(a) Consider two nodes (computers or routers), A and B, that have been connected by means of a single optical fibre link of length 2500 kilometers. Assume that optical signal propagates over the link at the speed of 2.5×10^8 m/s (meter/sec), and the link speed is 2 Mbps. If computer A is sending a frame of length 1,000 bytes to B, how long does it take the frame to be completely copied from A to B?

Solution:

Time to completely copy a frame, $T = T_{prop}$ (time to propagate) + T_{trans} (time to transmit) T_{prop}

= Distance/ speed of signal = 2500 Km / $(2.5 \times 10^8$ m/s) = $(2500 \times 10^3$ m) / $(2.5 \times 10^8$ m/s)

= 10 ms.

T_{trans} = Length of a frame / Link speed = 1000 bytes / 2 Mbps = (1000 x 8 bits) / (2 x 106 bps)

= 4 ms.

Therefore,

T = 10 ms + 4 ms = 14 ms.

It takes **14 ms** to completely copy a frame of 1000 bytes from A to B.

(b) Assume that a computer, A, is transmitting a frame to another computer, B, at a link speed (i.e., transmission rate) of 100 Mbps; the length of the CAT6 cable between A and B is 100 meters, and signal travels at the speed of 2×10^8 meters/sec in the cable. Compute the maximum number of bits of the frame that can simultaneously appear on the cable.

Solution:

T_{prop} (time to propagate) = Cable Length / speed of signal = 100 m / $(2 \times 10^8$ m/s)

= 0.5×10^{-6} Sec

The maximum number of bits that can simultaneously appear on the cable

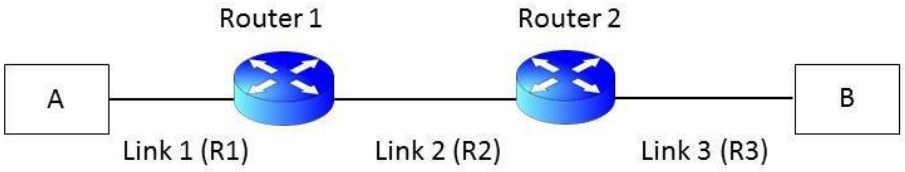
= The Bandwidth-delay product = (R x T_{prop})

= 100Mps * $(0.5 \times 10^{-6}$ Sec) = 50 Bits

(c) Suppose that host *A* wants to send a 1 Gigabit file to host *B*. The network between *A* and *B* has three links (See Fig. 1.) of rates $R_1 = 4\ Mbps$, $R_2 = 2\ Mbps$, and $R_3 = 1\ Mbps$. "Giga" means 10^9, "Mega" means 10^6, and "Kilo" means 10^3. Assume that the propagation delays on the three links are zero seconds. Make other assumptions as necessary and appropriate.

I. If *A* sends the file as 1000-byte packets, how long does it take to move the file from *A* to *B*? Show the details of your calculation.

II. Also, give an approximate answer to part (I) by using the concept of bottleneck bandwidth.



Solution:

(I)

File size: 1 Gigabits

Pkt size = 1000 bytes

Given: Propagation time = 0

Assumption: - We ignore the various headers.
- Routers have infinite buffers.
- Processing delay is 0

