Homework Assignment #1

CS168 Fall 2016

Submission instructions and due date to be posted on Piazza

(in the meantime please answer the questions on this sheet)

1. Statistical Multiplexing: 10 points

Consider three flows sending packets over a single link. The sending pattern of each flow is described by how many packets it sends within each one-second interval; the table below shows these numbers for the first ten intervals. A perfectly smooth (i.e., non-bursty) flow would send the same number of packets in each interval, but our three flows are very bursty, with highly varying numbers of packets in each interval:

Flow 1	1	8	3	15	2	1	1	34	3	4
Flow 2	6	2	5	5	7	40	21	3	34	5
Flow 3	45	34	15	5	7	9	21	5	3	34

A. What is the peak rate of flow 1?
B. What is the peak rate of flow 2?
C. What is the peak rate of flow 3?
D. What is the sum of these three peak rates?
E. Now consider all packets to be in the same aggregate flow (e.g., this aggregate flow sends 44 packets in the second interval: 8+2+34). What is the peak rate of this aggregate flow?
F. Is the sum of the peaks greater than the peak of the aggregate? (yes or no)
G. Is this the best explanation of statistical multiplexing you've ever seen? (yes or yes)

2. Burstiness: 20 points

Consider a three hop network connecting router A to router B to router C. The link between nodes A and B has speed 100Mbps and latency 0.1msec; the link between nodes B and C has speed 10Mbps and latency 0.1msec. We are sending a continuous stream of packets from A to C. Each packet is 3000bits.

The time between sending the first packet and the second packet is x msec; that is, the time elapsed between when the first packet **starts transmitting** on the A-B link and the second packet **starts transmitting** on the A-B link is x msec. The time between sending the second and third packets being transmitted on the A-B link is (1-x) msec. We repeat this process, where the time between sending an odd-numbered packet and the following even-numbered packet is x, and the time between sending an even-numbered packet and the following odd-numbered packet is (1-x). Note that the average sending rate of 6Mbits/sec is independent of x.

In the questions below, we ask about queueing delay at switch B. Queueing delay refers to the time each packet spends waiting for another packet to finish transmitting before starting its own transmission; the queueing delay of a packet does **not** include the packet's own transmission time.

A. What is the long-term average utilization of the A-B link (i.e., what fraction of the time is it busy)?
B. What is the long-term average utilization of the B-C link ?
C. What is the average queueing delay (time packets spend waiting for the previous packet to finish transmitting) at switch B if x=0.5?
D. What is the average queueing delay at switch B if x=0.7?
E. What is the average queueing delay at switch B if x=0.9?

Now assume that the A-B link has a bandwidth of 10Mbps.

F. What is the long-term average utilization of the A-B link?
G. What is the long-term average utilization of the B-C link?
H. What is the average queueing delay at switch B if x=0.5?
I. What is the average queueing delay at switch B if x=0.7?
J. What is the average queueing delay at switch B if x=0.9?

3. Packet Timing: 16 points

So far in class we have considered **store-and-forward** routers, where packets are fully received before they are forwarded to the next hop. Many modern routers are **cut-through**, where packets are forwarded to their next hop after the header arrives (rather than waiting for the entire packet to arrive). Note that routers cannot forward packets before the header is processed, because the header contains the information necessary to know where to forward the packet.

In the oversimplified scenario we consider here (where we ignore all processing times and other complicating issues), we assume that: (i) store-and-forward routers forward packets as soon as their last bit arrives and (ii) cut-through routers forward packets as soon as the last bit of the header arrives.

Consider the same three hop network as considered in problem 2, with the same link speeds and latencies used in the first part of the problem (100Mbps for the A-B link and 10Mbps for B-C link). Assume packet headers are 100 bits (which is false, but a useful assumption to make the arithmetic easier) and consider two packets X and Y, with X being 1000 bits (including the header) and Y being 2000 bits (including the header).

Assuming the router at B is store-and-forward:

A. If packet X is sent from A at time t=0, when does its last bit arrive at C?
B. If packet Y is sent from A at time t=0, when does its last bit arrive at C?
C. If packets X and Y are sent back-to-back from A at time t=0, with X sent before Y, when does Y's last bit arrive at C?
D. If packets X and Y are sent back-to-back from A at time t=0, with Y sent before X, when does X's last bit arrive at C?

