Chapter

Switching

PERFORMANCE

- **Throughput**
- **Propagation speed**
- **Propagation time**

SHANNON CAPACITY

$$C = B \log_2(1 + S/N)$$

Figure 8.1 *Switched network*

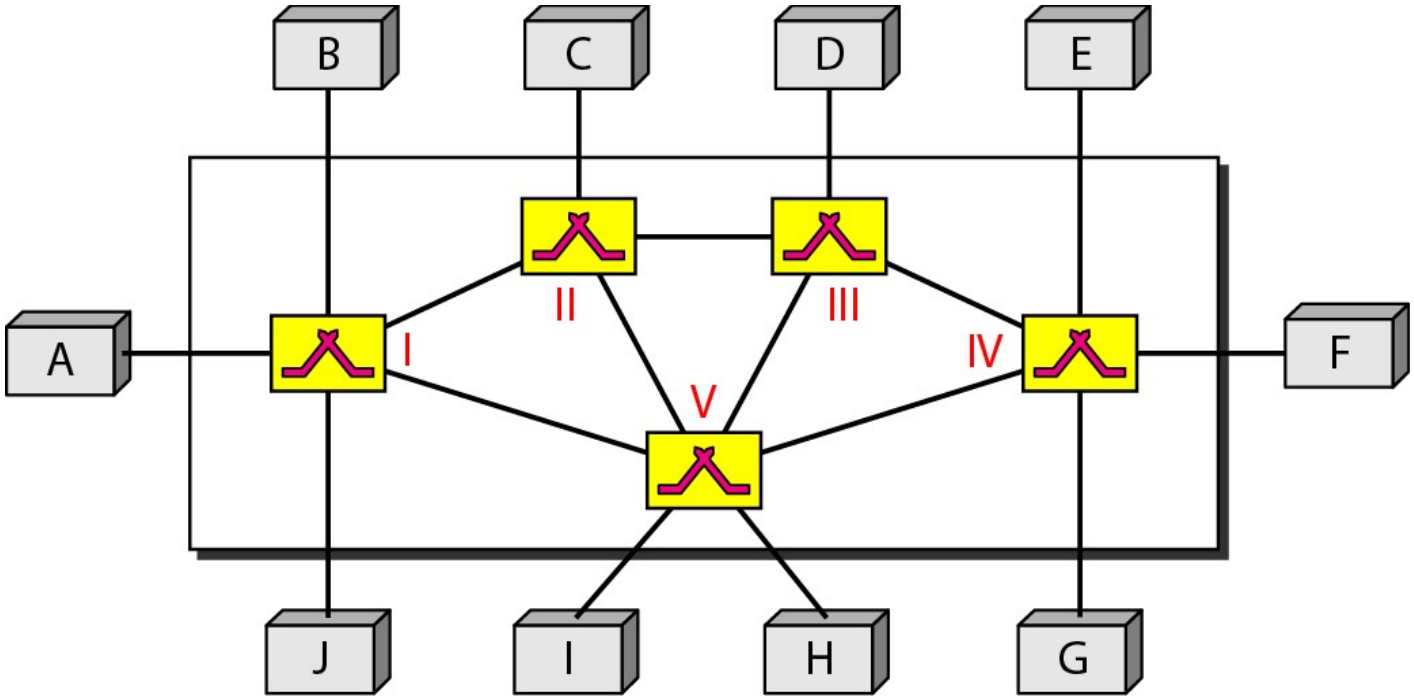
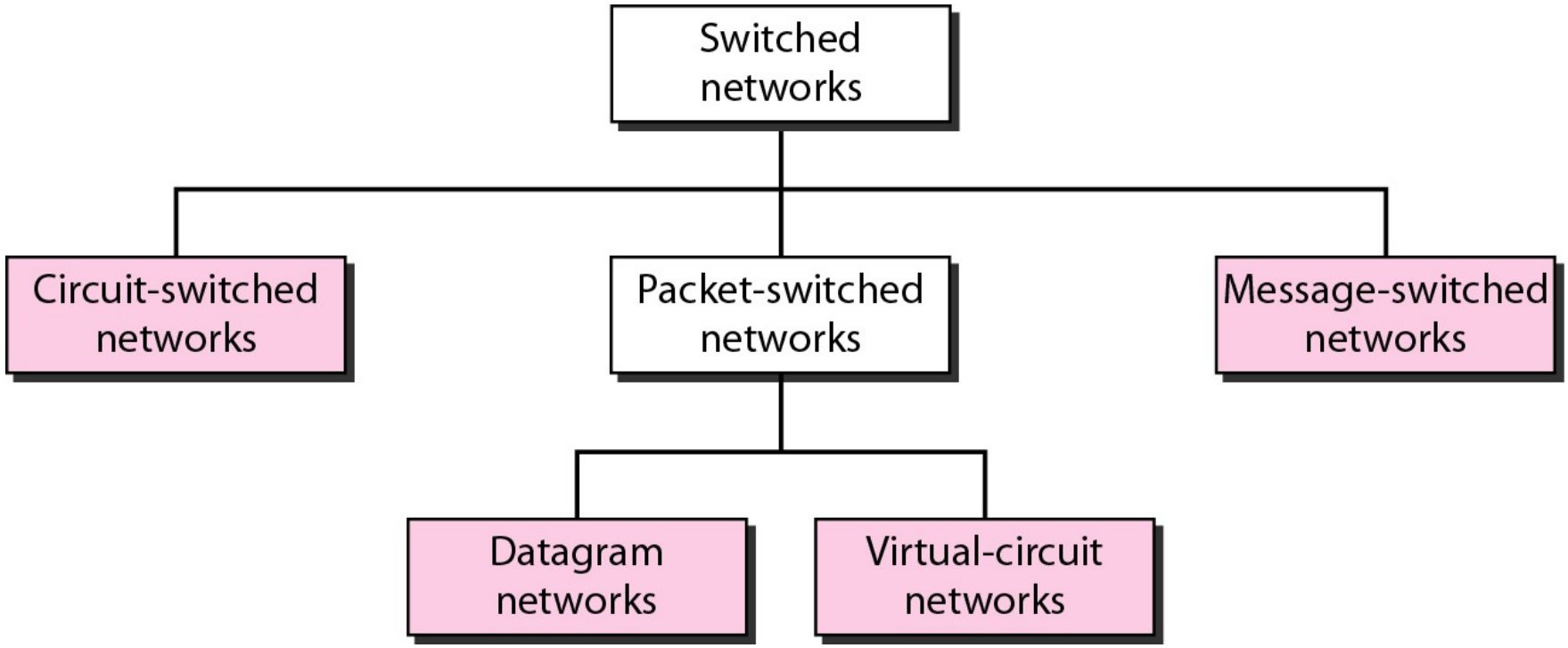


