# Problem Set 3

Direct Link Networks

***Due: Wednesday, Mar 1st, 9:29am***

## 1. Multiple Access

Nodes A and B, are attached via a 2200 m cable, and that they each have one frame of 250 bytes (including all headers and preambles) to send to each other. At time t = 0, both nodes attempt to send. There are 8 repeaters between A and B, and each inserts a 30-bit delay. The transmission rate is 100 Mbps. CSMA/CD with backoff intervals of multiples of 1500 bits is used. After the first collision, A chooses K=0 and B chooses K=1 in the exponential backoff protocol. Ignore the jam signal and the inter-delay prior to sending.

a. If the signal propagation speed is $2 \times 10^8$ m/sec, what is the one-way propagation delay (including repeater delays) between A and B in seconds?
b. Find the time (in seconds) that A's packet is completely delivered to B?
c. Now replace the repeaters with bridges, each of which has a 30-bit processing delay in addition to a store-and-forward delay. If only A has a packet to send, find the time (in seconds), when A's packet is delivered at B?

a. Total propagation delay is the sum of propagation time through the wire and delays in all repeaters.
Propagation time = Distance / Propagation Speed
= 2200m / 2 x $10^8$m/s
= 11 μs
Delay in Repeater = Delay in bits / Transmission Rate
= 30 bits / 100 Mbps
= 0.3 μs

Since there are 8 repeaters
Propagation Delay = Propagation time + 8 × Delay in Repeater
= 11 μs + 8 × 0.3 μs
= 13.4 μs

b. Propagation delay of 13.4 μs between A and B is smaller than the backoff interval of 13.4 μs (= 1340 bits/100 Mbps). With CSMA/CD, when the start of the frame from A arrives at B, B will not send a packet. Therefore, A's packet will be delivered to B without collision or retry. Then
Latency = Propagation Delay + Transmit Time
= 13.4μs + Size / Bandwidth
= 13.4μs + 250 bytes / 100 Mbps
= 13.4μs + 20μs
= 33.4μs
Therefore, A's packet is completely delivered to be at a time 33.4μs after it begins transmitting it. If we include the time required for the first collision to be detected, which is 1500 bit times, or 15μs, the packet is completely delivered 48.4μs after A began, ignoring the inter-frame delay.

c. Total propagation delay is the sum of propagation time through the wire and delays in all bridges. In each bridge, there is a store-and-forward delay, which is equal to the transmit time, and a 30-bit processing delay.
Propagation time = Distance / Propagation Speed
= 2200 m / 2 x $10^8$m/s
= 11 μs
Delay in Bridge = Store-and-forward Delay + Processing Delay

= Transmit Time + Processing Delay
= Size / Bandwidth + Delay in bits / Transmission Rate
= 250 bytes / 100 Mbps + 30 bits / 100 Mbps
= 20μs + 0.3μs
= 20.3μs

There are 8 bridges.

Propagation Delay = Propagation time + 8 × Delay in Bridge
= 11μs + 8 × 20.3μs
= 11 μs + 162.4 μs = 173.4 μs

Total latency becomes

Latency = Propagation Delay + Transmit Time
= 173.4μs + Size / Bandwidth
= 173.4 μs + 250 bytes / 100 Mbps
= 173.4 μs + 20μs
= 193.4μs

Therefore, at time t = 193.4μs, A's packet is completely delivered to B.

## 2. Ethernet Timing

This problem is about the Ethernet/IEEE 802.11 access protocol. To be definite, suppose that if a host detects a transmission while it is transmitting a frame, then: (i) if the host has already transmitted the 128 bit preamble, the host stops transmitting the frame and sends a 64 bit jamming sequence; (ii) Else the host finishes transmitting the 128 bit preamble and then sends a 64 bit jamming sequence. For simplicity, assume a collision is detected as soon as an interfering signal first begins to reach a host. Suppose the packets are 1024 bits long, which is the minimum length allowed. Hosts A and B are the only active hosts on a 10 Mbps Ethernet and the propagation time between them is 0.055ms, or 550 bit durations. Suppose A begins transmitting a frame at time t = 0, and just before the beginning of the frame reaches B, B begins sending a frame, and then almost immediately B detects a collision.

a. Does A finish transmitting the frame before it detects that there was a collision? Explain.

