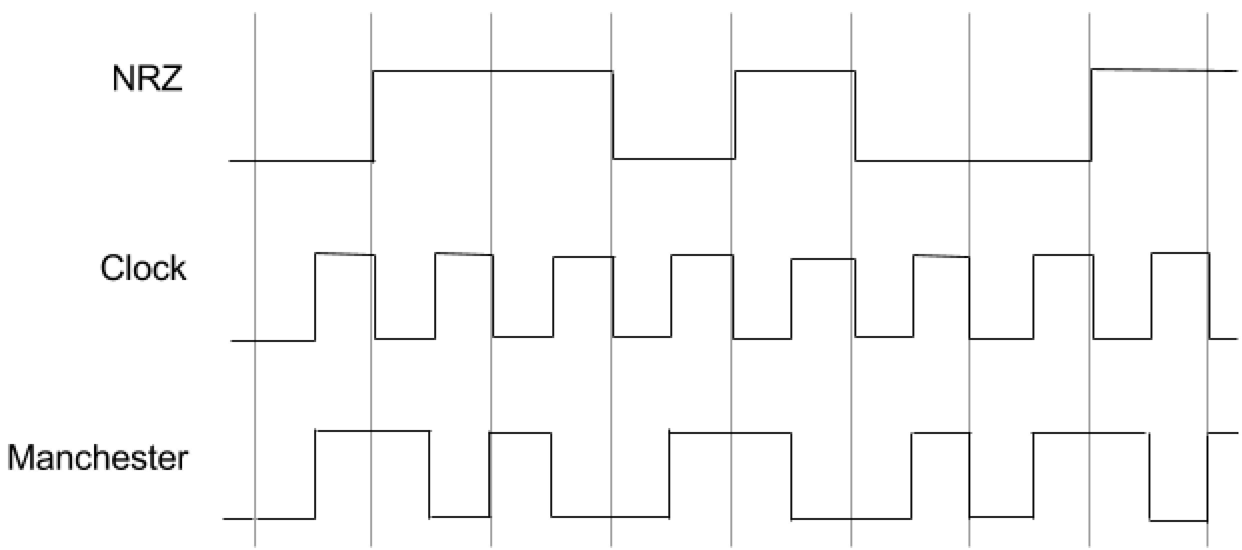
1, 3, 4, 6, 2, 5, 7, 8

Note: Resolve ties in the order of flow 1, flow 2, and flow 3

8 points total

- 4 points for part a correctness
  - -1 point per misordering
- 4 points for part b correctness
  - -1 point per misordering

4. **Signaling [8 points]**
   You are given an NRZ signal and a clock signal below. The NRZ signal encodes some data that you will be asked about.



a. What is the data encoded by the NRZ signal above in binary?

   0110 1001

   Note, because some may have still treated this problem as an NRZI encoding, I will grade b based upon the answer for a

   NRZI encoding could be- 0101 1101
   Or if take from incorrect discussion slides- 1001 0110

b. Draw the signal in the space above (or redraw it clear enough that it's obvious) that would encode the binary from part a in Manchester.

   See the above illustration

c. What is the difference between a synchronous encoding and an asynchronous encoding?

   Asynchronous- spend small amount on clock synchronization to allow a small chunk of data to be sent before there will be clock drift

   Synchronous- large cost to learn clock information that is amortized over sending many data bits together at a time; can continuously "learn" the clock from the transitions in the data stream

   If you answered something anywhere close to what is above for part c, you'll get full points

8 points total

- 2 points for a correctness
  - -1 point if almost, but not quite right
- 4 points for b correctness
  - -1 point if simple mistake
  - -1 additional point if more than one mistake
- 2 points for c correctness
  - -1 point if close, but not directly related

5. **MSL Curiosity [8 points]**

NASA launched a mars rover, called Curiosity, designed to study the planet's climate and geology. Curiosity has a few communications system. It can communicate with the Mars Reconnaissance Orbiter (MRO) at a speed of 2 Mbps with its UHF band radio. Assume that any communication done between Curiosity and the MRO is done when they are at a constant distance of 500 km (unrealistic, but just use it).

   a. Calculate the minimum RTT and the bandwidth-delay product for the link between Curiosity and the MRO. Assume this is a one-way link.

