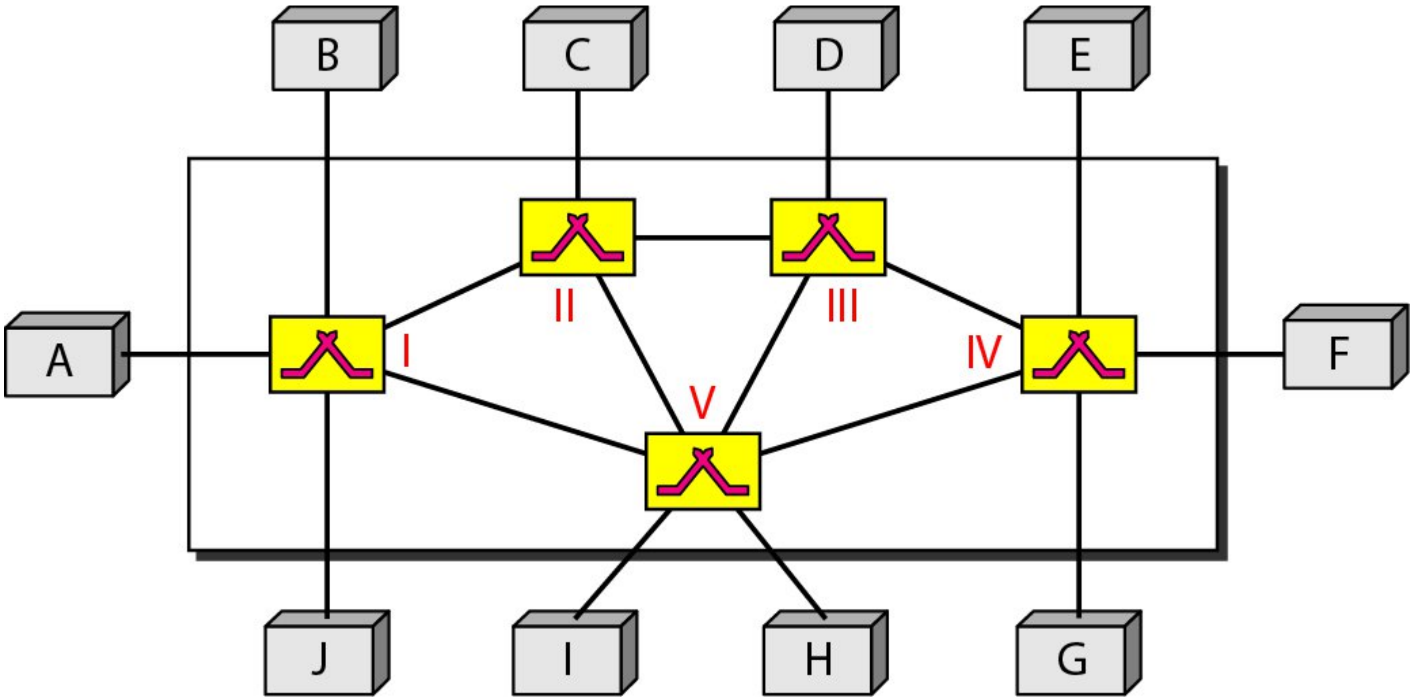


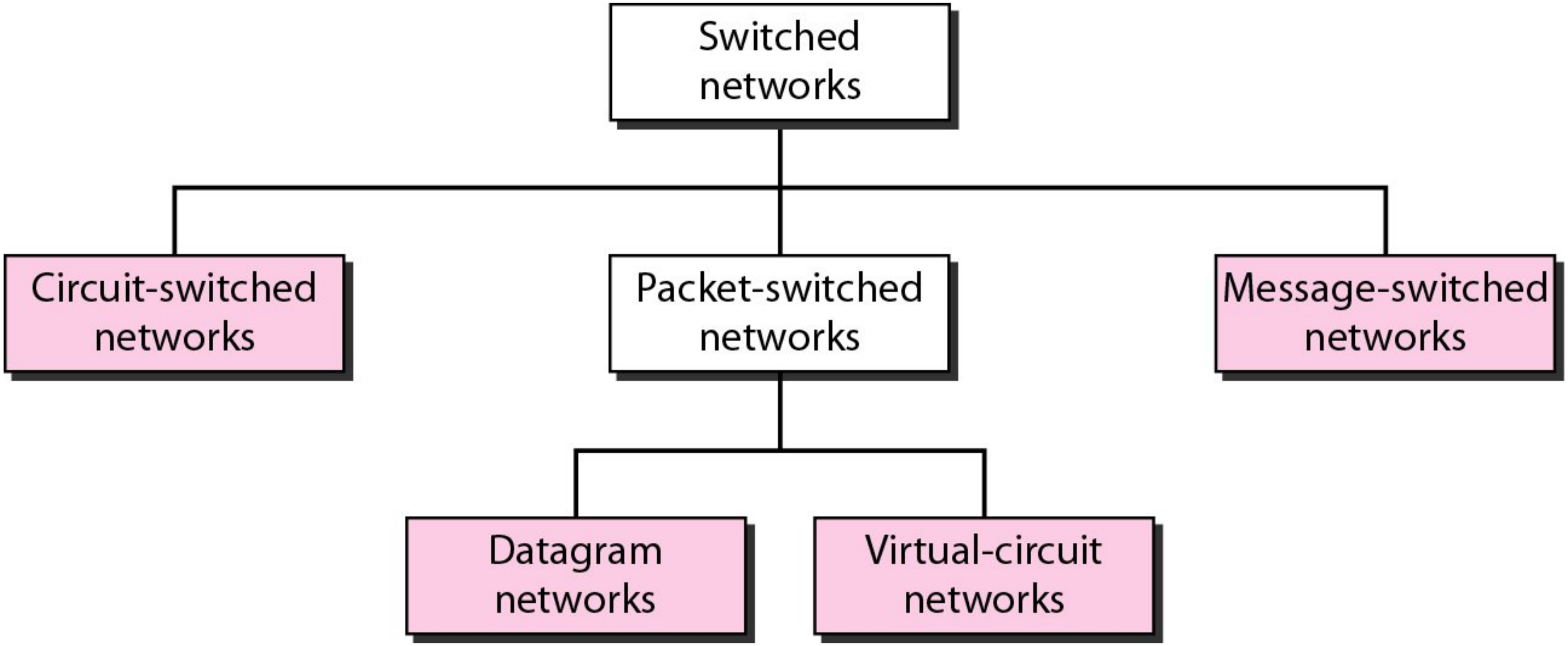
# Chapter 8

# Switching

## Figure 8.1 *Switched network*



## **Figure 8.2** *Taxonomy of switched networks*



# 8-1 CIRCUIT-SWITCHED NETWORKS

***A circuit-switched network consists of a set of switches connected by physical links. A connection between two stations is a dedicated path made of one or more links. However, each connection uses only one dedicated channel on each link. Each link is normally divided into n channels by using FDM or TDM.***