B detects the collision at $t = 0.055ms$. A detects that B is sending after another 0.055 $ms$. Therefore, A detects the collision at T= 0.110ms. At that time, A has only sent 1100 bits, which is less than the total number of bits that A was sending (128 preamble + 1024 bits). Thus the transmission is still going on at A.

b. What time does A finish sending a jamming signal? What time does B finish sending a jamming signal?

When A detects the collision, it has already finished sending the preamble. Thus, it starts immediately sending the jam signal, which is completed at time:

$$t_{a,end} = 0.110ms + 0.0064ms = \mathbf{0.1164}\boldsymbol{ms}$$

When B detects the collision, it has not finished sending the preamble yet. It has to send 128 bit for the preamble and 64 bit for the jamming signal. Thus, B's transmission is over at time:

$$t_{b,end} = 0.055ms + 0.0128ms + 0.0064ms = \mathbf{0.0742}\ \boldsymbol{ms}$$

c. What time does A first hear an idle channel again? What time does B first hear an idle channel again?

A hears idle channel after the jamming signal of B has reached, at $0.0742 + 0.055 = \mathbf{0.1292}\ \boldsymbol{ms}$;
B hears idle channel after A's jamming signal has reached, at $0.1164 + 0.055 = \mathbf{0.1714}\ \boldsymbol{ms}$.

d. Suppose each host next decides to retransmit immediately after hearing the channel idle. After the resulting (second) collision: When does A next hear the channel idle? When does B next hear the channel idle?

If A starts to send at $t = 0.1292\ ms$, its signal arrives at B at $0.1842ms$. At this time, B has already sent $(0.1842 - 0.1714)\ ms\ x\ 10\ Mbps = 128\ bits$, which means the preamble has been sent already. Then B will directly send the jamming sequence, which arrives at A at

$$t = 0.1842ms + 0.0064\ ms + 0.055\ ms = \mathbf{0.2456ms}.$$

If B starts to send at $t = 0.1714\ ms$, its bits arrive at A at $t = 0.2264\ ms$. At this time, A has already sent $(0.2264 - 0.1714)\ ms\ x\ 10\ Mbps = 550\ bits$. A will directly send the jamming sequence, which is fully received by B at

$$t = 0.2264\ ms + 0.0064\ ms + 0.055\ ms = \mathbf{0.2878\ ms}$$

e. Suppose after the second collision, A decides to wait 1024 bit durations to retransmit (if it hears silence after that long) and B decides to retransmit immediately after hearing a silent channel. Is the transmission of host B successful?

**Yes**. Because B's signal arrives at A at $t = 0.2878 + 0.0550 = 0.3428\ ms$. And at that time, A has only waited for 0.0972 ms which is 972 bits duration.

f. At the time A was planning to send its second retransmission, it senses a carrier present. Suppose at that particular time A decides to wait 2 x 0.1024 ms more until its next retransmission. What time does host A finish sending its packet?

As A senses carrier presence at $0.3428\ ms$, A will start retransmission at $0.5476\ ms$. The retransmission takes $0.1024ms + 0.0128ms = 0.1152ms$. **It finishes at $\mathbf{0.6628\ ms}$**. *[Note: the problem statement explicitly ignores the 9.6 s waiting period after successful frames. We'll still give full credit if you incorporated it.]*

## 3. Server Bandwidth

Consider a server with direct memory access (DMA) in and out of main memory. Assume the server's I/O bus speed is 700Mbps and the memory bandwidth is 1.2Gbps.

a. How many switched 2.4Mbps T1 links could be supported by the server?