Figure 8.2 *Taxonomy of switched networks*



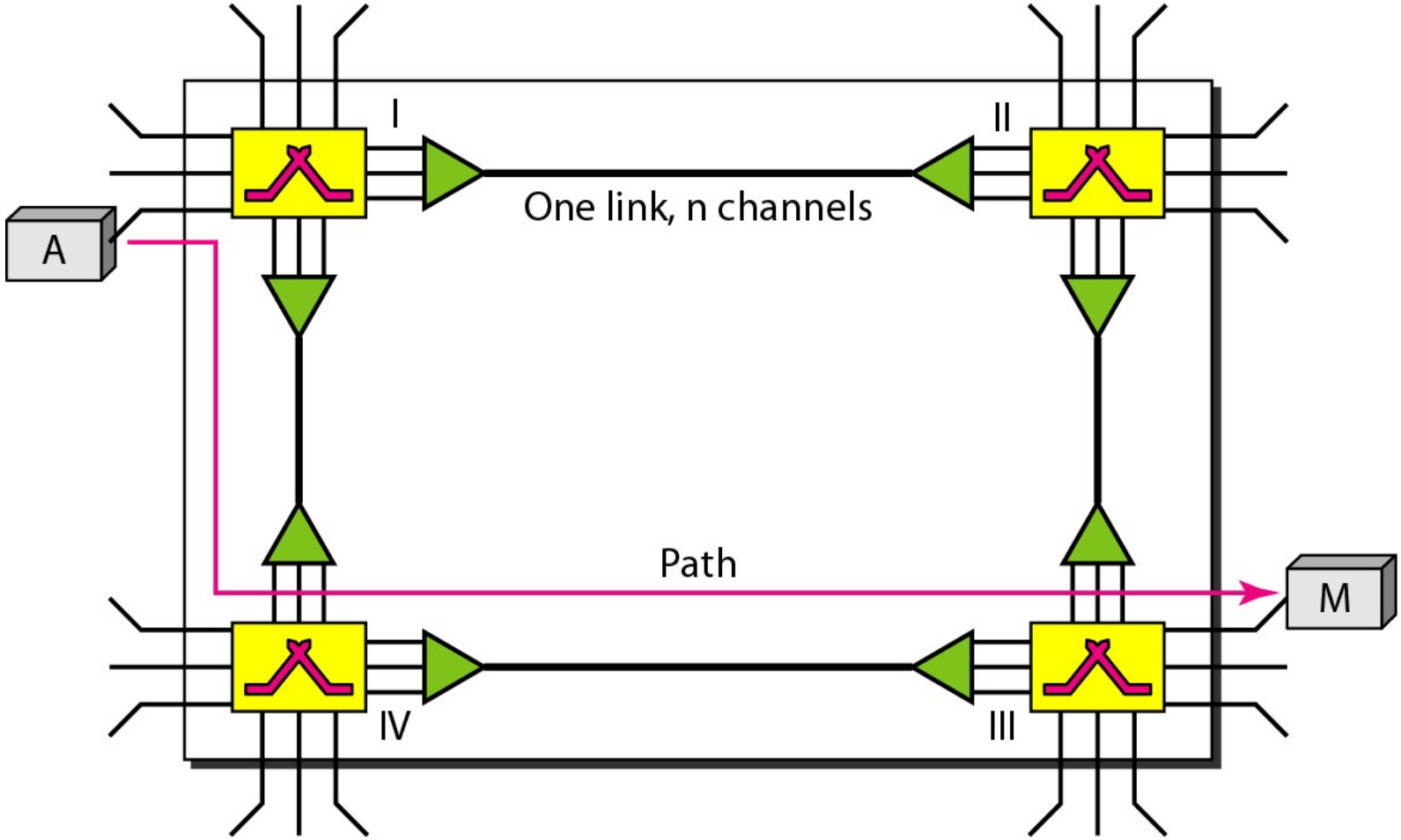
8-1 CIRCUIT-SWITCHED NETWORKS

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:

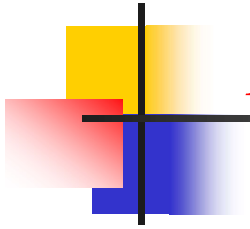
Three Phases
Efficiency
Delay
Circuit-Switched Technology in Telephone Networks

Figure 8.3 *A trivial circuit-switched network*



Note

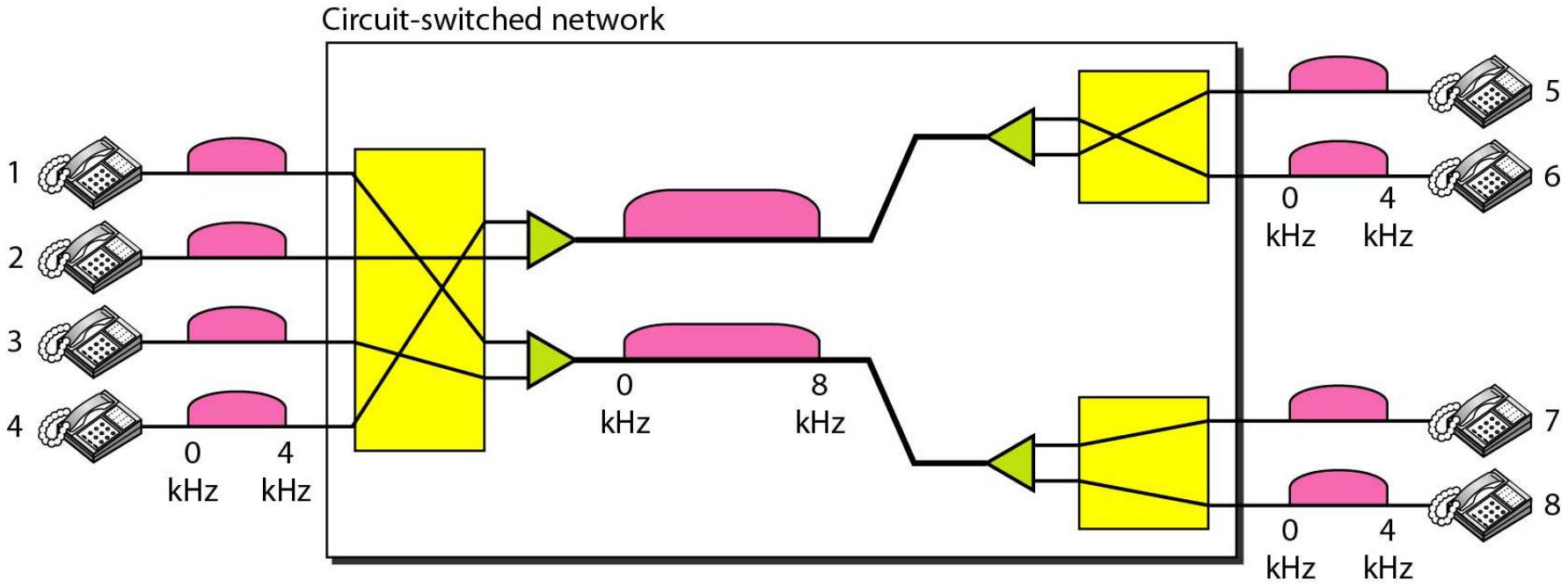
In circuit switching, the resources need to be reserved during the setup phase; the resources remain dedicated for the entire duration of data transfer until the teardown phase.