***Topics discussed in this section:***

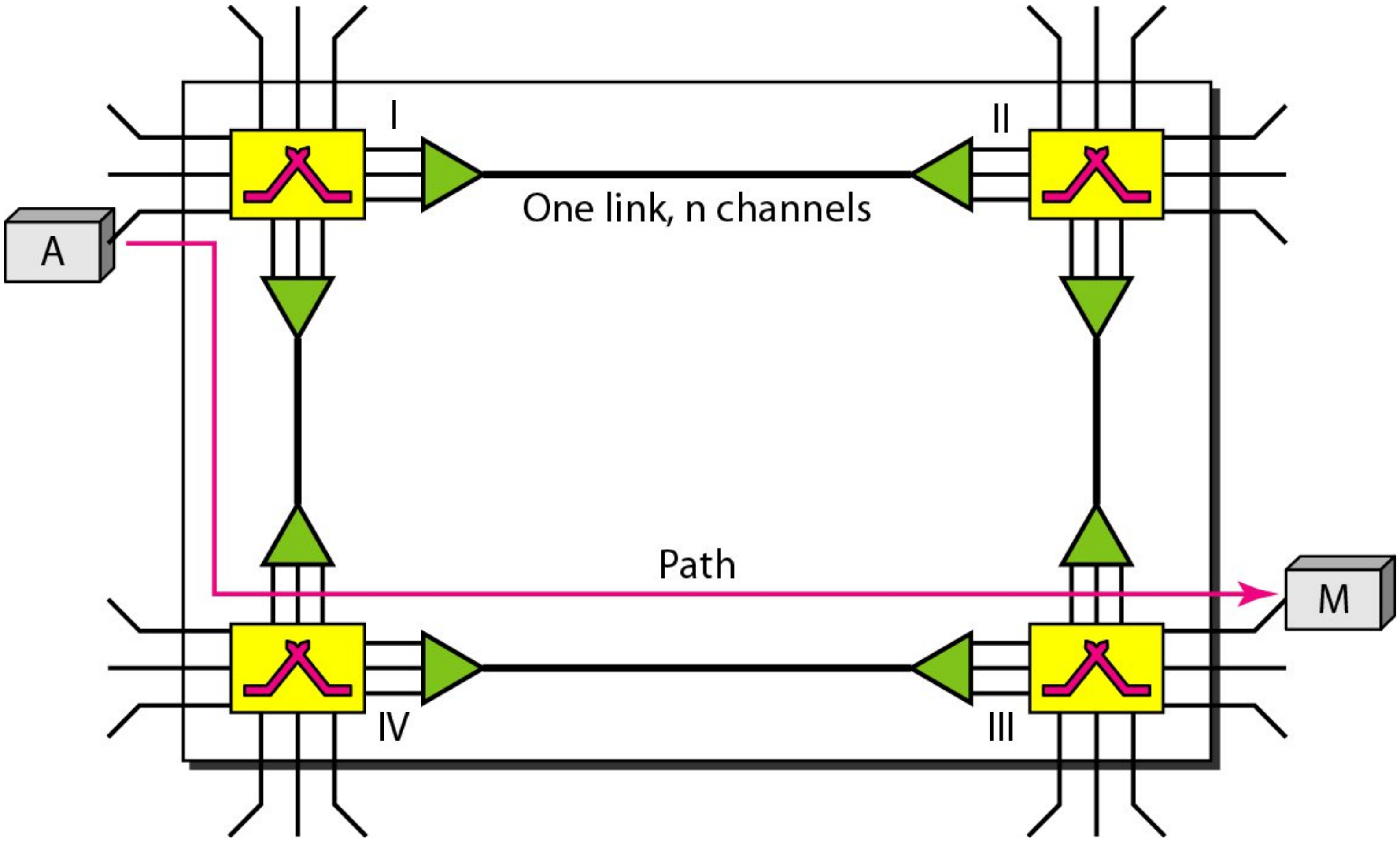
**Three Phases**
**Efficiency**
**Delay**
**Circuit-Switched Technology in Telephone Networks**

**Note**

**A circuit-switched network is made of a set of switches connected by physical links, in which each link is divided into *n* channels.**

- Circuit switching is a technique that directly connects the sender and the receiver in an unbroken path.
- Telephone switching equipment, for example, establishes a path that connects the caller's telephone to the receiver’s telephone by making a physical connection.
- With this type of switching technique, once a connection is established, a dedicated path exists between both ends until the connection is terminated.
- Routing decisions must be made when the circuit is first established, but there are no decisions made after that time.

## **Figure 8.3** *A trivial circuit-switched network*



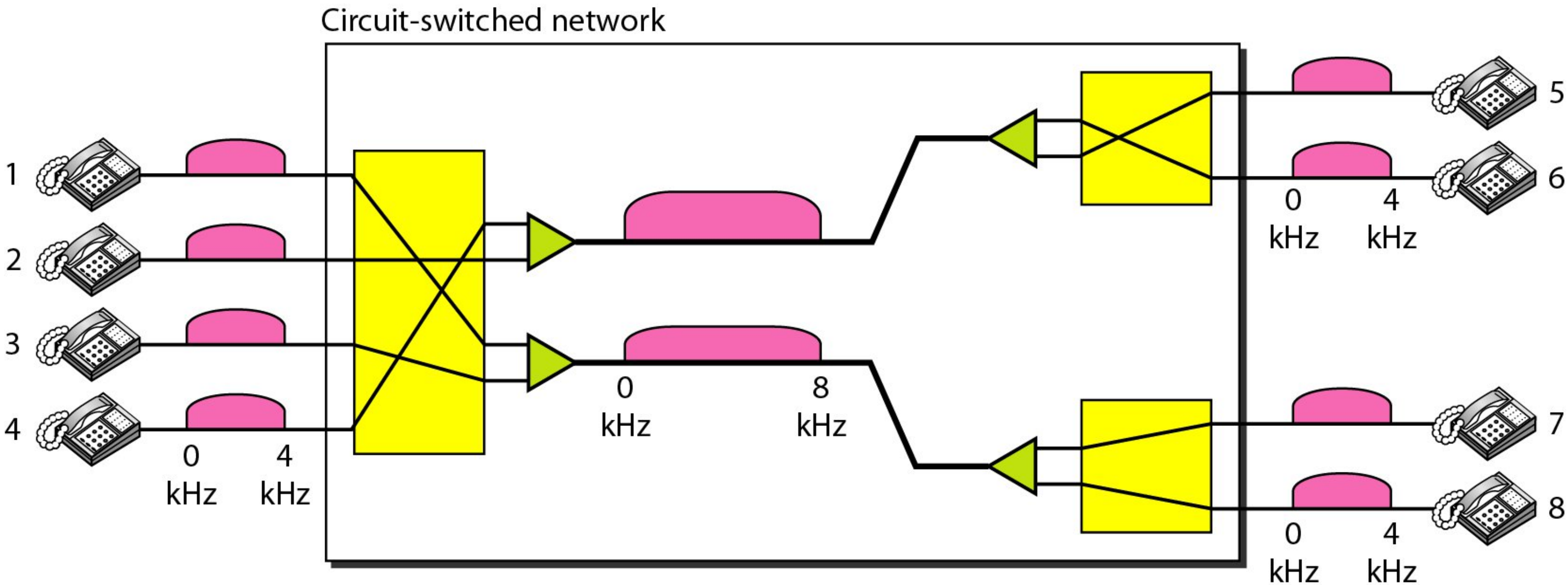
***Note***

**In circuit switching, the resources need to be reserved during the setup phase; the resources remain dedicated for the entire duration of data transfer until the teardown phase.**

## Example 8.1

***As a trivial example, let us use a circuit-switched network to connect eight telephones in a small area. Communication is through 4-kHz voice channels. We assume that each link uses FDM to connect a maximum of two voice channels. The bandwidth of each link is then 8 kHz. Figure 8.4 shows the situation. Telephone 1 is connected to telephone 7; 2 to 5; 3 to 8; and 4 to 6. Of course the situation may change when new connections are made. The switch controls the connections.***

