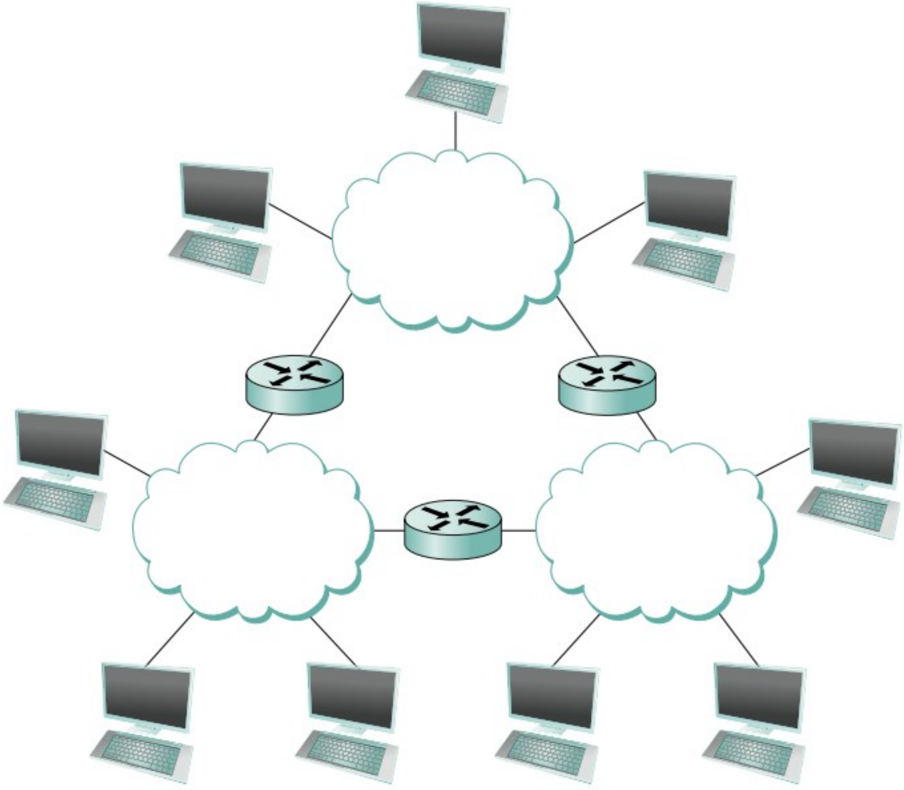
Latency

Internetwork



Internetwork

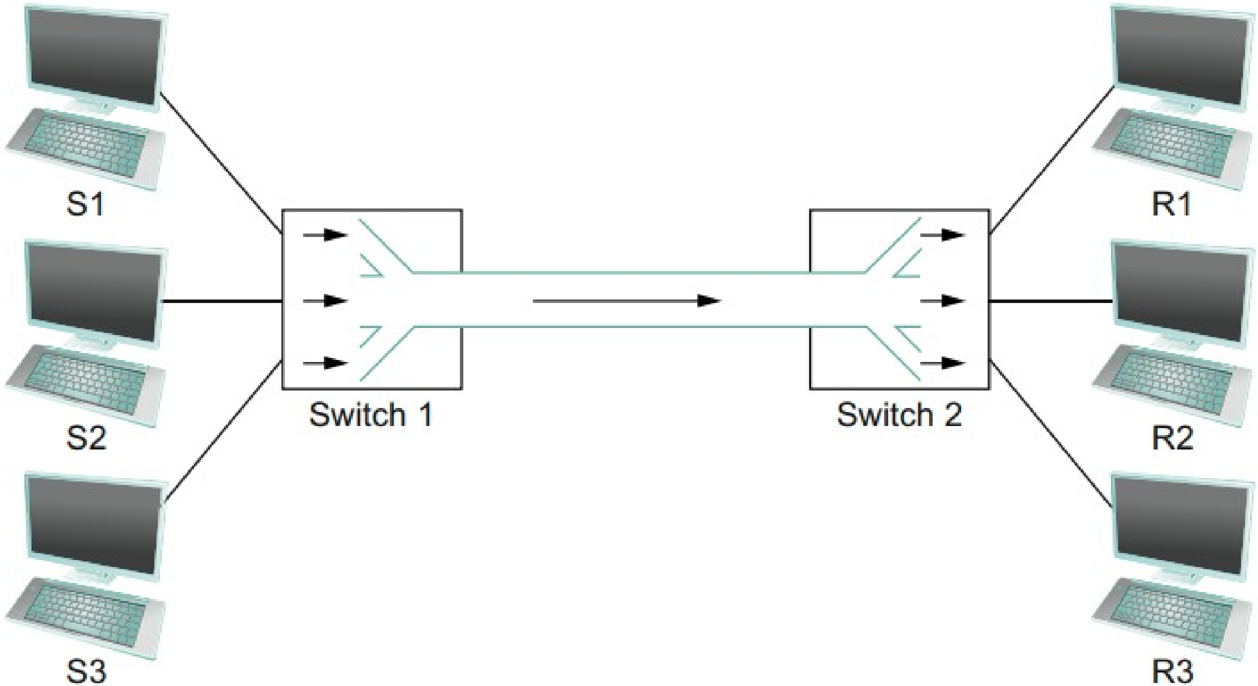


FIGURE 1.5 Multiplexing multiple logical flows over a single physical link.