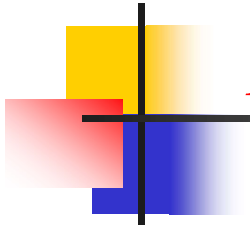


Example 8.1

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*

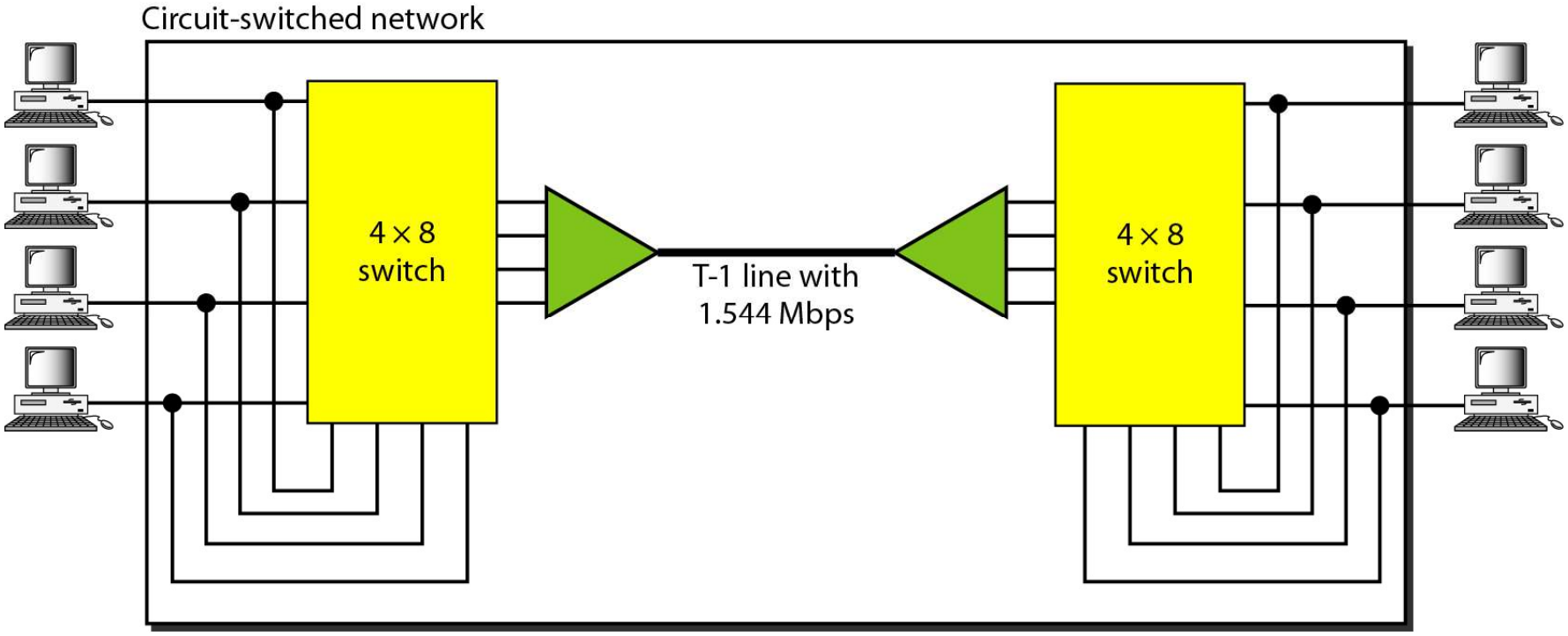
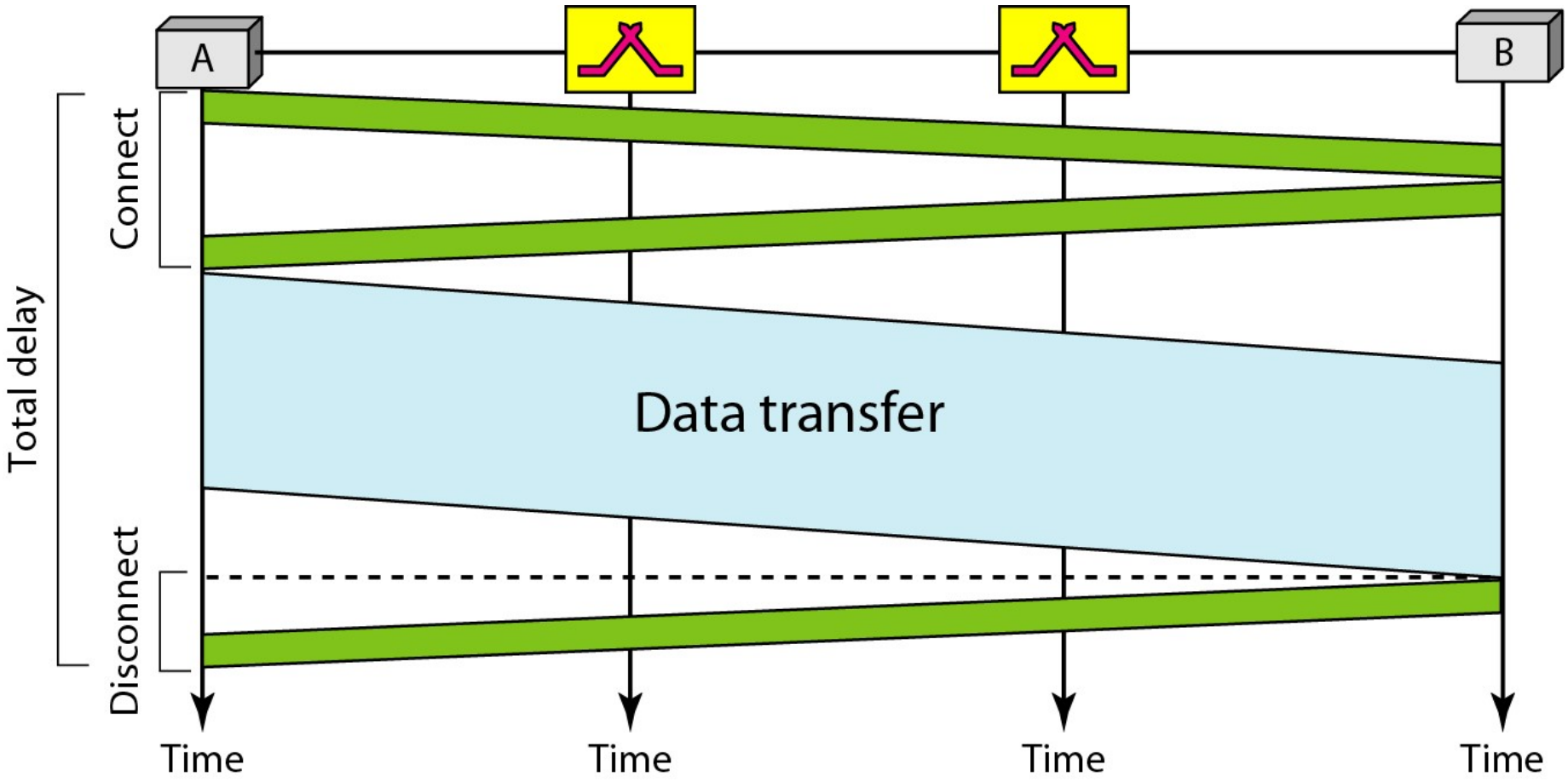


Figure 8.6 *Delay in a circuit-switched network*



Note

Switching at the physical layer in the traditional telephone network uses the circuit-switching approach.

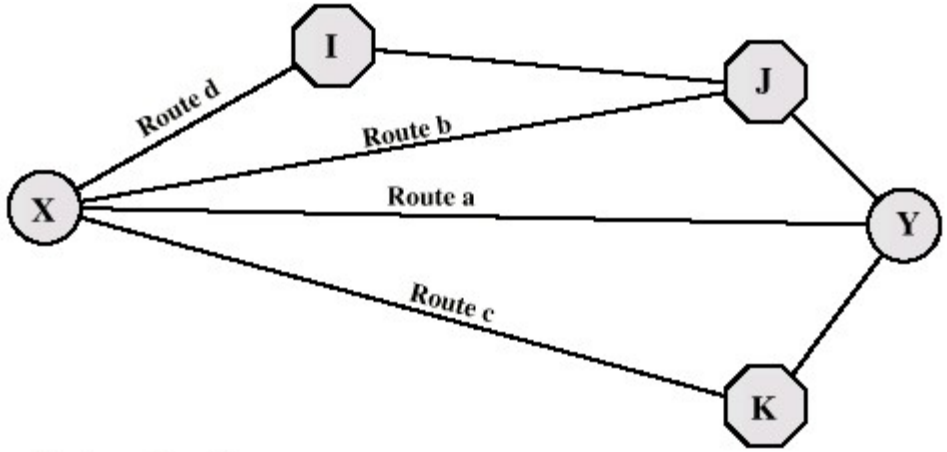
Circuit-Switched Routing

- Many connections will need paths through more than one switch
- Need to find a route
  - Efficiency
  - Resilience
- Public telephone switches are a tree structure
  - Static routing uses the same approach all the time
- Dynamic routing allows for changes in routing depending on traffic
  - Uses a peer structure for nodes

Alternate Routing

- Possible routes between end offices predefined
- Originating switch selects appropriate route
- Routes listed in preference order
- Different sets of routes may be used at different times

Alternate Routing Diagram



(a) Topology

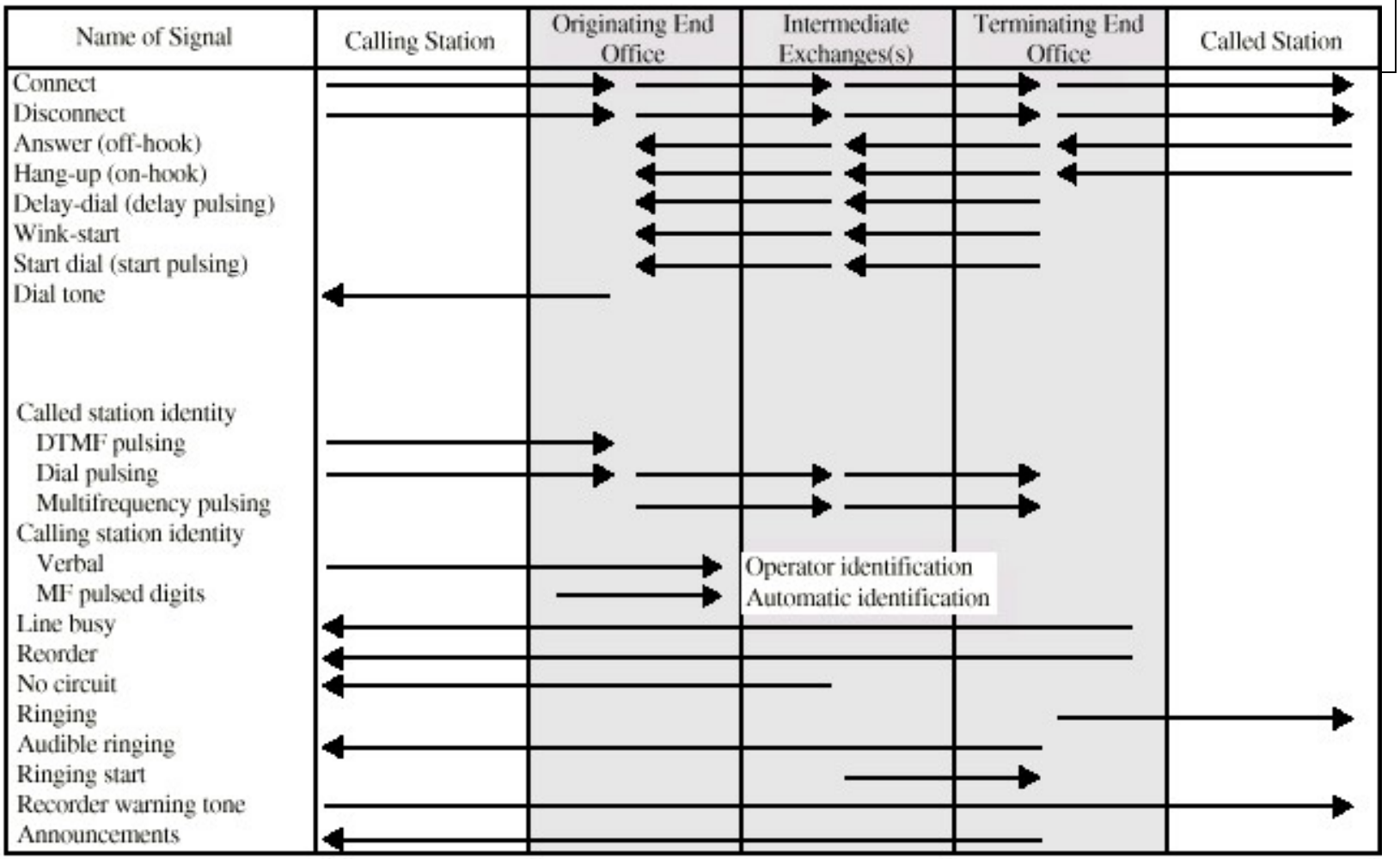
Time Period	First route	Second route	Third route	Fourth and final route
Morning	a	b	c	d
Afternoon	a	d	b	c
Evening	a	d	c	b
Weekend	a	c	b	d