Assuming the router at B is cut-through:

E. If packet X is sent from A at time t=0, when does its last bit arrive at C?
F. If packet Y is sent from A at time t=0, when does its last bit arrive at C?
G. If packet X and Y are sent back-to-back from A at time t=0, with X sent before Y, when does Y's last bit arrive at C?
H. If packet X and Y are sent back-to-back from A at time t=0, with Y sent before X, when does X's last bit arrive at C?

4. Routing: 9 points

Consider a network with nodes 1 through 20. We can't see the network itself, but we do see (by sending probe packets from various hosts towards host X and recording the paths they take) what paths result from several routing algorithms. These routing algorithms are ***all run on the same underlying topology***. Below, a route Y-3-14-8-X denotes a packet sent from host Y being forwarded to node 3, then node 14, then node 8, and finally being delivered to host X.

A. The first routing algorithm produced the following paths:

   Y-2-17-4-X
   Z-5-10-3-1-X
   W-11-18-6-14-6-14-…

   Which (if any) of the following can you conclude is **false**:

   i. This routing algorithm always produces valid routing state.
   ii. This routing algorithm is destination-based.
   iii. This routing algorithm always produces shortest paths (by hop count).

B. The second routing algorithm produced the following paths:
   Y-2-17-4-X
   Z-16-20-3-1-X
   W-11-1-3-14-X

   Which of the following can you conclude is **false**:

   i. The routing algorithm always produces valid routing state.
   ii. The routing algorithm is destination-based.
   iii. The routing algorithm always produces shortest paths (by hop count).

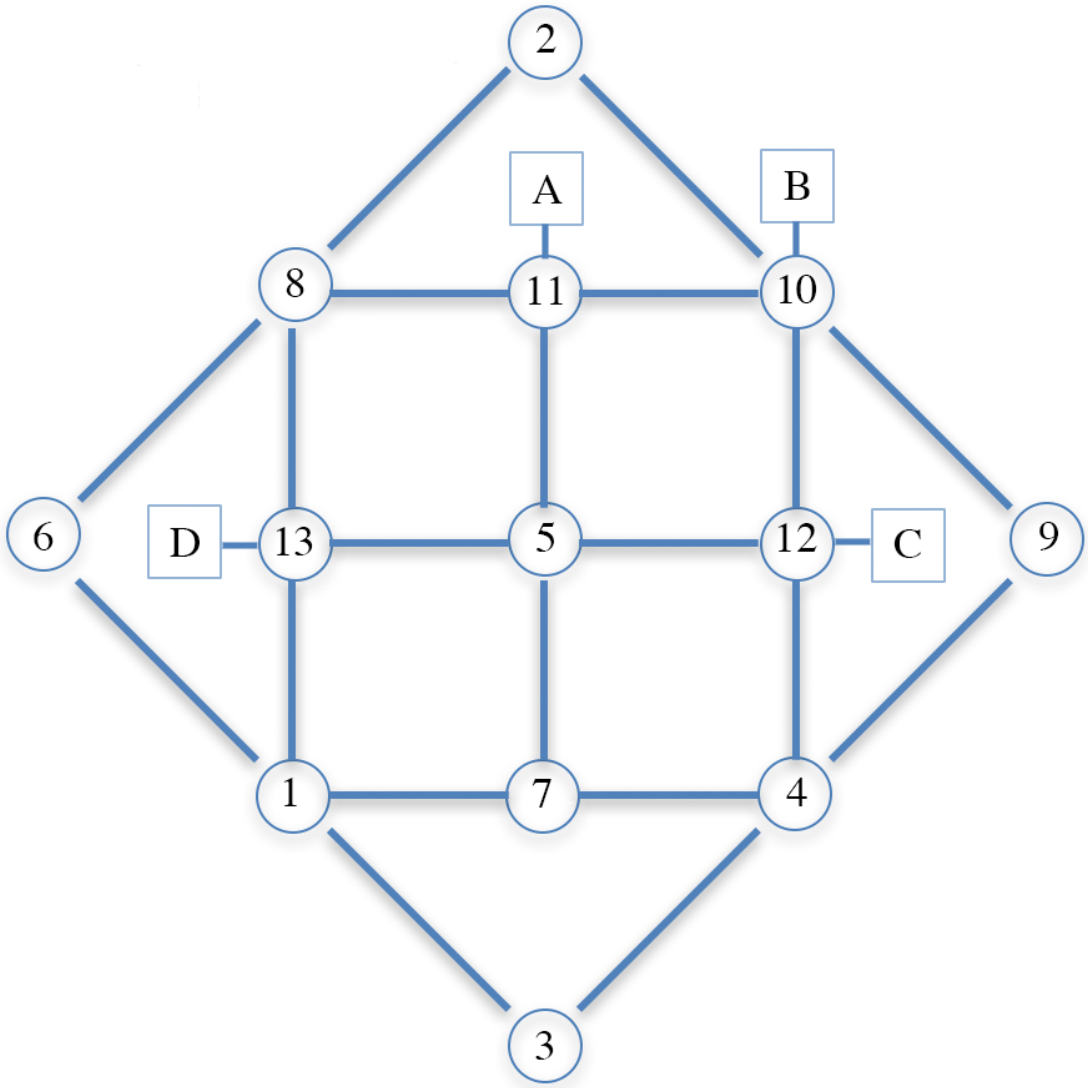
C. The third routing algorithm produced the following paths:
   Y-2-17-4-X
   Z-19-5-7-3-1-X
   W-11-10-6-14-X