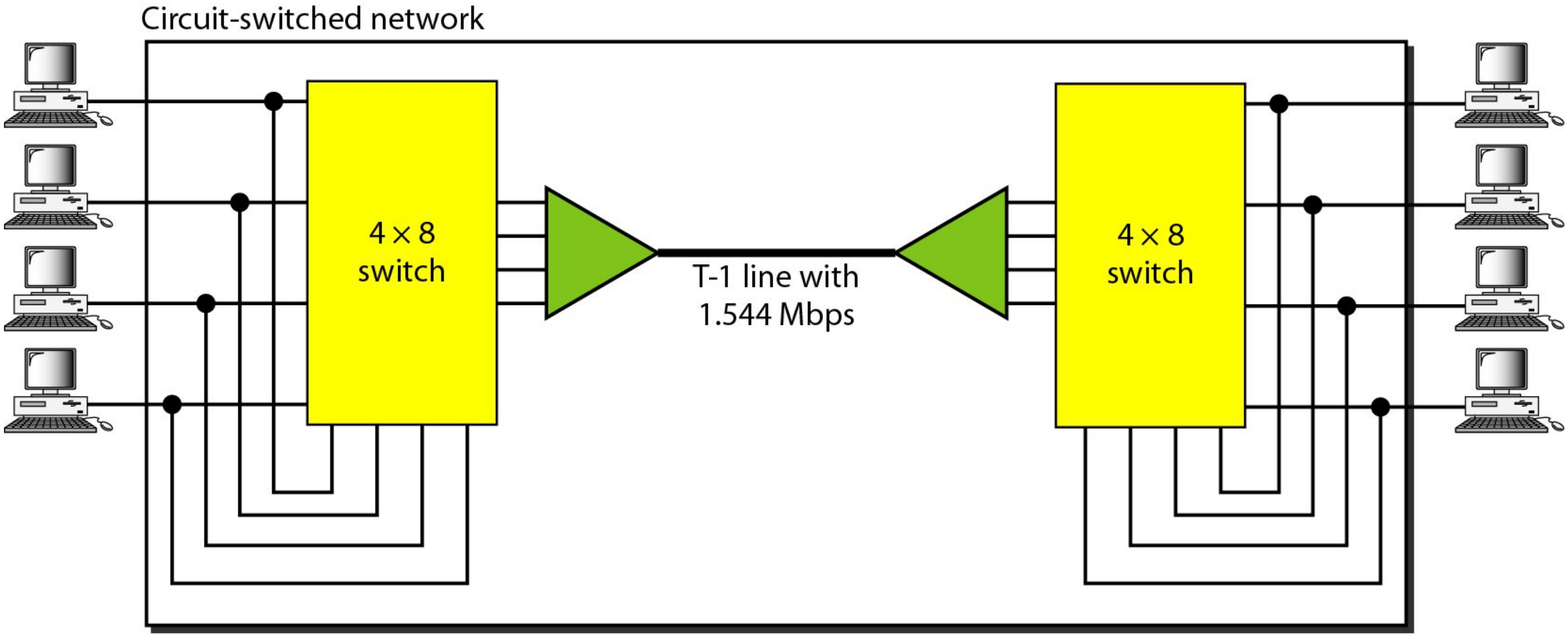
## **Figure 8.4** *Circuit-switched network used in Example 8.1*



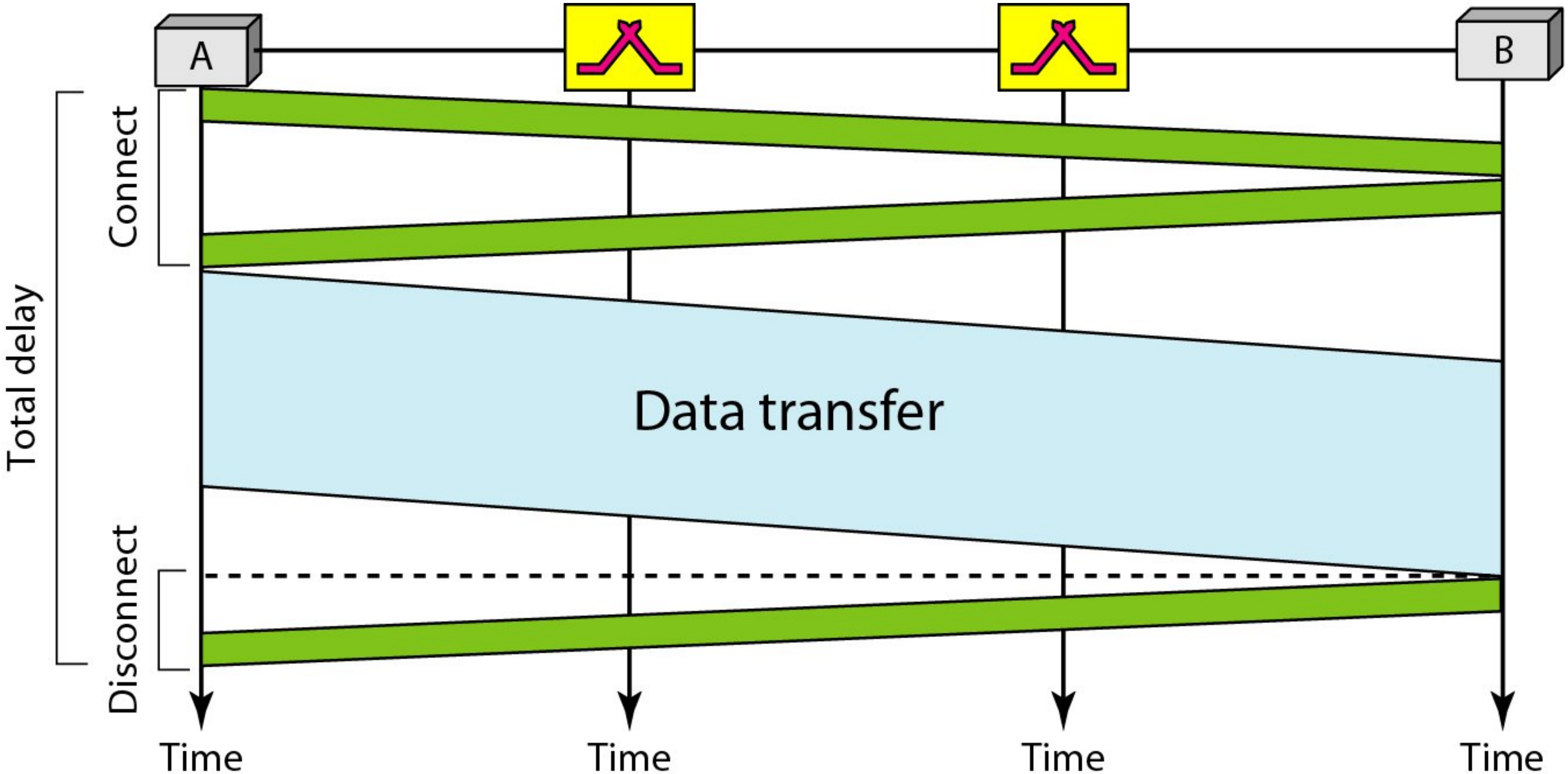
## Example 8.2

***As another example, consider a circuit-switched network that connects computers in two remote offices of a private company. The offices are connected using a T-1 line leased from a communication service provider. There are two 4 × 8 (4 inputs and 8 outputs) switches in this network. For each switch, four output ports are folded into the input ports to allow communication between computers in the same office. Four other output ports allow communication between the two offices. Figure 8.5 shows the situation.***

## Figure 8.5 *Circuit-switched network used in Example 8.2*



## Figure 8.6 *Delay in a circuit-switched network*



# 8-2 DATAGRAM NETWORKS

***In data communications, we need to send messages from one end system to another. If the message is going to pass through a packet-switched network, it needs to be divided into packets of fixed or variable size. The size of the packet is determined by the network and the governing protocol.***