(b) Routing table

Control Signaling Functions

- Audible communication with subscriber
- Transmission of dialed number
- Call can not be completed indication
- Call ended indication
- Signal to ring phone
- Billing info
- Equipment and trunk status info
- Diagnostic info
- Control of specialist equipment

Control Signals



Note: A broken line indicates repetition of a signal at each office, whereas a solid line indicates direct transmittal through intermediate offices.

Location of Signaling

- Subscriber to network
  - Depends on subscriber device and switch
- Within network
  - Management of subscriber calls and network
  - More complex

In-Channel Signaling

- Use same channel for signaling and call
  - Requires no additional transmission facilities
- Inband
  - Uses same frequencies as voice signal
  - Can go anywhere a voice signal can
  - Impossible to set up a call on a faulty speech path
- Out-of-band
  - Voice signals do not use full 4kHz bandwidth
  - Narrow signal band within 4kHz used for control
  - Can be sent whether or not voice signals are present
  - Need extra electronics
  - Slower signal rate (narrow bandwidth)

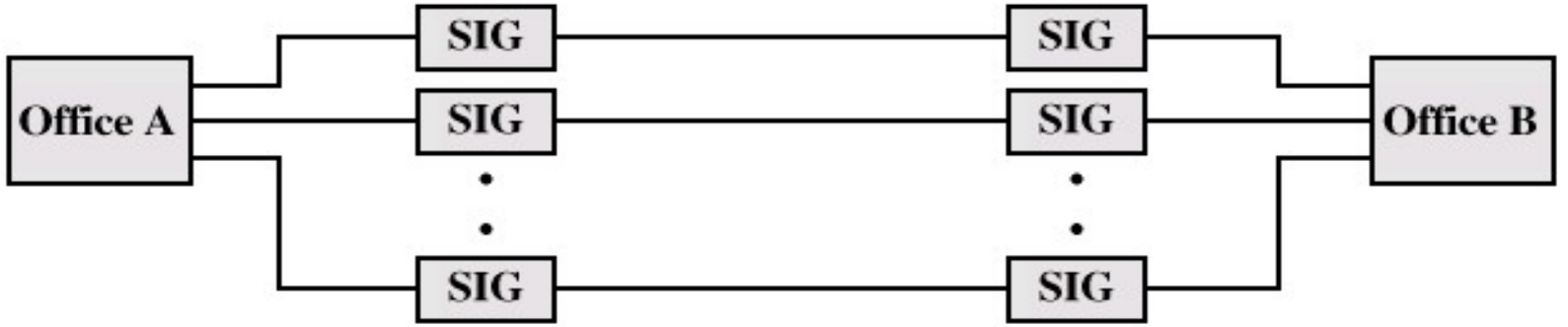
Drawbacks of In-Channel Signaling

- Limited transfer rate
- Delay between entering address (dialing) and connection
- Overcome by use of common channel signaling

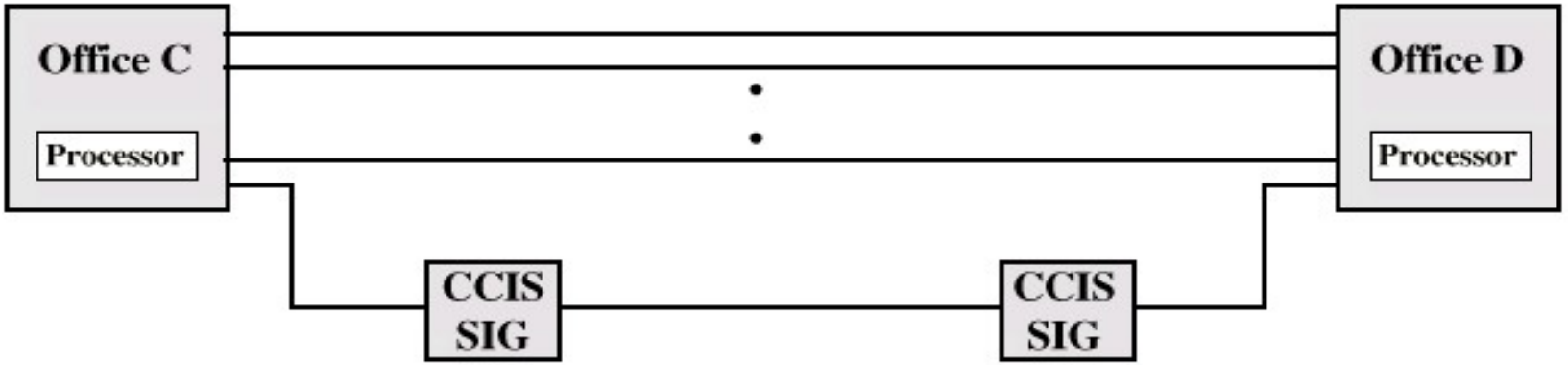
Common Channel Signaling

- Control signals carried over paths independent of voice channel
- One control signal channel can carry signals for a number of subscriber channels
- Common control channel for these subscriber lines
- Associated Mode
  - Common channel closely tracks interswitch trunks
- Disassociated Mode
  - Additional nodes (signal transfer points)
  - Effectively two separate networks