Internetwork

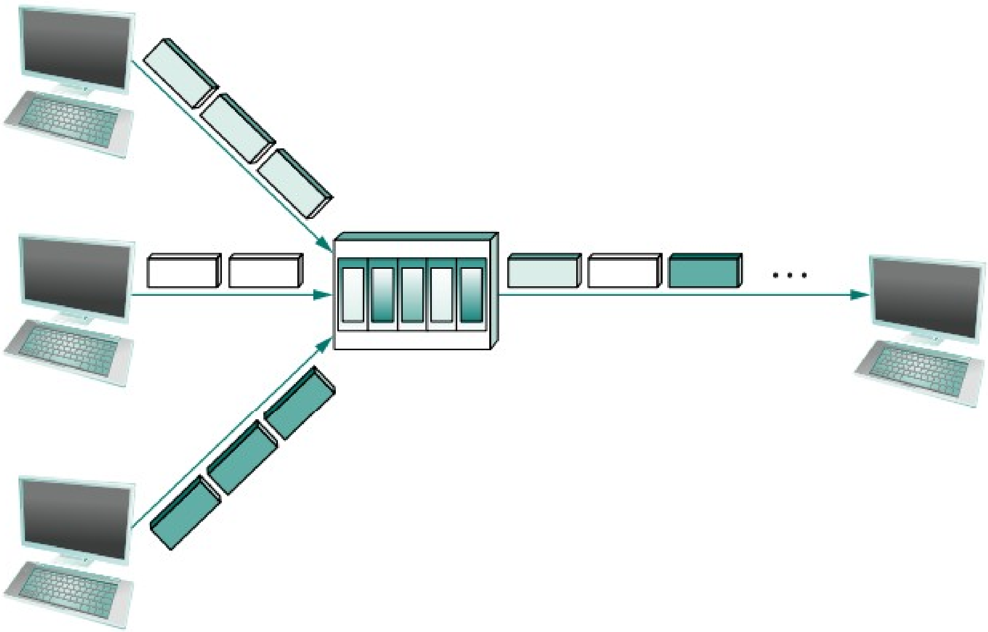


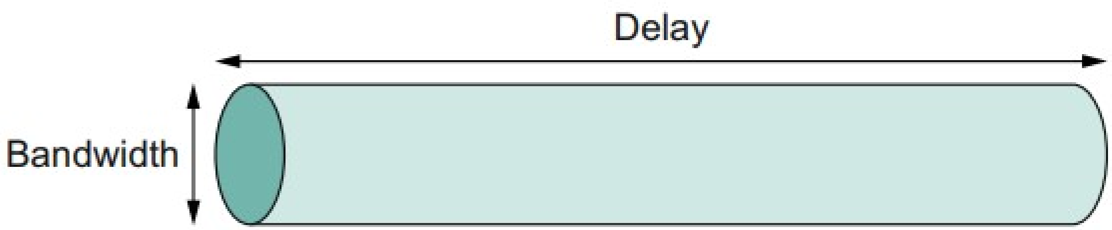
FIGURE 1.6 A switch multiplexing packets from multiple sources onto one shared link.