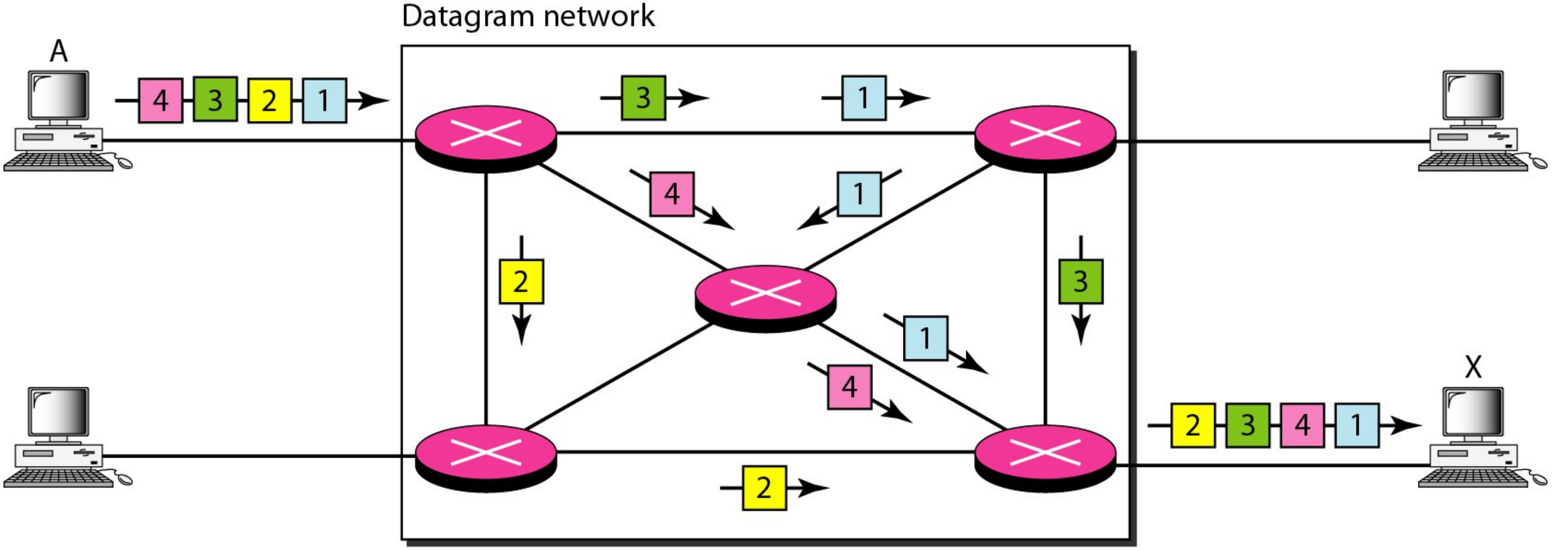
***Topics discussed in this section:***

**Routing Table**
**Efficiency**
**Delay**
**Datagram Networks in the Internet**

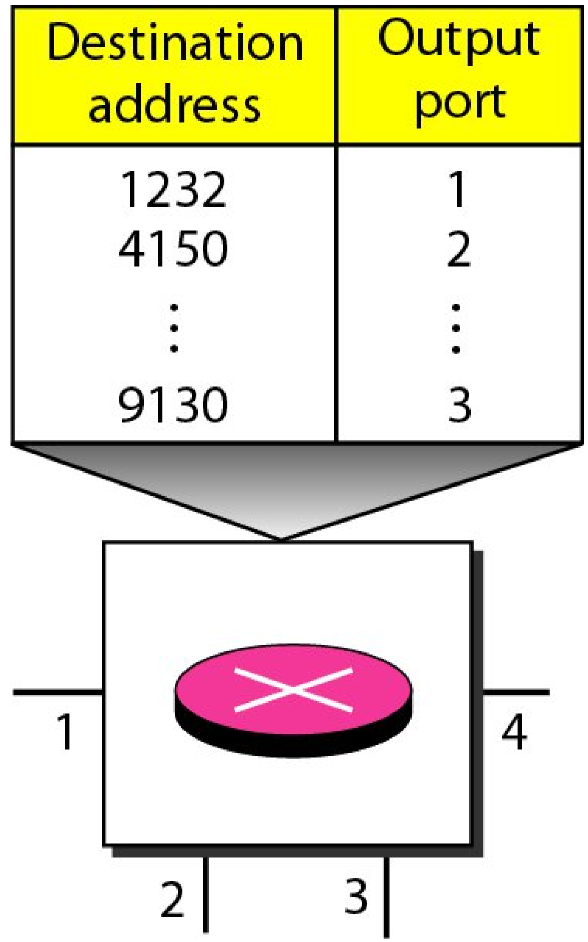
*Note*

**In a packet-switched network, there is no resource reservation; resources are allocated on demand.**

## Figure 8.7 *A datagram network with four switches (routers)*



# Figure 8.8 *Routing table in a datagram network*



*Note*

**A switch in a datagram network uses a routing table that is based on the destination address.**

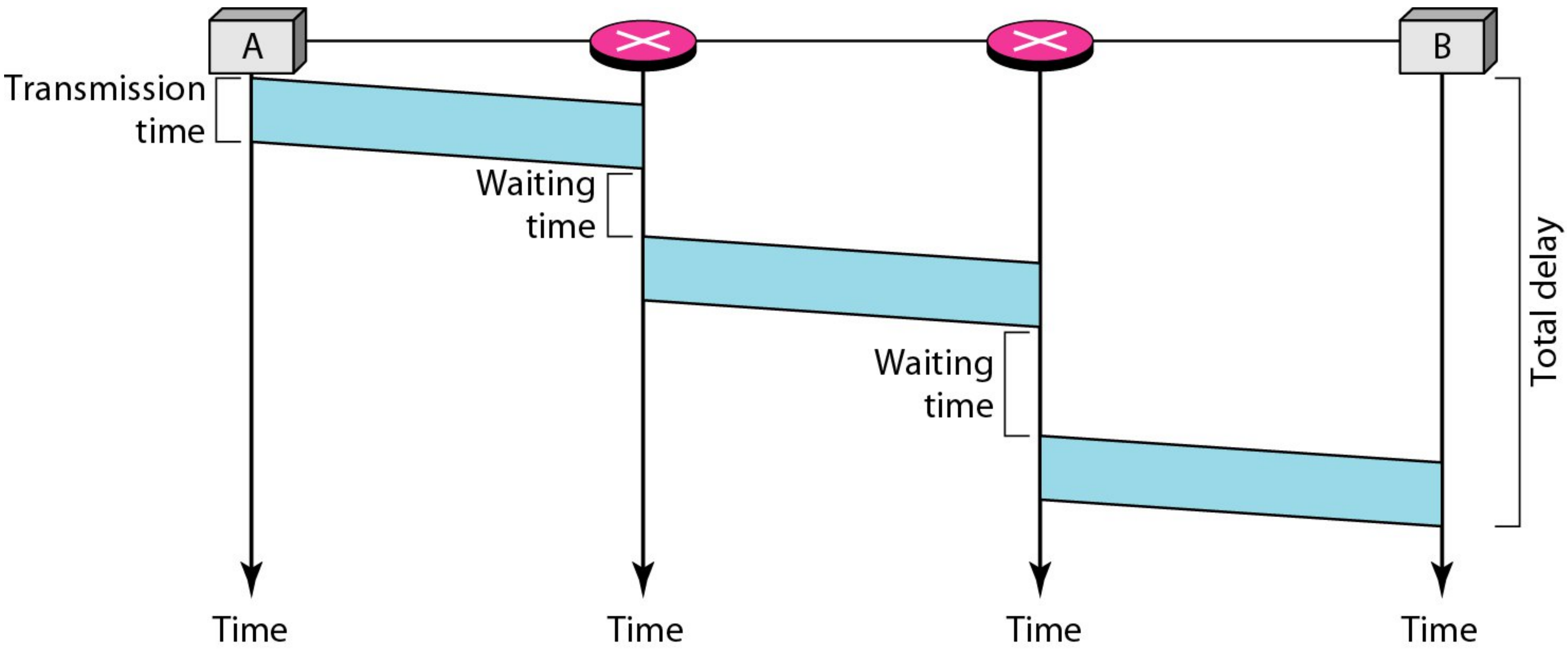
***Note***

**The destination address in the header of a packet in a datagram network remains the same during the entire journey of the packet.**

**Types of Delays in Packet Switching**

- **Transmission Delay:** Time required by the **spent** station to transmit data to the link.
- **Propagation Delay:** Time of data propagation through the link.
- **Queueing Delay:** Time spent by the packet at the destination's queue.
- **Processing Delay:** Processing time for data at the destination.