Common vs. In-Channel Signaling



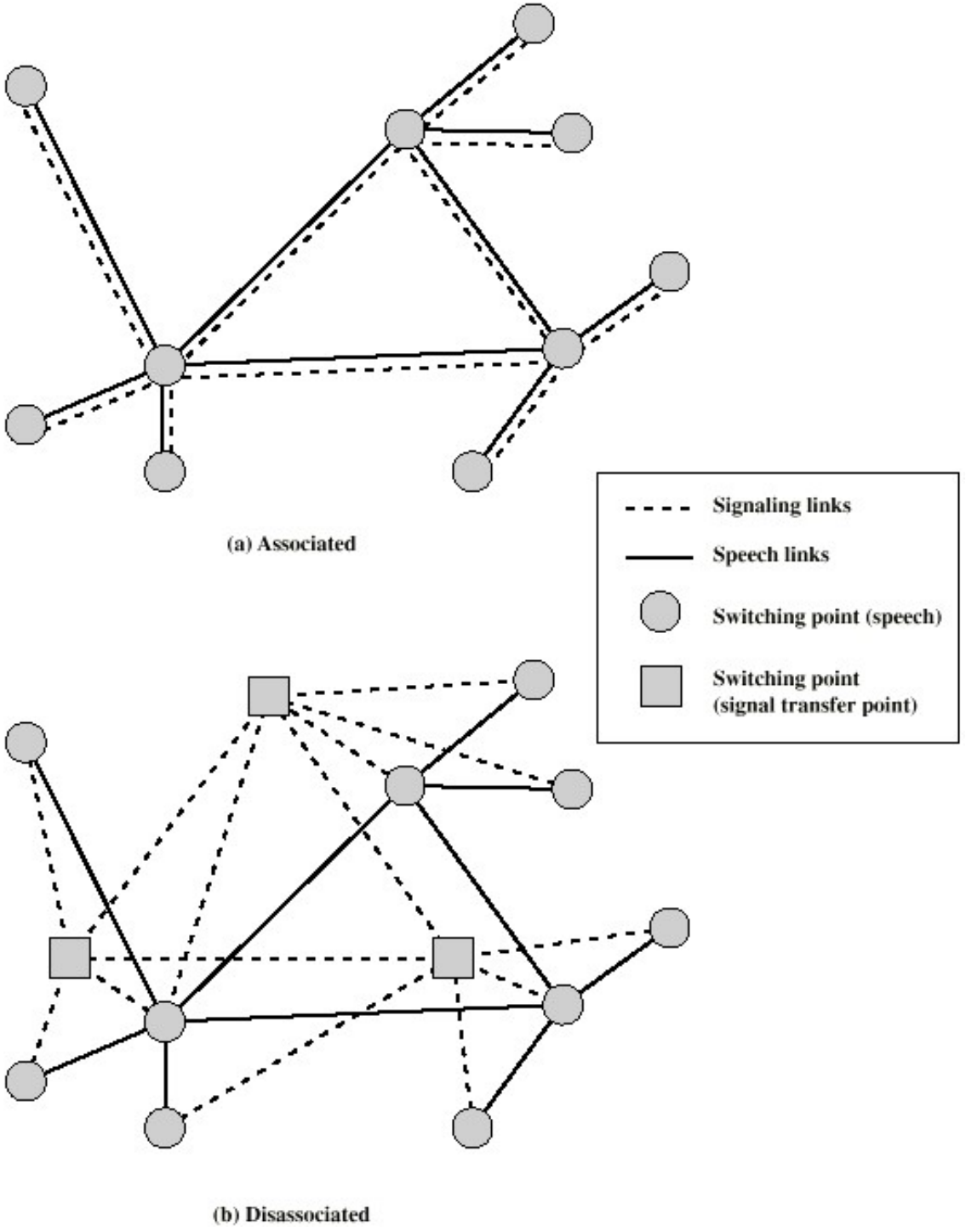
(a) Inchannel



(b) Common channel

CCIS SIG: Common-channel interoffice signaling equipment
SIG: Per-trunk signaling equipment

Signaling Modes



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

Two Basic Forms of Packet Switching

- Packets handled in two ways
  - Datagram (covered in this section)
  - Virtual circuit (covered in the next section)

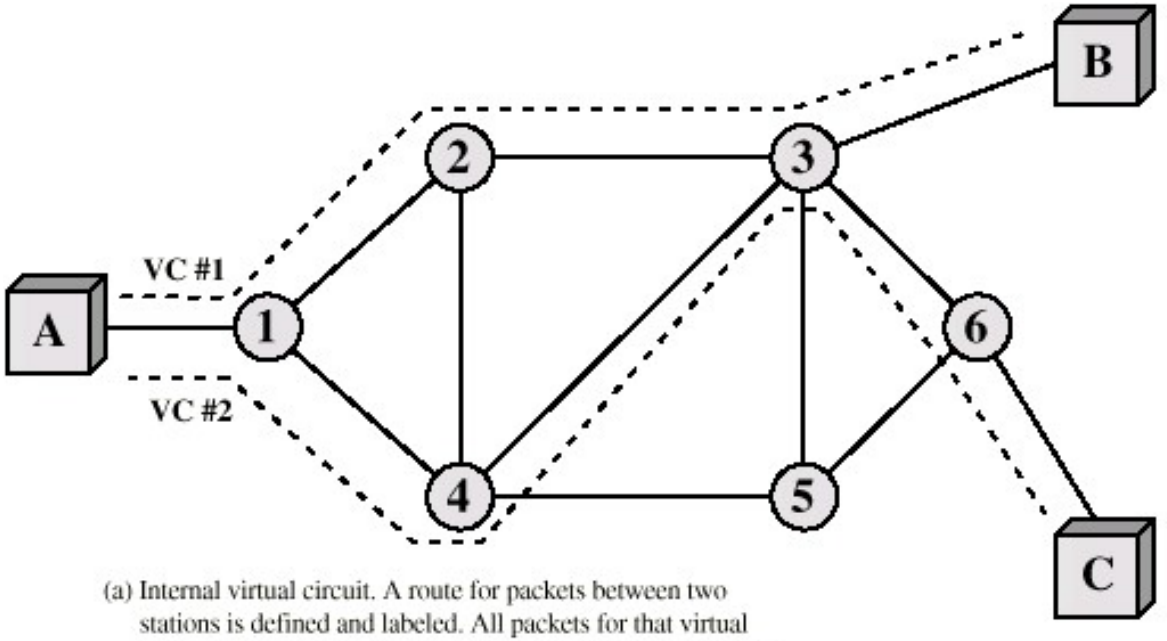
Datagram

- Each packet treated independently
- Packets can take any practical route
- Packets may arrive out of order
- Packets may get lost or delayed
- Up to receiver to re-order packets and recover from missing packets

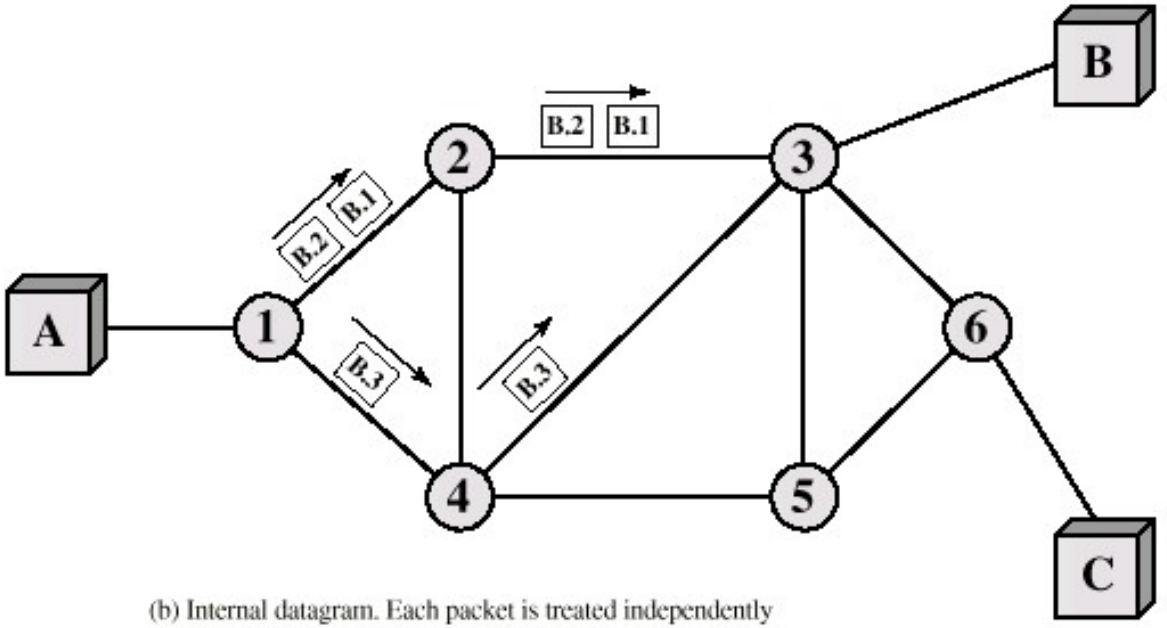
Virtual Circuit

- Preplanned route established before any packets sent
- Call request and call accept packets establish connection (handshake)
- Each packet contains a virtual circuit identifier instead of destination address
- No routing decisions required for each packet
- Clear request to drop circuit
- Not a dedicated

Internal Virtual Circuit and Datagram Operation



(a) Internal virtual circuit. A route for packets between two stations is defined and labeled. All packets for that virtual circuit follow the same route and arrive in the same sequence.



(b) Internal datagram. Each packet is treated independently by the network. Packets are labeled with a destination address and may arrive at the destination node out of sequence.

