Suppose a 100-Mbps point-to-point link is being set up between Earth and a new lunar colony. The distance from the moon to Earth is approximately 385,000 km, and data travels over the link at the speed of light—$3 * 10^8$ m/s.

(a) Calculate the minimum RTT for the link.

(b) Suppose Mission Control on Earch wishes to download a 25MB image from a camera on the lunar base. What is the minimum amount of time that will elapse between when the request for the data goes out and the transfer is finished?

(c) Using the RTT as the delay, calculate the delay*bandwidth product for the link.

(d) Imagine that Mission Control requests one 25MB image and then waits until it starts receiving the file before sending another request (the size of the request is negligible). Use the delay*bandwidth product to determine what percentage of the link is utilized.

Solution:

(a) The time for data to travel from earth to the moon is:
$\frac{(385{,}000km*1000m/km)}{3*10^8 m/s} = 1.28333s$
So the minimum RTT is $1.2833 * 2 = 2.56666s$

(b) From (a), the request will take $1.28333s$ to reach the moon. The time to put the picture on the link is:
$\frac{25MB*1024kB/MB*1024byte/kB*8bits/byte}{100Mbps*1000kb/Mb*1000bits/kb} = \frac{209715200}{100000000} = 2.097152s$
Then it will take another $1.28333s$ to return to earth. The total time is:
$2 * 1.28333s + 2.097152s = 4.66382$

(c) $2.56666s * 100Mbps * 1000000bits/Mb = 256666000bits$

(d) The cycle time for this is 1 RTT. From (c) we see that the link would be fully utilized if 256666000 bits were transferred during this time. The total number of bits transferred is:
$25MB * 1024kB/MB * 1024bytes/kB * 8bits/byte = 209715200bits$
The link utilization is $209715200/256666000 = 81.707\%$

If you assume that the earth doesn't send a request until the entire picture has been received, then the time for a cycle is 4.66382 seconds from (b).
$4.66382s * 100Mbps * 1000000bits/Mb = 466382000bits$
$209715200/466382000 = 44.923\%$

Calculate the latency (from first bit sent to last bit received) for the following:

(a) A 10-Mbps link with a single store-and-forward switch in the path, and a packet size of 5,000 bits. Assume that each section of the link introduces a propogation delay of 10 microseconds, and that the switch begins retransmitting immediately after it has finished receiving the packet.

(b) Same as (a) but with three switches

(c) Same as (a) but assume the switch implements cut-through switching: it is able to begin retransmitting the packet after the first 200 bits have been received.

Solution:

(a) To put the packet on the first link it will take:
$\frac{5000bits}{10-Mbps*1000000bits/Mb} = 0.0005s = 0.5ms$
Then it will take another .01 ms for the switch to finish receiving the packet for a total of .51 ms. It will take another .51 ms for the switch to send, and then for the destination to receive all of the packet. The total latency is:
$2 * 0.51ms = 1.02ms$

(b) From (a) we know that each link section will take .51 ms. The total time will be: $4 * 0.51ms = 2.04ms$

(c) To begin we can calculate the time it will take to send the first 200 bits: $\frac{200bits}{10-Mbps*1000000bits/Mb} = 0.00002s = 0.02ms$
Then .01 ms later the switch can start sending the packet. It will take .5 ms (from (a)) to put the entire packet on the wire (As the switch is sending out the packet, it will continue receiving the rest of the packet). Then it will take .01 ms for the destination to finish receiving the entire packet:
$0.02ms + 0.01ms + 0.5ms + 0.01ms = .54ms$