## **Figure 8.9** *Delay in a datagram network*




$$\text{Total delay} = 3T + 3\tau + w_1 + w_2$$

***Note***

**Switching in the Internet is done by using the datagram approach to packet switching at the network layer.**

**In a packet switching network, packets are routed from source to destination along a single path having two intermediate nodes. If the message size is 24 bytes and each packet contains a header of 3 bytes, then the optimum packet size is-**

**4 bytes**
**6 bytes**
**7 bytes**
**9 bytes**

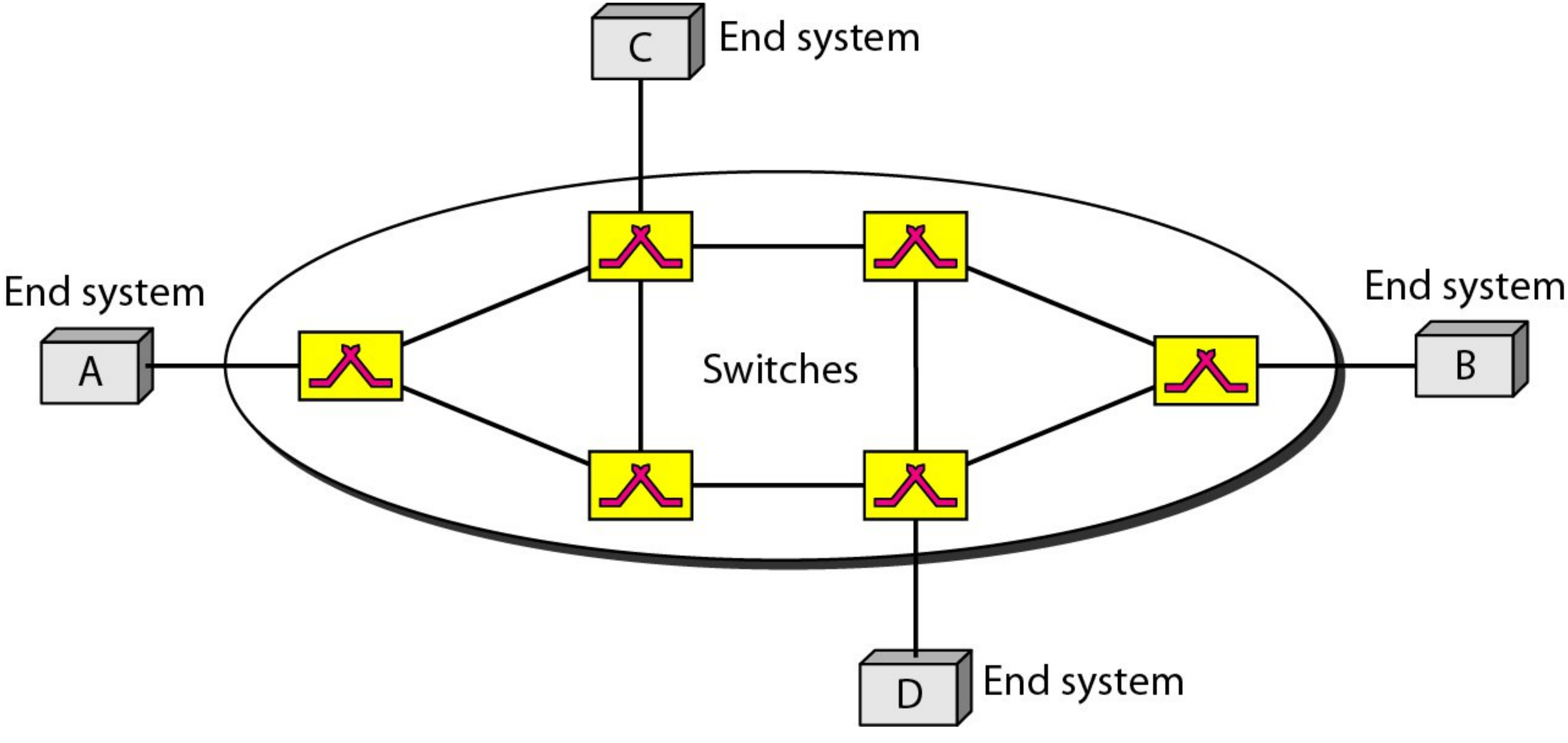
# 8-3 VIRTUAL-CIRCUIT NETWORKS

***A virtual-circuit network is a cross between a circuit-switched network and a datagram network. It has some characteristics of both.***