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

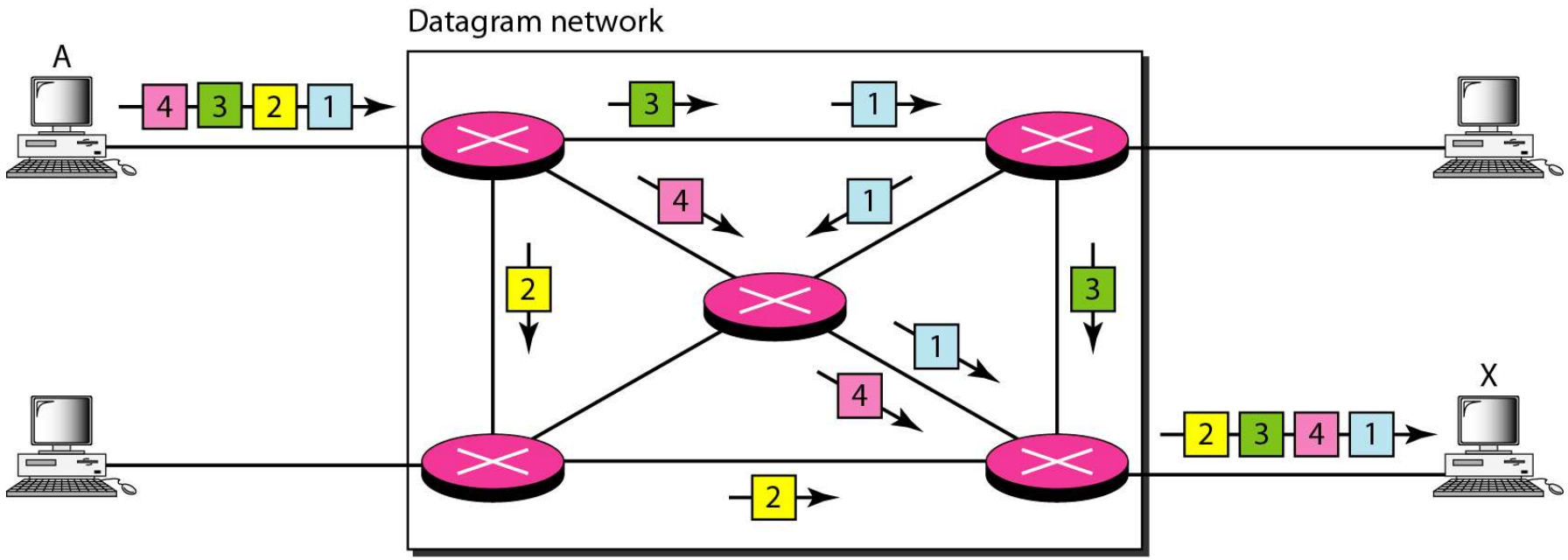
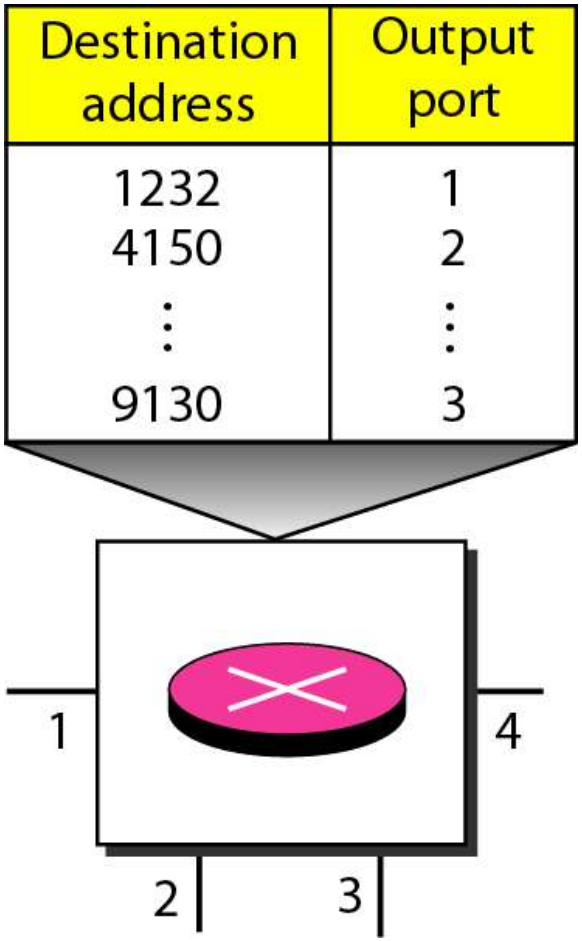


Figure 8.8 *Routing table in a datagram network*



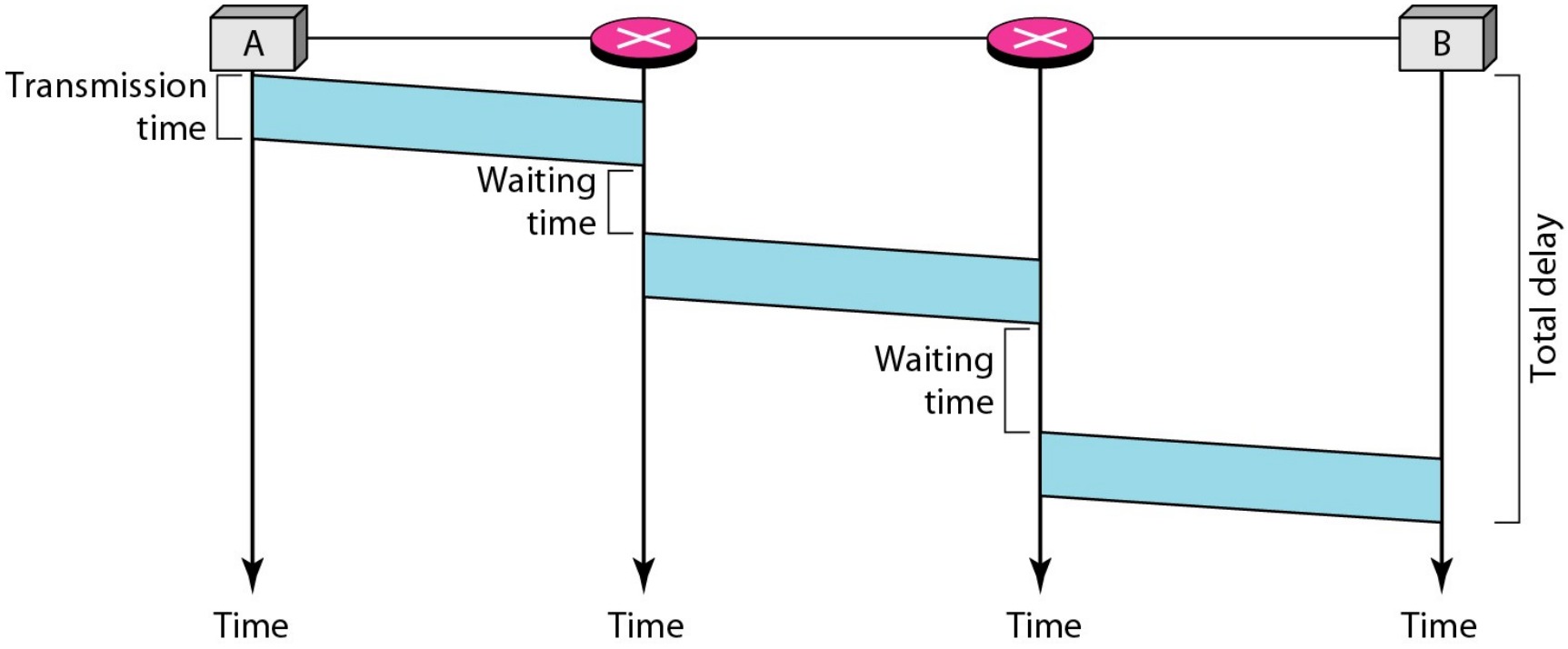
Note

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.