Internetwork

$$\text{Latency} = \text{Propagation} + \text{Transmit} + \text{Queue}$$

$$\text{Propagation} = \text{Distance/SpeedOfLight}$$

$$\text{Transmit} = \text{Size/Bandwidth}$$



Delay x Bandwidth Product

Example 3.11

Another example of a nonperiodic composite signal is the signal received by an old-fashioned analog black-and-white TV.

A TV screen is made up of pixels. If we assume a resolution of 525 × 700,(525 vertical and 700 horizontal) we have 367,500 pixels per screen.

If we scan the screen 30 times per second, this is 367,500 × 30 = 11,025,000 pixels per second. The worst-case scenario is alternating black and white pixels. In this case, we need to represent one color by the minimum amplitude and other color by maximum amplitude.

We can send 2 pixels per cycle. Therefore, we need 11,025,000 / 2 = 5,512,500 cycles per second, or Hz.

The bandwidth needed is 5.5125 MHz.

Excercise - 1

For the following, assume that no data compression is done, although in practice this would almost never be the case. For (a) to (c), calculate the bandwidth necessary for transmitting in real time:

(a) Video at a resolution of 640 × 480, 3 bytes/pixel, 30 frames/second.

(b) Video at a resolution of 160 × 120, 1 byte/pixel, 5 frames/second.

(c) CD-ROM music, assuming one CD holds 75 minutes' worth and takes 650 MB.

(d) Assume a fax transmits an 8 × 10-inch black-and-white image at a resolution of 72 pixels per inch. How long would this take over a 14.4-kbps modem?

Excercise - 1

For the following, assume that no data compression is done, although in practice this would almost never be the case. For (a) to (c), calculate the bandwidth necessary for transmitting in real time:

(a) Video at a resolution of 640 × 480, 3 bytes/pixel, 30 frames/second.

Bandwidth = 640 x 480 x 3 x 8 x 30 = 22,11,84,000 bits/second

(b) Video at a resolution of 160 × 120, 1 byte/pixel, 5 frames/second.

Bandwidth = 160 x 120 x 8 x 5 =7,68,000

(c) CD-ROM music, assuming one CD holds 75 minutes' worth and takes 650 MB.

650 MB / 75 Minutes => 0.1444 M per second

Bandwidth = 650 x 2^{20} x 8 for 4500 seconds

= 650 x 1048576 x 8 *4500 =5,45,25,95,200/4500* bps

= 1211687.822 bps

Excercise - 1

For the following, assume that no data compression is done, although in practice this would almost never be the case. For (a) to (c), calculate the bandwidth necessary for transmitting in real time:

(d) Assume a fax transmits an 8 × 10-inch black-and-white image at a resolution of 72 pixels per inch. How long would this take over a 14.4-kbps modem?

Bandwidth = 8x 72 x 10 x 72 =414720 pixels. Bits 1 bit per pixel => 414720 bps

Transmit = Size /Bandwidth

= 414720 / 14.4 x **1024** bps

= 414720/14745.6

= 28.125 sec

Excercise - 2

Consider a point-to-point link 2 km in length. At what bandwidth would propagation delay (at a speed of 2×10^{8} m/s) equal transmit delay for 100-byte packets? What about 512-byte Packets?

$$\text{Latency} = \text{Propagation} + \text{Transmit} + \text{Queue}$$

$$\text{Propagation} = \text{Distance/SpeedOfLight}$$

$$\text{Transmit} = \text{Size/Bandwidth}$$

Propagation delay = Distance / Propagation Speed = 2000 m / ($2 * 10^{8}$) m/s = 10^{-5} s
Propagation delay = transmit delay ?