Which of the following can you conclude is **false**:

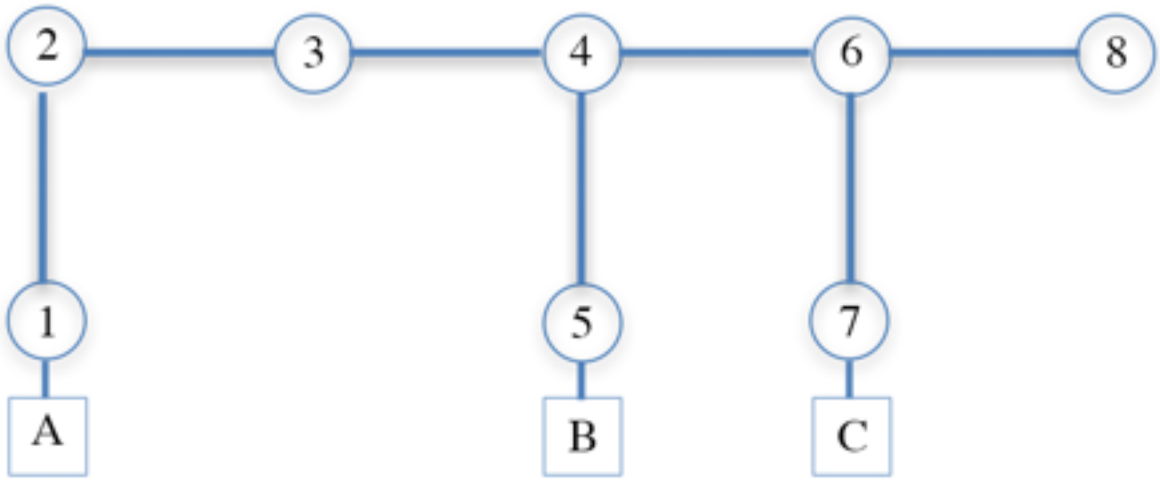
   i. The routing algorithm always produces valid routing state.
   ii. The routing algorithm is destination-based.
   iii. The routing algorithm always produces shortest paths (by hop count).

5. Routing: 10 points

Consider the network shown on the next page, with nodes (i.e., routers/switches) 1-13, and hosts A, B, C, and D (which are attached to a nearby switch). If you use the spanning tree created by the Spanning Tree Protocol (as defined in class), and assuming all the switches have the correct forwarding information (i.e., they know which port to use to reach each destination), what path do packets take from A to B?


2
A
B
8
11
10
6
D
13
5
12
C
9
1
7
4
3

6. Learning switches: 9 points



Consider a simple spanning tree shown above, equipped with learning switches at the numbered nodes. Assume in the beginning that none of the switches have any forwarding state. For the questions below, list which nodes the packets traverse, include all nodes that are traversed by flooded packets.

A. When host B sends a packet to host A, through which nodes does the packet traverse?

B. When host A now sends to host B, through which nodes does the packet traverse?

C. When host C now sends to host A, through which nodes does the packet traverse?