Figure 8.9 *Delay in a datagram network*



Note

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

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*

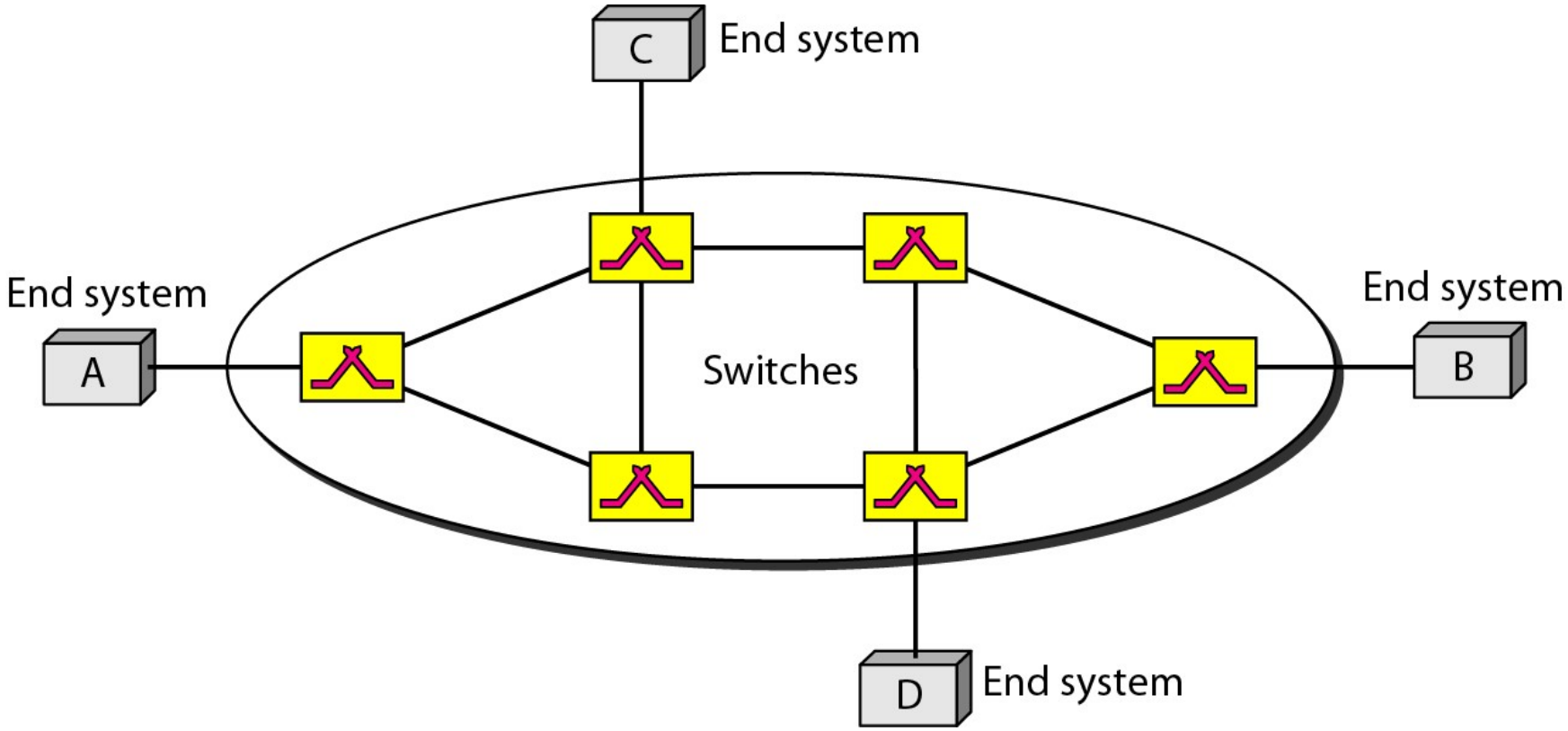


Figure 8.11 *Virtual-circuit identifier*

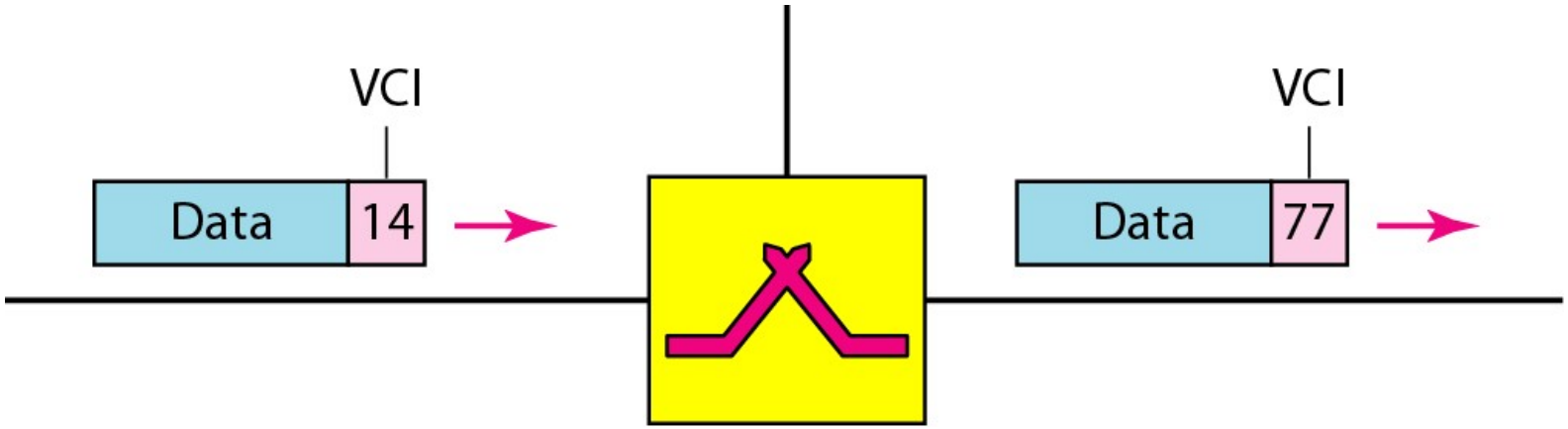


