**Worksheet 2 - Delay & Bandwidth**

1. Calculate the total time required to transfer a 1.5 MB file in the following cases, assuming RTT of 80ms, a packet size of 1KB and an initial 2XRTT of “handshaking” before it is sent.
   1. The b/w is 10Mbps, and the data packets can be sent continuously.
   2. The b/w is 10Mbps, but after we finish sending each data packet, we must wait one RTT before sending the next.
2. Suppose a 128 kbps p2p link is set up between earth and a rover on mars. The distance from the earth to mars (when they are the closest together) is approximately 55Gm, and data travels over the link at the speed of light 3X108 m/s
   1. Calculate the minimum RTT for the link
   2. Calculate the delay X bandwidth product of the link
   3. A camera on the rover takes pictures of its surroundings and sends these to the earth. How quickly can it reach Mission Control on Earth? Assume that each image is 5Mb in size
3. Calculate the latency (from first bit sent to the last bit received) for the following:
   1. 1 Gbps Ethernet with a single store and forward switch in the path, and a packet size of 5000bits. Assume that each link introduces a propagation delay of 10 microsecond and that the switch begins retransmitting immediately after it has finished receiving the packet.
   2. Same as a) but with 3 switches
   3. Same as b) but assume the switch implements “cut-through” switching. It is also able to begin retransmitting the packet after the first 128 bits have been received.
4. Suppose two hosts, A and B are separated by 10,000 kms and are connected by a direct link of R = 1Mbps. Suppose the propagation speed over the link is 2.5 x 108 m/s.
   1. Calculate the bandwidth-delay product, R x tprop
   2. Consider sending a file of 400,000 bits from A to B. Suppose the file is sent continuously as one big message. What is the maximum number of bits that will be in the link at any given time?
   3. How long does it take to send the above file if it is sent continuously?
   4. Suppose now that the file is broken up into 10 packets with each packet containing 40,000 bits. Suppose that each packet is acknowledged by the receiver and the transmission time of an acknowledgement packet is negligible. Finally, assume that the sender cannot send a packet until the preceding packet is acknowledged. How long does it take to send the file?