1. Suppose Host A wants to send a large file to Host B. The path from Host A to Host B has three links, of rates R1 = 500 kbps, R2= 2 Mbps, and R3 = 1 Mbps.
    a. Assuming no other traffic in the network, what is the throughput for the file transfer?
    b. Suppose the file is 4 million bytes. Dividing the file size by the throughput, roughly how long will it take to transfer the file to Host B
    c. Repeat (a) and (b), but now with R2 reduced to 100 kbps.

Solution:

(a) Throughput is limited by the minimum of the capacity of the links. Here, minimum is R1. So throuhput is 500 kbps.

(b) Divide the size of the file by the throughput to get approximate time to transfer to B.

$t=(4*10^6*8)/(500*10^3)=64sec.$

(c) R2 being reduced to 100 kbps, so throuhput is now 100 kbps.

Time to transfer $t= (4*10^6*8)/(100*10^3)= 320sec.$

The links R1, R2 and R3 are connected sequentially, so the whole transfer has to wait for the slowest link. That is why we do not consider individual transfer times.

2. Consider the circuit-switched network in Figure 1. Recall that there are 4 circuits on each link. Label the four switches A, B, C and D, going in the clockwise direction.
    a. What is the maximum number of simultaneous connections that can be in progress at any one time in this network?
    b. Suppose that all connections are between switches A and C. What is the maximum number of simultaneous connections that can be in progress?
    c. Suppose we want to make four connections between switches A and C, and another four connections between switches B and D. Can we route these calls through the four links to accommodate all eight connections?

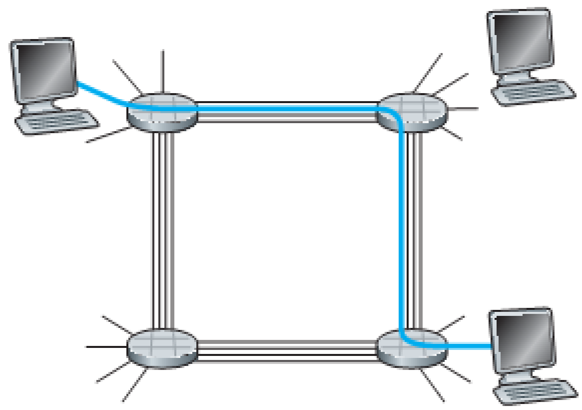

Figure 1

Solution:

a) Between the switch in the upper left and the switch in the upper right we can have 4 connections. Similarly we can have four connections between each of the 3 other pairs of adjacent switches. Thus, this network can support up to 16 connections.

b) We can 4 connections passing through the switch in the upper-right-hand corner and another 4 connections passing through the switch in the lower-left-hand corner, giving a total of 8 connections.

c) Yes. For the connections between A and C, we route two connections through B and two connections through D. For the connections between B and D, we route two connections through A and two connections through C. In this manner, there are at most 4 connections passing through any link.

3. Consider a packet of length L which begins at end system A and travels over three links to a destination end system. These three links are connected by two packet switches. Let d_i, s_i, and R_i denote the length, propagation speed, and the transmission rate of link i, for i= 1, 2, 3. The packet switch delays each packet by d_proc. Assuming no queuing delays, in terms of d_i, s_i, R_i, (i= 1,2,3), and L, what is the total end-to-end delay for the packet? Suppose now the packet is 1,500 bytes, the propagation speed on all three links is 2.5 * 10^8 m/s, the transmission rates of all three links are 2 Mbps, the packet switch processing delay is 3 msec, the length of the first link is 5,000 km, the length of the second link is 4,000 km, and the length of the last link is 1,000 km. For these values, what is the end-to-end delay?

Solution:

three links are connected by two packet switches

2 times dpoc will be added i.e 3msec*2 = 0.006 sec

Tt = L/R = 1500 bytes/ 2Mbps = 0.006 sec

for three links 6ms*3 = 18ms

and now Tp is individually calculated as they are different

Tp= D/S

Tp1 = 5000km/(2.5X10^8 m/sec) = 0.020 sec

Tp2 = 4000km/(2.5X10^8 m/sec) = 0.016 sec

Tp3 = 1000km/(2.5X10^8 m/sec) = 0.004 sec

adding all we get

0.018+0.006+0.020+0.016+0.004= 0.064 sec = 64msec

4. Consider Figure 2. Now suppose that there are M paths between the server and the client. No two paths share any link. Path k(k= 1, . . ., M) consists of N links with transmission rates R_{k1}, R_{k2},……….,R_{kN} (where, k is path number and 1,2,…N are the links number between server and client). If the server can only use one path to send data to the client, what is the maximum throughput that the server can achieve? If the server can use all M paths to send data, what is the maximum throughput that the server can achieve?

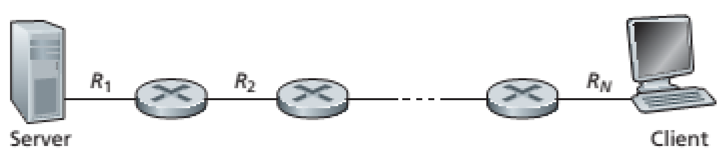

Figure 2

Solution:

Because server connect to the client by M paths so:

a) If the server uses a single path to send data to the client, then the maximum throughput is the maximum of set minimum{R1k, R2k,.., RNk} = max{min{R11, R21,.., RN1}, min{R12, R22,.., RN2}, ..., min{R1M, R2M,.., RNM}}

b) If the server uses all the M paths to send data, then the maximum throughput is the sum of all throughput of each path

$= \sum_{i=1 \rightarrow M} (\min\{R1k, R2k, .., RNk\})$

5. Consider Figure 2. Suppose that each link between the server and the client has a packet loss probability p,and the packet loss probabilities for these links are independent. What is the probability that a packet (sent by the server) is successfully received by the receiver? If a packet is lost in the path from the server to the client, then the server will re-transmit the packet. On average, how many times will the server re-transmit the packet in order for the client to successfully receive the packet?

Solution:

Consider the given data:
Loss probability of packet between the server and the client =p
Probability that the packet is successfully received through the receiver p1.
The probability that the packet transmitted by the server is received by the client successfully is 1/p1
The probability of successful transmissions -1 if the packet re-transmitted by the server is received.
So, the probability that the packet re-transmitted by the server is received by the client is $1/p_1$-1.

6. You are designing a data transfer system for a large video streaming platform. The platform has multiple data centers connected through a path with 3-4 switches. To ensure smooth video playback, the video files are split into multiple packets, and pipelining is used to enhance transmission efficiency. Each switch introduces a propagation delay of 2.5 milliseconds, and the transmission time for each packet is 1.5 milliseconds. The pipeline can accommodate up to 3 packets simultaneously. Assuming a video file size of 600 MB, calculate the total time taken to complete the transmission of the video from the source data center to the destination data center.

Solution:

- **Packet Generation and Transmission Time : Total transmission time = (600 MB / Average Packet size) * Transmission time per packet**
- **Pipeline Filling : 2.5 milliseconds for the first packet to reach the first switch.**
- **Pipeline Transmission : All three pipeline slots are utilized, so the transmission time for each packet is 1.5 milliseconds.**

- **Pipeline Draining: The remaining packets that are outside the pipeline still need to travel through the switches, each taking 2.5 milliseconds per switch.**