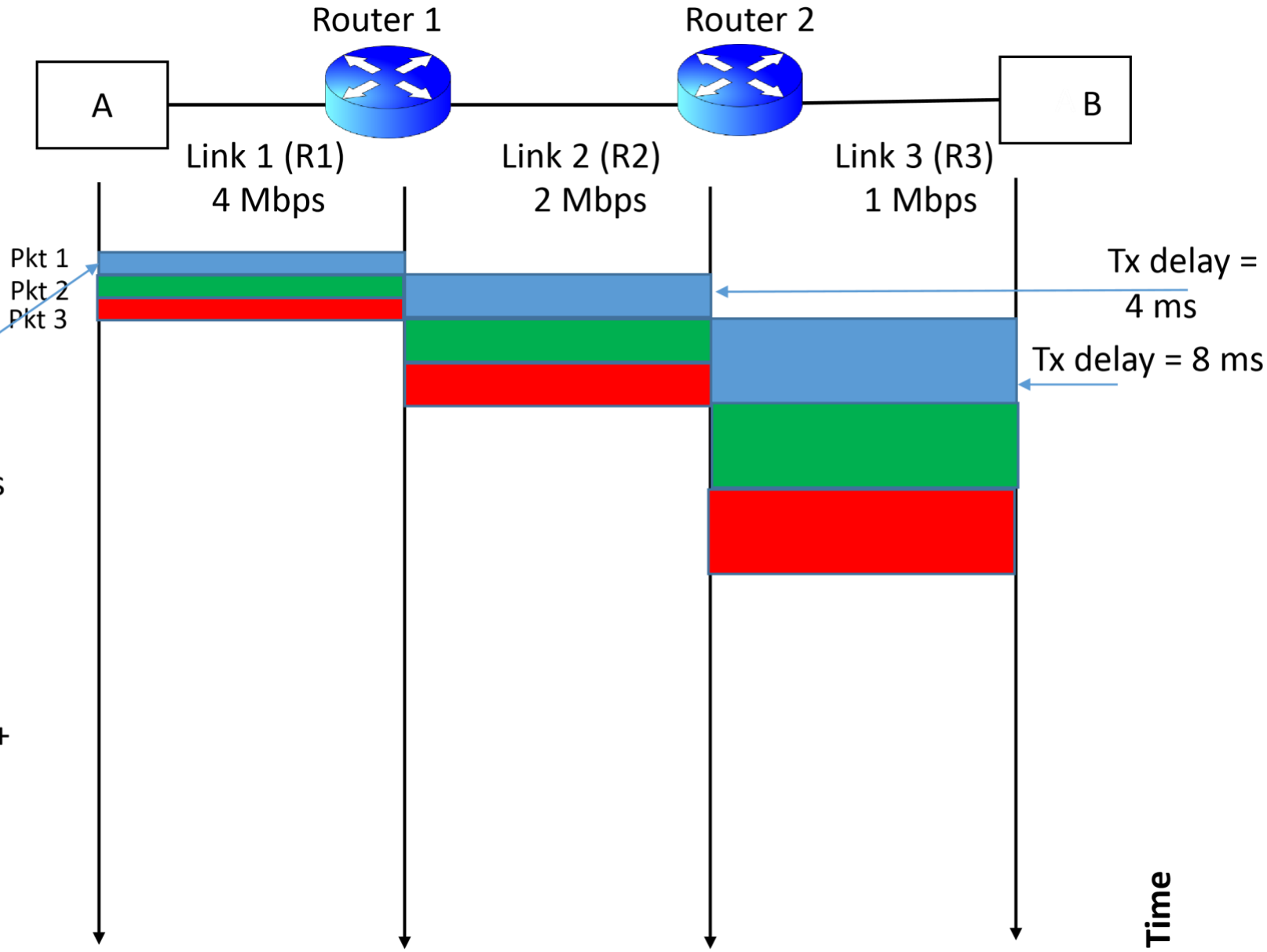
Tx delay = Pkt size/Tx rate
= (1000 x 8) bits/ 4 Mbps
= 8000 bits/(4 x 10^6) bps
= 2 x 10^{-3} s
= 2 ms

Total # of pkts is N.

File transfer time, Tf = (N X link #3 Tx delay) + 2 ms + 4 ms

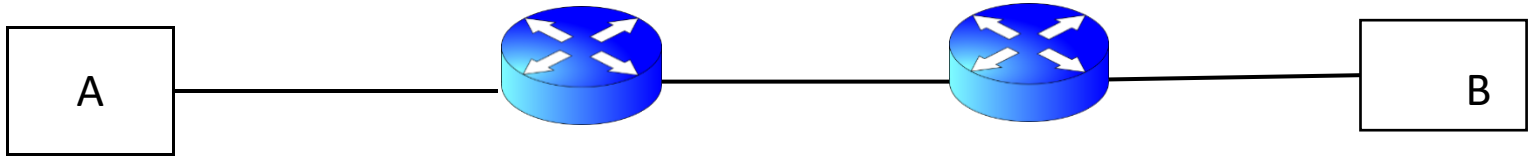
N = 1 Gigabits/8000 bits = $10^9/8000 = 10^6/8$
= 125,000

Tf = (125,000 X 8 ms) + 6 ms = 1000 s + 6 ms



= 1000.006 s Router 1

Router 2



Link 1 (R1)
Mbps

Link 2 (R2)
2 Mbps

Link 3 (R3) 4
1 Mbps

Part (ii) Also, give an approximate answer to

part (I) by using the concept of Bottleneck link bottleneck

bandwidth.

File transfer time =~ Total amount of data /rate of the bottleneck link

= 1 Gigabits/1 Mbps = 10^9 bits/ 10^6 bits = 1000 s