The I/O bus speed is slower than the memory bus, so the I/O bus is the bottleneck. A transfer into memory and a transfer out of memory is needed per packet for DMA architecture, each of which goes through the I/O bus. The server can then transfer data at 700/2 = 350Mbps. Therefore:

$$\left\lfloor \frac{350}{2.4} \right\rfloor = \mathbf{145}$$

interfaces can be supported

b. Suppose the server switching time is such that it can forward packets at the rate of 2200 packets per second. Determine the throughput as a function of the packet size.

Let the length of the packet be *L* bits. The throughput is then:

$$\mathbf{min}\ (\mathbf{350} \cdot \mathbf{10^6}, \mathbf{2200} \cdot \boldsymbol{L})\ \boldsymbol{bps}.$$

c. At what packet size does the memory bandwidth become the limiting factor?

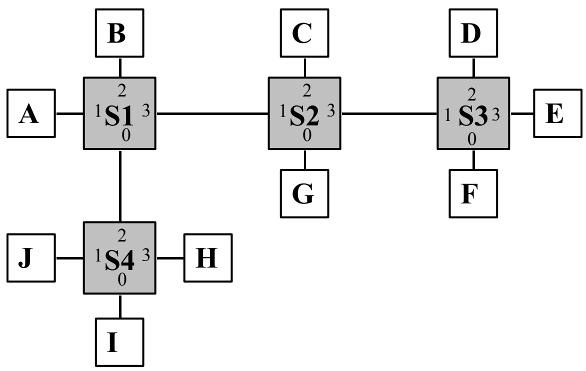
As specified in part a), the I/O bus becomes the bottleneck before the memory bus, so the memory bandwidth is **NEVER** the limiting factor.

Note: The I/O bus bandwidth become the limiting factor instead when:

$$L = \frac{350 \cdot 10^6}{2200} = 159.09Kb = 19.89KB$$

## 4. Virtual Circuits

Consider the use of virtual circuits with the network shown below. Assume that each switch port has an associated variable, NextVCIOut, initially set to 0. When an outgoing connection is made through a port, it is assigned VCI = NextVCIOut. NextVCIOut is then incremented.




The following connections are made, in order:

A connects to D
A connects to J
H connects to C
E connects to F
D connects to B
B connects to D

a. After the connections are made, what is the Virtual Circuit table at each switch? Use the form of P&D Table 3.3, page 177, to report your answer.
b. What is NextVCIOut for each port at each switch?
c. What sequence of VCIs does a packet from H to C get?
d. What sequence of VCIs does a packet from D to B get?

Sol

a.

| In Port | In VCI | Out Port | Out VCI |
|---|---|---|---|
| S1 | | | |
| 1 | 0 | 3 | 0 |
| 1 | 1 | 0 | 0 |
| 0 | 0 | 3 | 1 |
| 3 | 0 | 2 | 0 |
| 2 | 0 | 3 | 2 |
| S2 | | | |
| 1 | 0 | 3 | 0 |
| 1 | 1 | 2 | 0 |
| 3 | 0 | 1 | 0 |
| 1 | 2 | 3 | 1 |

| | | | |
|---|---|---|---|
| S3 | | | |
| 1 | 0 | 2 | 0 |
| 3 | 0 | 0 | 0 |
| 2 | 0 | 1 | 0 |
| 1 | 1 | 2 | 1 |
| S4 | | | |
| 2 | 0 | 1 | 0 |
| 3 | 0 | 2 | 0 |