Bandwidth = Size of packet / Transmit delay =
= (100 * 8) bits / 10^{-5} s=
= $8 * 10^{7}$ bits/s =
= 80 Mbps
If we have 512-byte packets:
Bandwidth = Size of packet / Transmit delay =
= (512 * 8) bits / 10^{-5} s =
= $4.096 * 10^{8}$ bits/s =
= 409.6 Mbps

Excercise - 3

For a Dial up link of 56 Kbps bandwidth and 86 μs round trip delay find the delay X Bandwidth product.

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For a Dial up link of 56 Kbps bandwidth and 86 μs round trip delay find the delay X Bandwidth product.

Delay X Bandwidth =

$=86 \times 10^{-6} \times 56 \times 2^{10}$ b/s

$= 4816 \times 1024 \times 10^{-6}$ bits

$= 49{,}31{,}584 \times 10^{-6}$

= 4.931bits approximately 5 bits

Excercise - 4

For a wireless LAN of 54 Mbps bandwidth and 0.33 µs Round trip delay find the delay x bandwidth product.

Delay X Bandwidth =0.33 X 10^{-6} sec x 54 X 2^{20} bps

=0.33 X 10^{-6} sec x 54 X 2^{20} bps

= 18.68 bits which is approximately 19 bits.

Note:

2^{10} = 1,024 10^{3} = 1,000

2^{20} = 10,48,576 10^{6} = 10,00,000

Excercise - 5

Suppose a 100 Mbps point to point link is being set up between earth and a new lunar colony. The distance from moon to earth is approximately 3,85,000 kms and data travels over the link at the speed of light 3 X 108 m/sec.

a. Calculate the minimum RTT for the link.

b. Using the RTT as the delay, calculate the delay X bandwidth product for the link.

c. A camera on the lunar base takes pictures of earth and saves them in digital format disk. Suppose mission control on earth wishes to download most current image, which is 25MB. What is the minimum amount of time that will elapse between when the request for the data goes out and the transfer finished?

Excercise - 5

Suppose a 100 Mbps point to point link is being set up between earth and a new lunar colony. The distance from moon to earth is approximately 3,85,000 kms and data travels over the link at the speed of light 3 X 10^8 m/sec.

a. Calculate the minimum RTT for the link.

RTT => Round Trip Delay = 2 x Propagation Delay

= 2 x (distance / Speed of Light)

= 2 x (3,85,000 x 10^3 m / 3 x 10^8 m/s)

= 2 x (385 x 10^6 / 3 x 10^8)

= 2.57 sec

Excercise - 5

Suppose a 100 Mbps point to point link is being set up between earth and a new lunar colony. The distance from moon to earth is approximately 3,85,000 kms and data travels over the link at the speed of light 3 X 108 m/sec.

a. Calculate the minimum RTT for the link. RTT = 2.57 sec

b. Using the RTT as the delay, calculate the delay X bandwidth product for the link.

Delay x Bandwidth = 1.285 x 100 x 2^{20}

= 128.5 Mbits

Excercise - 5

Suppose a 100 Mbps point to point link is being set up between earth and a new lunar colony. The distance from moon to earth is approximately 3,85,000 kms and data travels over the link at the speed of light 3 X 108 m/sec.

c. A camera on the lunar base takes pictures of earth and saves them in digital format disk. Suppose mission control on earth wishes to download most current image, which is 25MB. What is the minimum amount of time that will elapse between when the request for the data goes out and the transfer finished?

Transmit time = size / BW = 25MB / 100Mbps = 200/100 = 2 sec

Latency = Transmit + propagation = 2 sec+ 1.285 = 3.285 sec

Reference

Computer Networks: A Systems Approach, Larry L. Peterson and Bruce S. Davie, Sixth Edition, MK publications. 2022