      RTT = 2 * (distance)/(speed of light) = 2 * (500 * 10^3)/(3 * 10^8) = 3.33 ms
      Bandwidth-delay = (bandwidth) * (RTT/2) = (2 * 10^6) * (3.33 * 10^-3) / 2 = about 3333 bits

   b. Let us assume that the space probe sends 10MB of data to the MRO when it can. What would be the total time for the MRO to get the entire 10MB of data? (ie. the time taken for a single 10MB data transfer)

      Data to transfer = 10MB = 80 * 2^20 bits
      Time to transmit all data = (data to transfer)/(bandwidth) = (80 * 2^20)/(2 * 10^6) = about 41.943 s
      Total Time to get all data = (time to transmit all data) + (RTT/2) = (41.943) + (.00166) = 41.94466 s

      I will grade the total time up to the precision of whatever decimal place is given.

   c. If the MRO is only in range of Curiosity for 8 minute intervals, how much data can be transferred from Curiosity to the MRO in one interval?

      Max data transfer = (bandwidth) * (time of interval) = (2 * 10^6) * (60*8) = 960 * 10^6 bits = (960 * 10^6)/(8 * 2^20) MB = about 114.44MB

Assume the speed of light is 3x10^8 m/s

8 points total

- 3 points for a correctness
  - -1 point if answers are close and show work
- 3 points for b correctness
  - -1 point if answer is close and shows work
- 2 points for c correctness
  - -1 point if answer is close and shows work

6. **Sharing the Ethernet [8 points]**
   In this problem, for each scenario, there will be some number of hosts on a LAN using the Ethernet protocol. An example scenario is given below followed by the answer for the example scenario in Figure 2. The light blue boxes with a letter in them means that the host with that letter is successfully transmitting on the channel. The red boxes indicate that a collision has occurred. Each numbered column is a time period of 1us. We'll also make a few simplifying assumptions:
   - When a collision occurs, it takes 1us before the Ethernet channel is free again
   - A host that has collided will choose its exponential backoff value at the end of the 1us in which the collision occurred
   - Exponential backoffs are calculated using 1us time periods (ie. an exponential backoff of 3 will cause a wait of 3us before attempting to transmit again)
   - Each host needs to use 3us to successfully transmit a packet
   - Each host only needs to successfully transmit 1 packet

Ex.
Consider the following scenario. Suppose there are some hosts A, B, and C on a LAN. A and B make their first attempt to transmit (starting with carrier sense) while C is successfully transmitting the last 1/3 of a packet in time period 0. Also, let's say we know that values that will be randomly chosen by each host after each collision shown in Figure 1. The table's rows are each host and the columns are the exponential backoff choices. Using this knowledge we can create a table of what would happen on the Ethernet channel during each time period shown in Figure 2. Note that only the first two columns of Figure 1 are used by each host because it turns out each host only experiences two collisions in this example.

	K = 0...1	K = 0...3	K = 0...7
A	1	2	6
B	1	0	4

Figure 1

0	1	2	3	4	5	6	7	8	9
C				B			A		
A & B attempt	A & B collide		A & B random same backoff of 1 and collide	B randomly backs off 0 and transmits		A attempts after having randomed a backoff of 2	A transmits after it stops hearing B		

Figure 2

* Disregard the varying widths of the time periods as that occurred only to allow comments to be fit in the last row of the table

a. Now consider a slightly more complicated problem. Suppose there are hosts A, B, C, and D on a LAN. Hosts B and C make their first attempt to transmit while host A is successfully transmitting the last 1/3 of its packet at time period 0. Host D makes its first attempt to transmit at time period 7. The first table provided contains the exponential backoffs that will be chosen by each host when a collision occurs. Fill in the second table with the events that would follow from this description like in the example that is given to you above.

	K = 0...1	K = 0...3	K = 0...7
B	0	3	5
C	0	2	3
D	1	1	7

0	1	2	3	4	5	6	7	8	9
A					C				
B & C attempt	B & C collide	B & C random same backoff of 0 and collide			C randoms a backoff of 2 and transmits	B attempts to transmit after a backoff of 3	D attempts to transmit for the first time	B & D collide	

10	11	12	13	14	15	16	17	18	19
D				B					
D randoms a backoff of 1 and transmits				B now transmits after a backoff of 5					

* You will be graded first on what you put in the row 1 of each time period. Giving a brief description of what's happening at each time period is recommended for partial credit. If you do not want to use color in your table, please make it clear what event is occurring at each time period. A simple legend may be useful to ensure you are graded properly.

8 points total for correctness

- -2 point total if hosts don't transmit for 3 time periods
- -1 point total if it doesn't have the first two collisions
- -1 point for each host not in the correct position