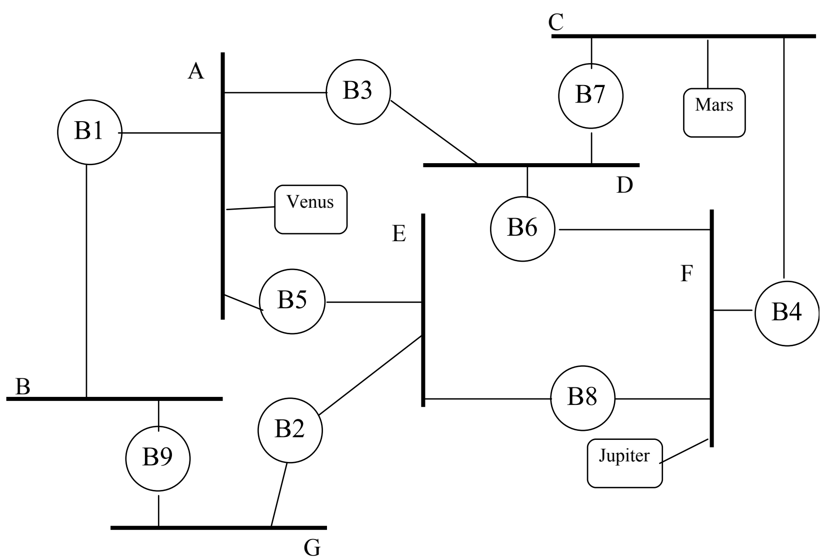
| | | S1 | S2 | S3 | S4 |
|---|---|---|---|---|---|
| Port | 0 | 1 | 0 | 1 | 0 |
| | 1 | 0 | 1 | 1 | 1 |
| | 2 | 1 | 1 | 2 | 1 |
| | 3 | 3 | 2 | 0 | 0 |

b. H→C: 0,0,1,0

c. D→B: 0,0,0,0

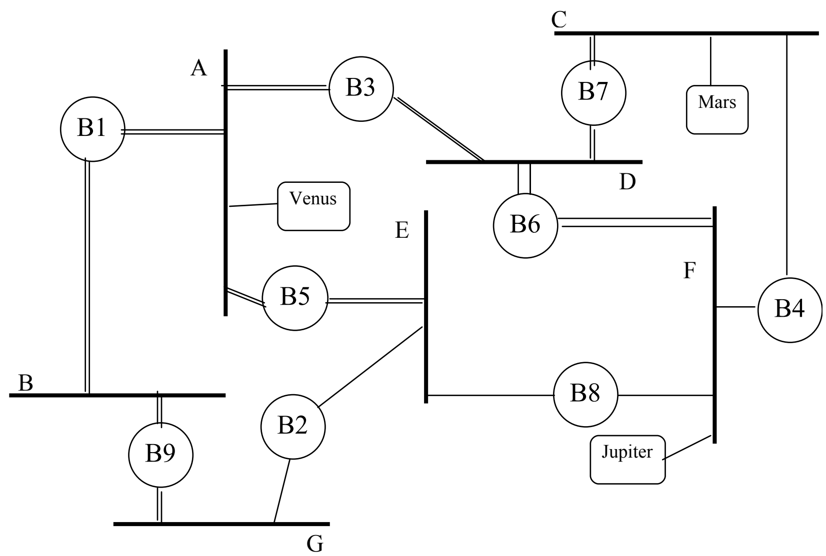
## 5. Spanning Tree Algorithm for Intelligent Bridges

Suppose the Perlman spanning tree algorithm and the bridge learning algorithm for forwarding are used for the network shown below.




a. Indicate which bridge is root, which ports are root ports (i.e. the preferred port for reaching the root bridge), which bridge is the designated bridge for each LAN, and which ports are designated ports (i.e. the ports that connect some LAN to its given designated bridge). Hint: bridges that are not designated bridges for any LAN, and ports that are not either root ports or designated ports do not play a role in the routing of packets. The remaining bridges together with the LANs form a spanning tree.
b. Suppose after the configuration is complete, host Mars attaches to LAN C, host Venus attaches to LAN A and Jupiter attaches to LAN F. Suppose Mars sends a message to Jupiter, then Jupiter sends a message to Mars, then Venus sends a message to Jupiter. For each of the three messages, indicate which LANs the message is heard on.

Sol




a.

| Bridge | Root | Root Port | LANs |
|---|---|---|---|
| B1 | X | - | A,B |
| B2 | - | E | - |
| B3 | - | A | D |
| B4 | - | F | - |
| B5 | - | A | E |
| B6 | - | D | F |
| B7 | - | D | C |
| B8 | - | E | - |
| B9 | - | B | G |

b.

Mars → Jupiter: A, B, C, D, E, F, G (All)
Jupiter → Mars: C, D, F
Venus → Jupiter: A, B, D, E, F, G