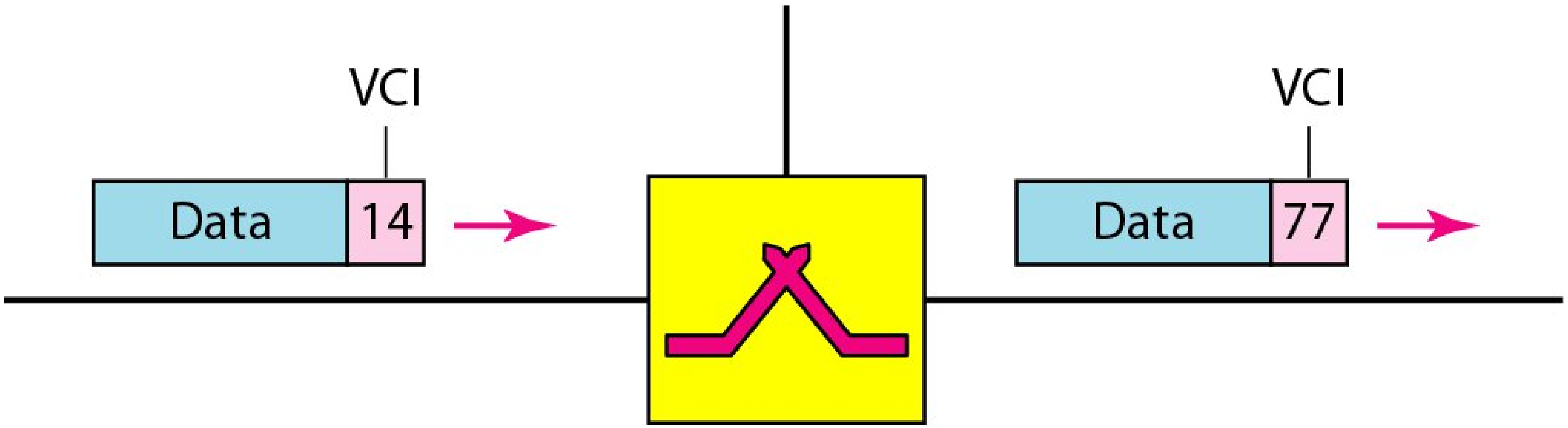
***Topics discussed in this section:***

**Addressing**
**Three Phases**
**Efficiency**
**Delay**
**Circuit-Switched Technology in WANs**

## **Figure 8.10** *Virtual-circuit network*

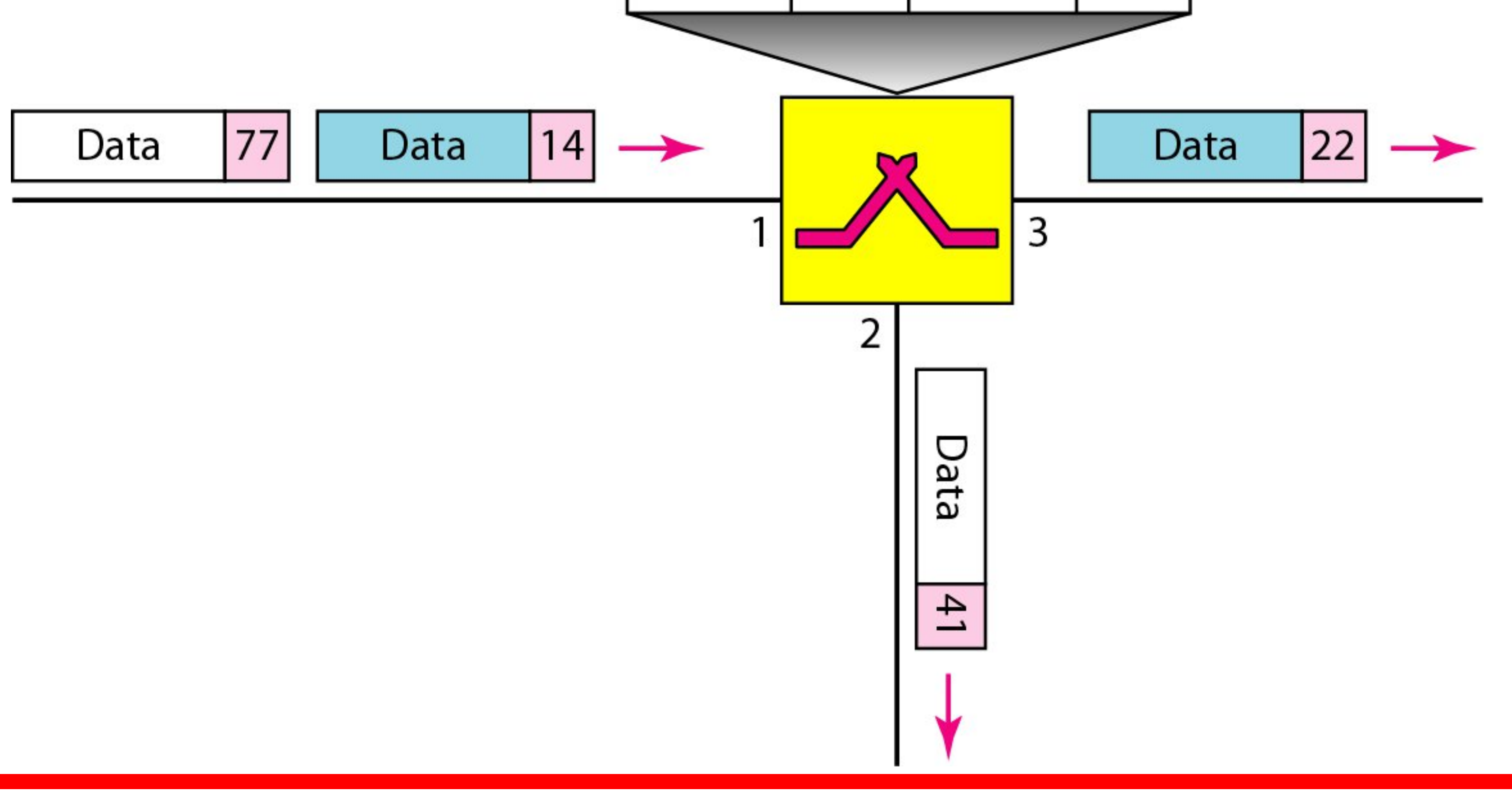


## **Figure 8.11** *Virtual-circuit identifier*

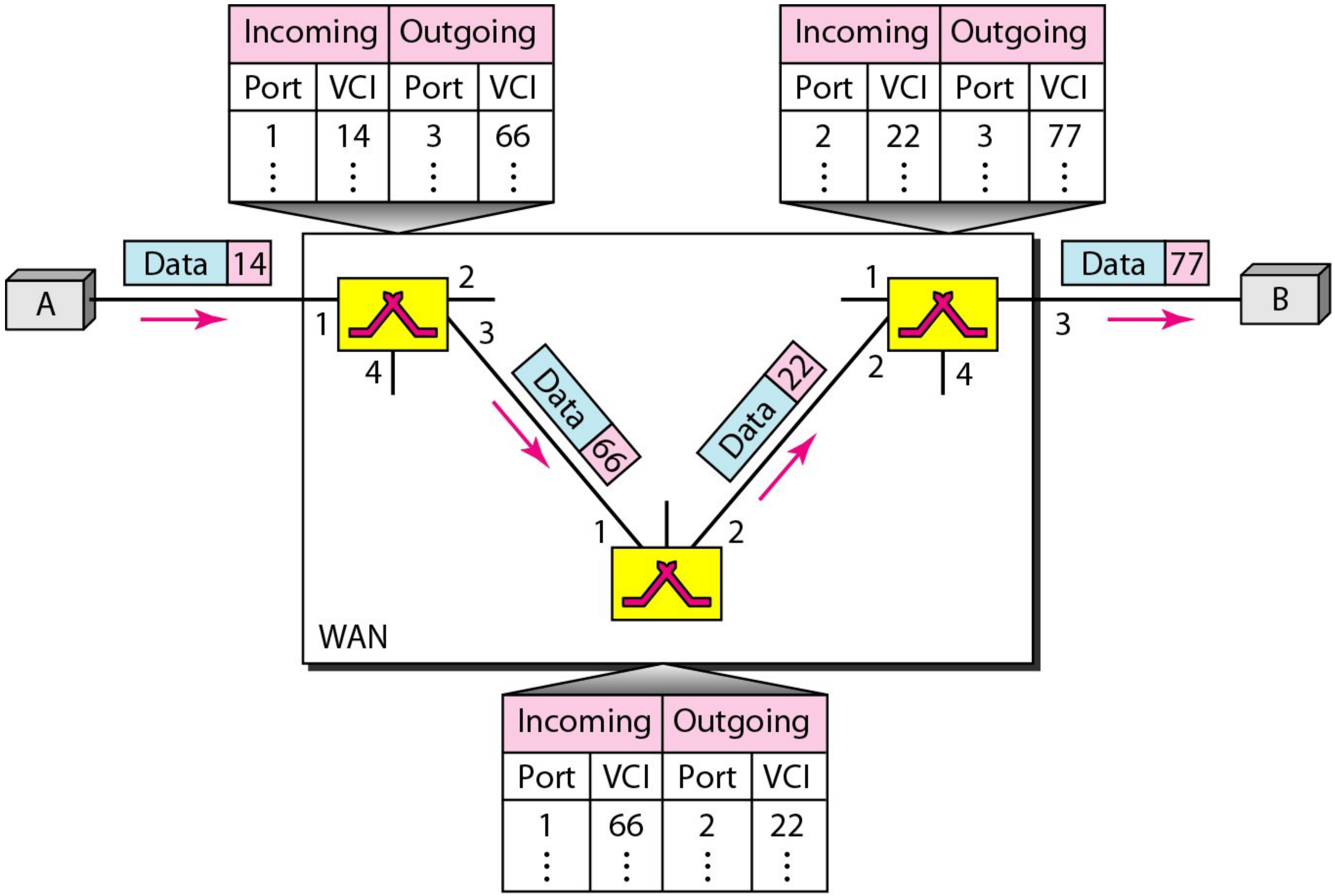


## **Figure 8.12** *Switch and tables in a virtual-circuit network*

| Incoming | | Outgoing | |
|---|---|---|---|
| Port | VCI | Port | VCI |
| 1 | 14 | 3 | 22 |
| 1 | 77 | 2 | 41 |



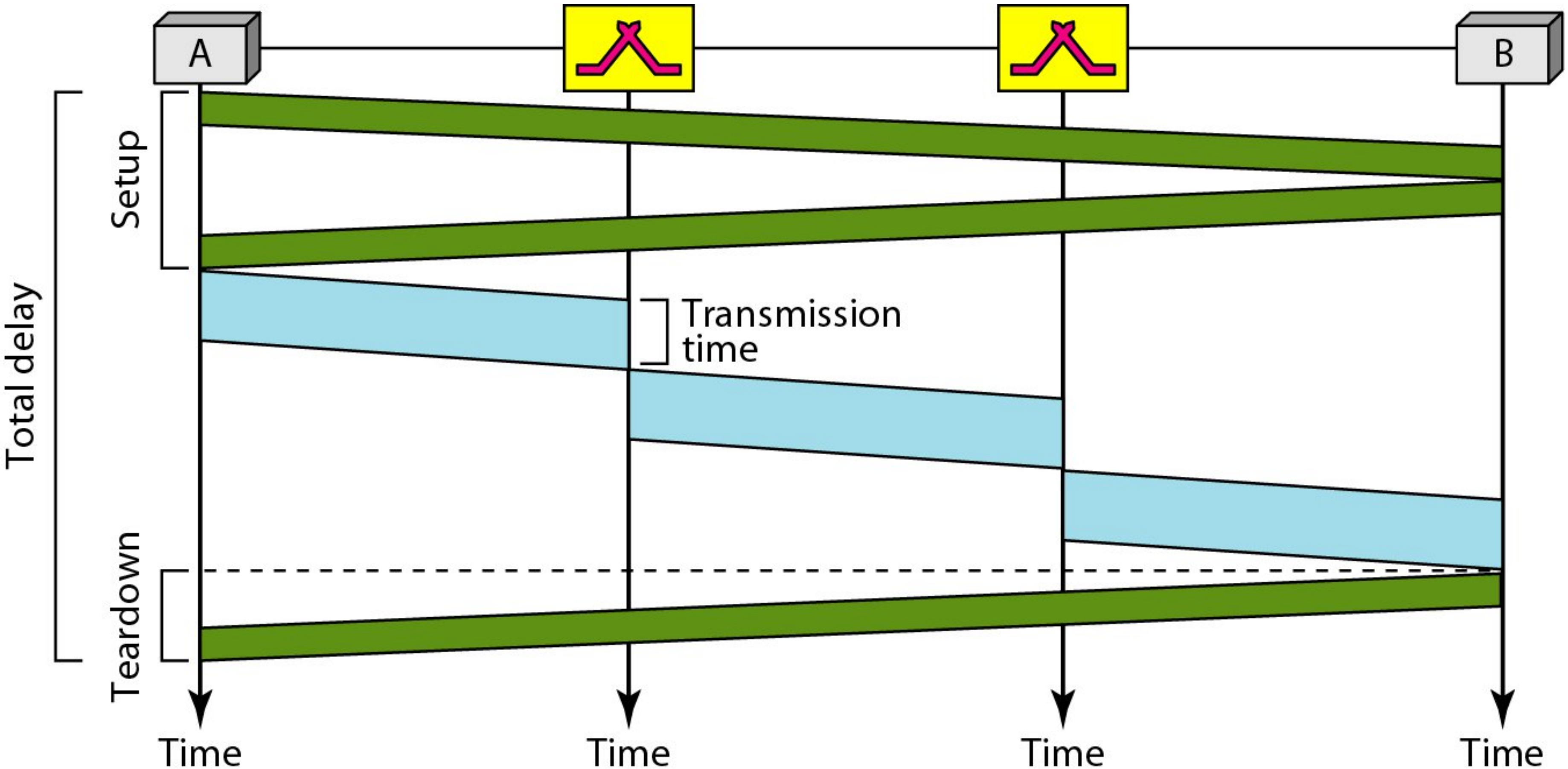
## **Figure 8.13** *Source-to-destination data transfer in a virtual-circuit network*



***Note***

**In virtual-circuit switching, all packets belonging to the same source and destination travel the same path; but the packets may arrive at the destination with different delays if resource allocation is on demand.**

## Figure 8.16 *Delay in a virtual-circuit network*



***Note***

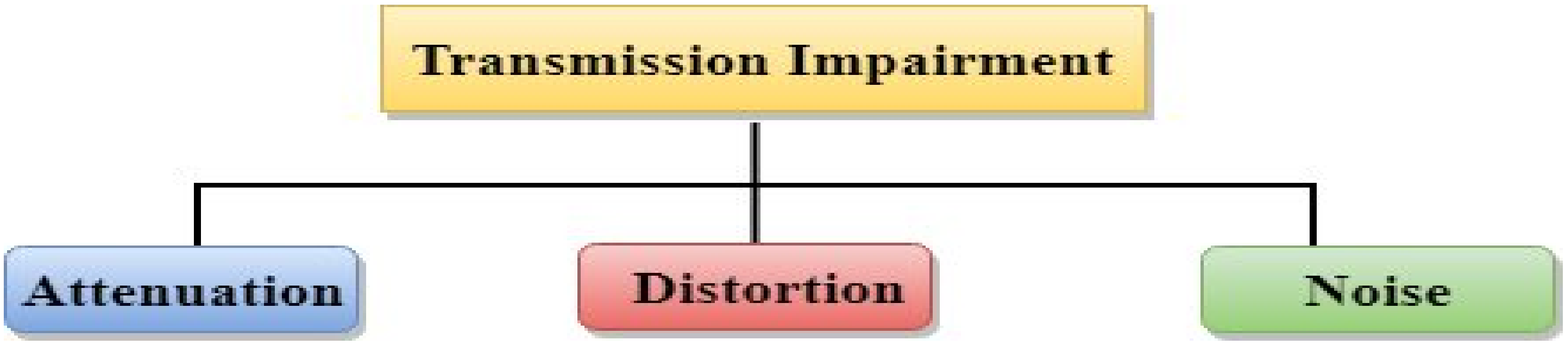
**Switching at the data link layer in a switched WAN is normally implemented by using virtual-circuit techniques.**

| Packet Switching | Circuit Switching |
|---|---|
| In packet switching data is divided into packets, and packets is sent independently. | There is a dedicated path for each packet in circuit switching. |
| In Packet switching, data is processed at all intermediate nodes including the source system. | In-Circuit switching, data is processed at the source system only. |
| The delay between data units in packet switching is not uniform. | The delay between data units in circuit switching is uniform. |
| Packet switching is less reliable. | Circuit switching is more reliable. |
| Transmission of the data is done not only by the source but also by the intermediate routers. | Transmission of the data is done by the source. |
| Less wastage of resources. | Wastage of resources is more in Circuit Switching. |
| In Packet Switching there is no physical path between the source and the destination. | In-Circuit Switching there is a physical path between the source and the destination. |
| Call setup is not required in packet switching. | Call setup is required in circuit switching. |
| Packet switching requires complex protocols for delivery. | Circuit switching requires simple protocols for delivery. |
| Latency is high in Packet switching. | Latency is low in circuit switching. |
| Littel bit more overheating in packet switching. | Overheading is low in circuit switching. |

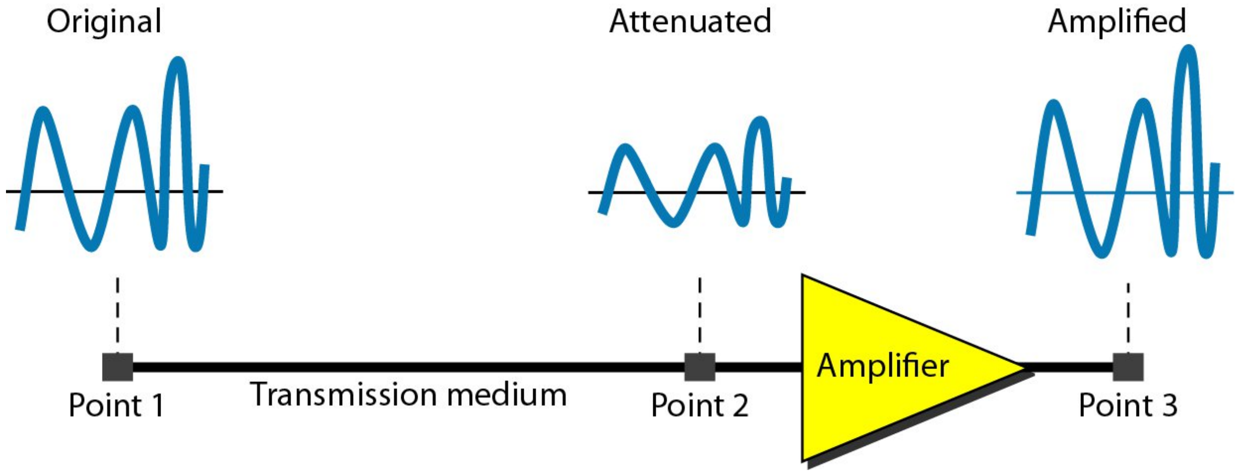
# Transmission media

- communication channel that carries the information from the sender to the receiver. Data is transmitted through the electromagnetic signals.
- Some factors need to be considered for designing the transmission media
- Bandwidth
- Impairment
- Interferences.

# Causes Of Transmission Impairment



## Figure 3.26 **Attenuation**




$$Attenuation(dB) = 10\log_{10}(P2/P1)$$

## Example 3.26

**Suppose a signal travels through a transmission medium and its power is reduced to one-half. This means that P2 is (1/2)P1. In this case, the attenuation (loss of power) can be calculated as**

$$10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{0.5 P_1}{P_1} = 10 \log_{10} 0.5 = 10(-0.3) = -3 \text{ dB}$$

**A loss of 3 dB (–3 dB) is equivalent to losing one-half the power.**

## Example 3.27

**A signal travels through an amplifier, and its power is increased 10 times. This means that $P_2$ = $10P_1$ . In this case, the amplification (gain of power) can be calculated as**

$$10 \log_{10} \frac{P_2}{P_1} = 10 \log_{10} \frac{10P_1}{P_1}$$

$$= 10 \log_{10} 10 = 10(1) = 10 \text{ dB}$$

## Example 3.30

**The loss in a cable is usually defined in decibels per kilometer (dB/km). If the signal at the beginning of a cable with −0.3 dB/km has a power of 2 mW, what is the power of the signal at 5 km?**

## Solution

**The loss i ... els is 5 × (−0.3) = −1 ... culate the power as**

$$\text{dB} = 10 \log_{10} \frac{P_2}{P_1} = -1.5$$

$$\frac{P_2}{P_1} = 10^{-0.15} = 0.71$$

$$P_2 = 0.71 P_1 = 0.7 \times 2 = 1.4 \text{ mW}$$

## Figure 3.28 Distortion

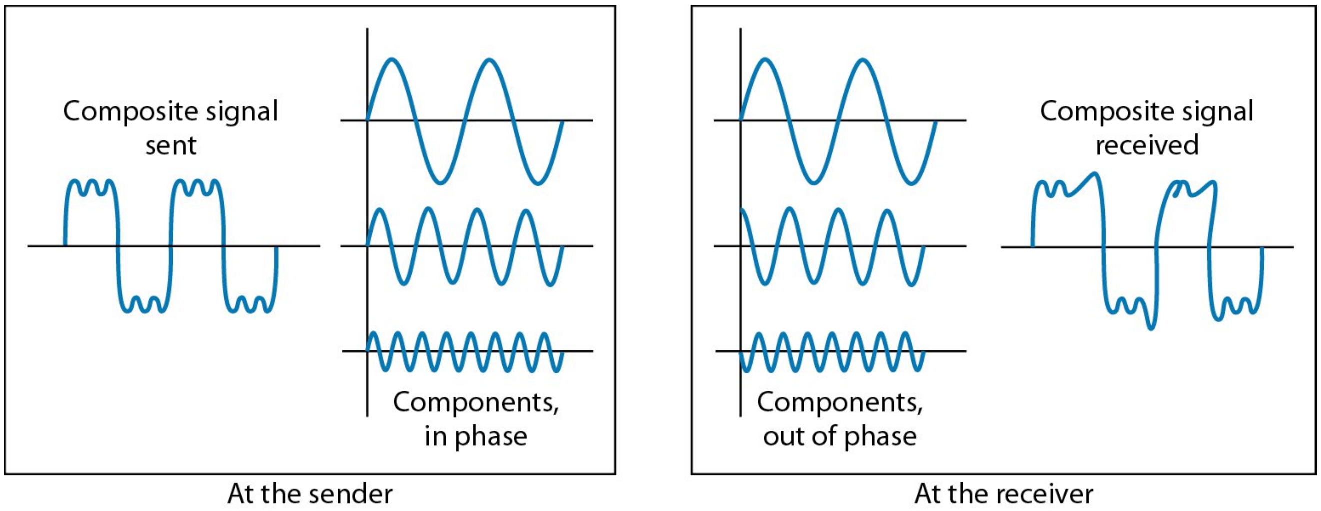
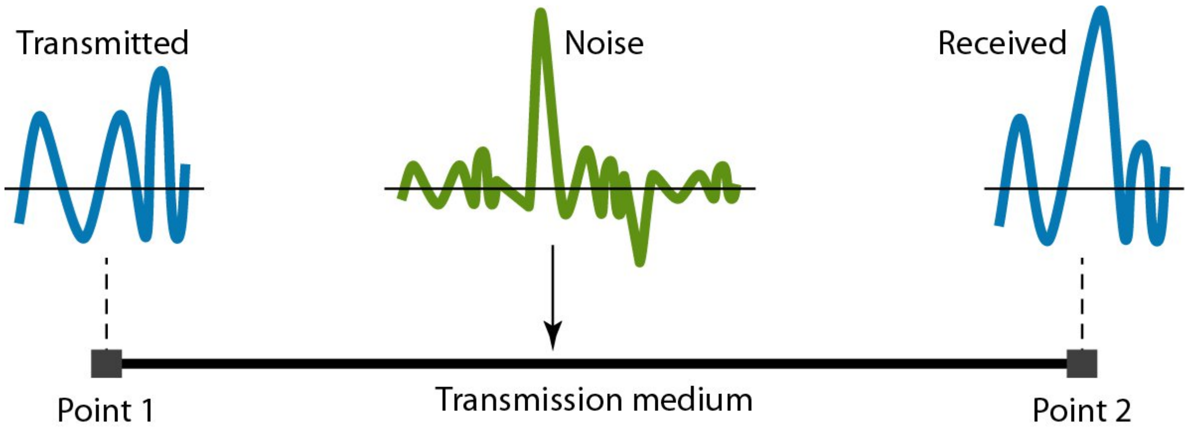


**Figure 3.29** **Noise**




**SNR = AVG SIGNAL POWER / AVG NOISE POWER**

**$SNR_{dB}$ = 10Log10SNR**

## Example 3.31

**The power of a signal is 10 mW and the power of the noise is 1 μW; what are the values of SNR and $SNR_{dB}$ ?**

**Solution**

**The values of SNR and SNRdB can be calculated as follows:**

$$SNR = \frac{10{,}000\ \mu W}{1\ mW} = 10{,}000$$

$$SNR_{dB} = 10 \log_{10} 10{,}000 = 10 \log_{10} 10^4 = 40$$

# Performance

**Bandwidth**

In networking, we use the term *bandwidth* in two contexts.

- The first, *bandwidth in hertz,* refers to the range of frequencies in a composite signal or the range of frequencies that a channel can pass.
- The second, *bandwidth in bits per second,* refers to the speed of bit transmission in a channel or link.

The **throughput** is a measure of how fast we can actually send data through a network.

**Latency (Delay)**

Latency = propagation time + transmission time + queuing time + processing delay

Propagation time = Distance / (Propagation Speed)

Transmission time = (Message size) / Bandwidth

# Performance

Jitter: The variation in the latency on a packet flow between two systems when some packets take longer to travel from one system to the other.

latency measures the average time it takes for a packet to reach its destination, jitter focuses on the fluctuations or variations in those arrival times

## Example 3.44

A network with bandwidth of 10 Mbps can pass only an average of 12,000 frames per minute with each frame carrying an average of 10,000 bits. What is the throughput of this network?

### Solution

We can calculate the throughput as

$$\textbf{Throughput} = (12{,}000 \times 10{,}000) / 60 = 2 \text{ Mbps}$$

The throughput is almost one-fifth of the bandwidth in this case.

## Example 3.45

What is the propagation time if the distance between the two points is 12,000 km? Assume the propagation speed to be $2.4 \times 10^8$ m/s in cable.

### Solution

We can calculate the propagation time as

$$\textbf{Propagation time} = (12{,}000 \times 10{,}000) / (2.4 \times 2^8) = 50 \text{ ms}$$

## Example 3.46

What are the propagation time and the transmission time for a 2.5-KB (kilobyte) message (an e-mail) if the bandwidth of the network is 1 Gbps? Assume that the distance between the sender and the receiver is 12,000 km and that light travels at $2.4 \times 10^8$ m/s.

### Solution

We can calculate the propagation and transmission time as

$$\textbf{Propagation time} = (12{,}000 \times 1000) / (2.4 \times 10^8) = 50 \text{ ms}$$

$$\textbf{Transmission time} = (2500 \times 8) / 10^9 = 0.020 \text{ ms}$$

## Example 3.47

What are the propagation time and the transmission time for a 5-MB (megabyte) message (an image) if the bandwidth of the network is 1 Mbps? Assume that the distance between the sender and the receiver is 12,000 km and that light travels at $2.4 \times 10^8$ m/s.

### Solution

We can calculate the propagation and transmission times as

$$\textbf{Propagation time} = (12{,}000 \times 1000) / (2.4 \times 10^8) = 50 \text{ ms}$$

$$\textbf{Transmission time} = (5{,}000{,}000 \times 8) / 10^6 = 40 \text{ s}$$