Figure 8.12 *Switch and tables in a virtual-circuit network*

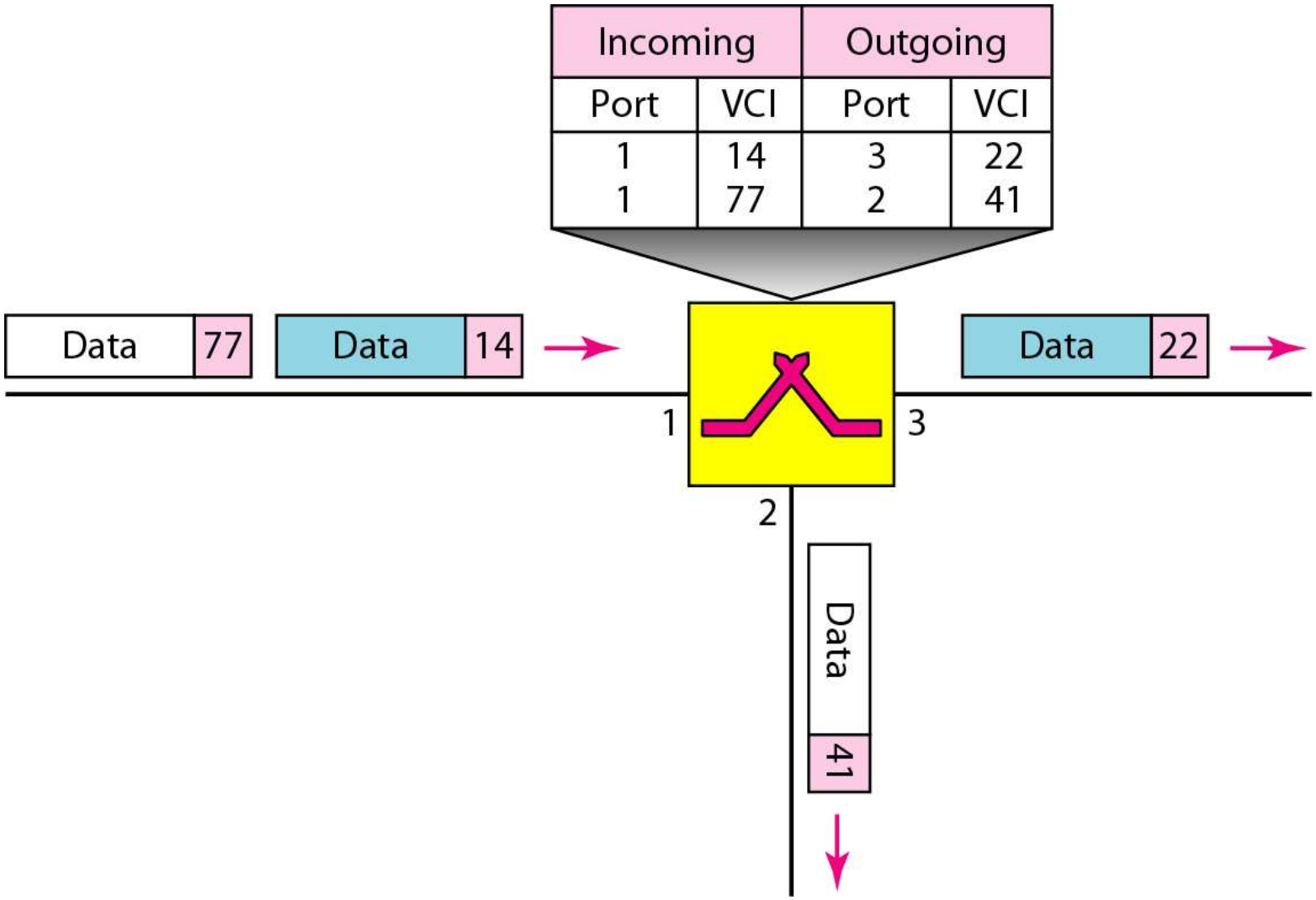


Figure 8.13 *Source-to-destination data transfer in a virtual-circuit network*

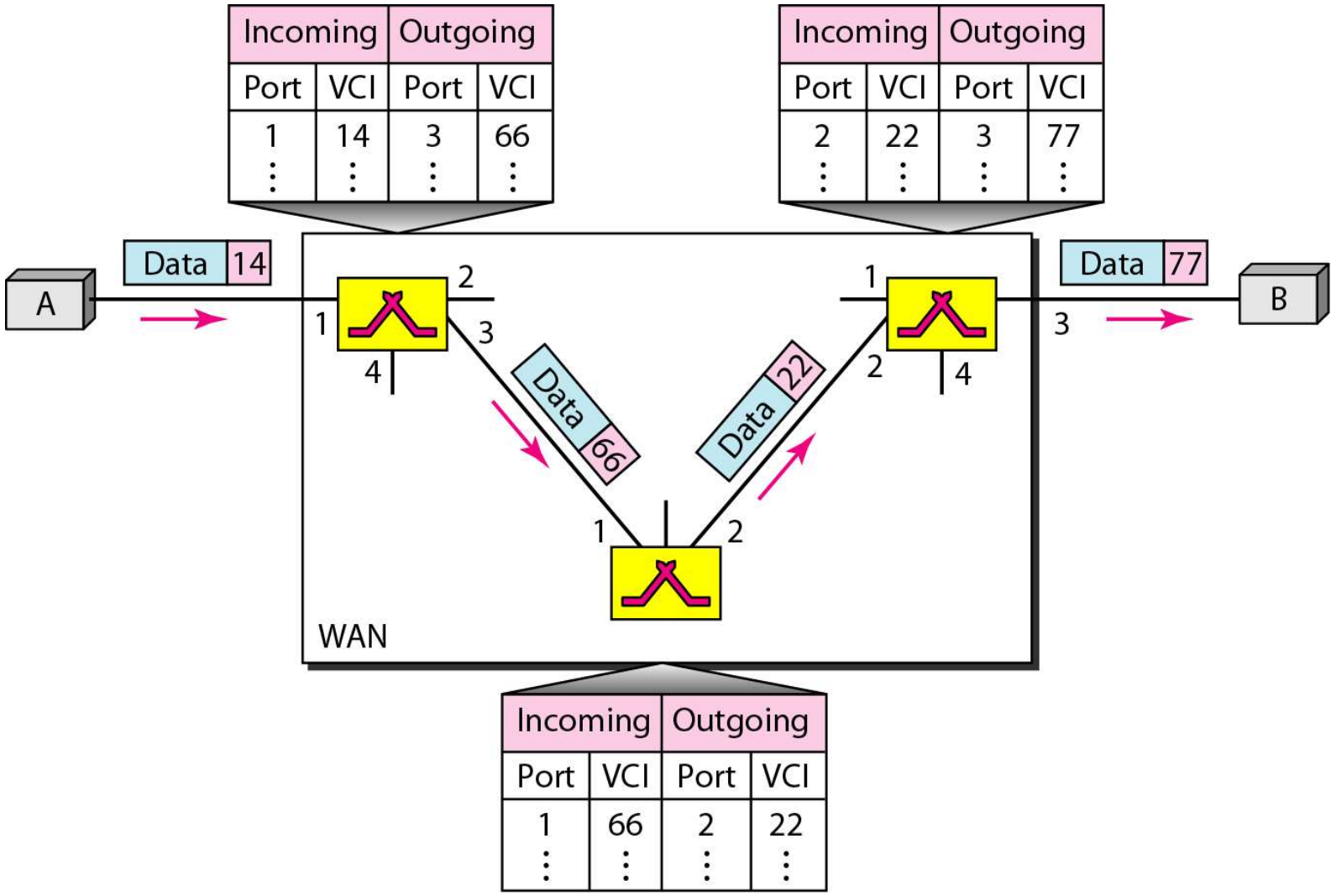


Figure 8.14 *Setup request in a virtual-circuit network*

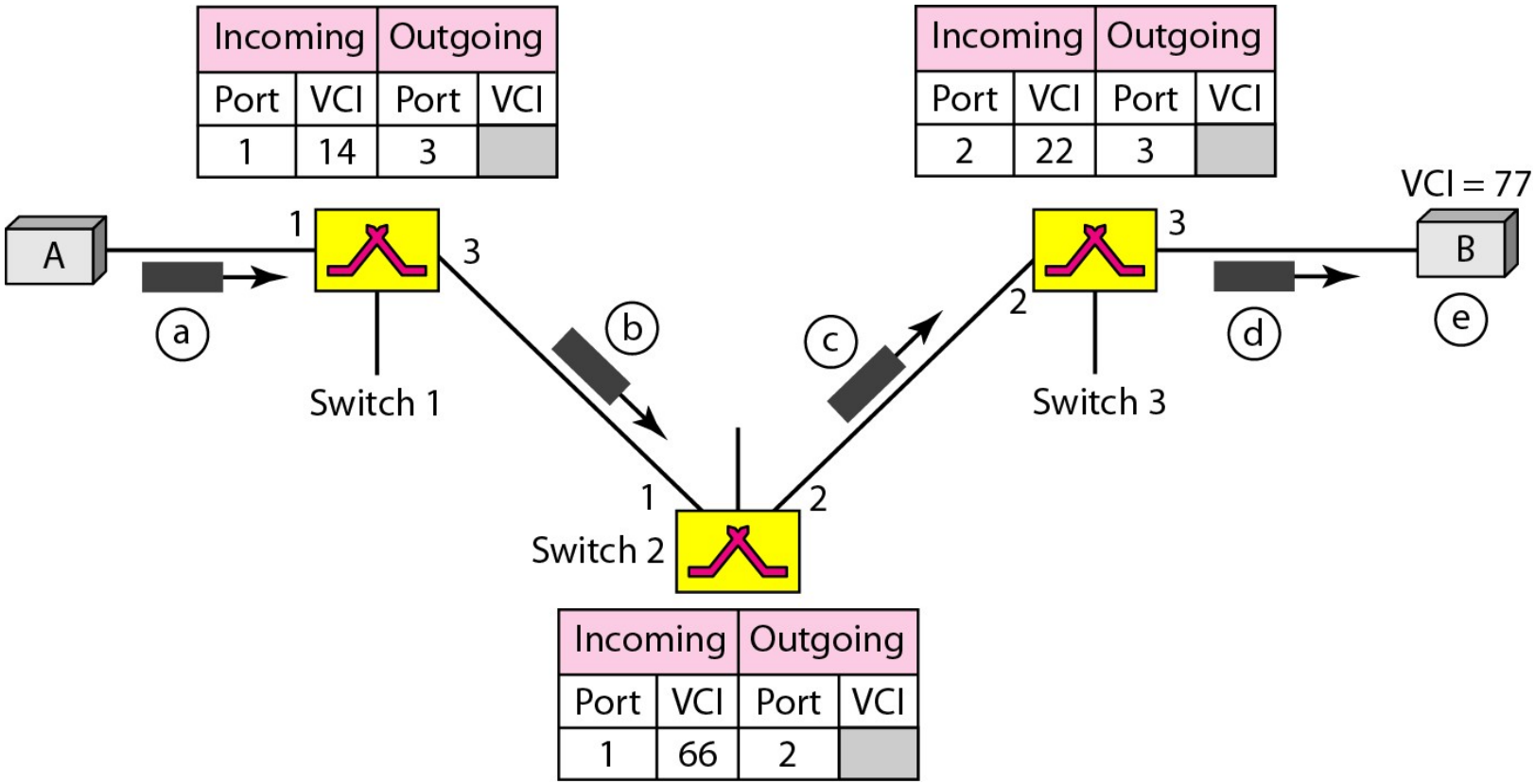
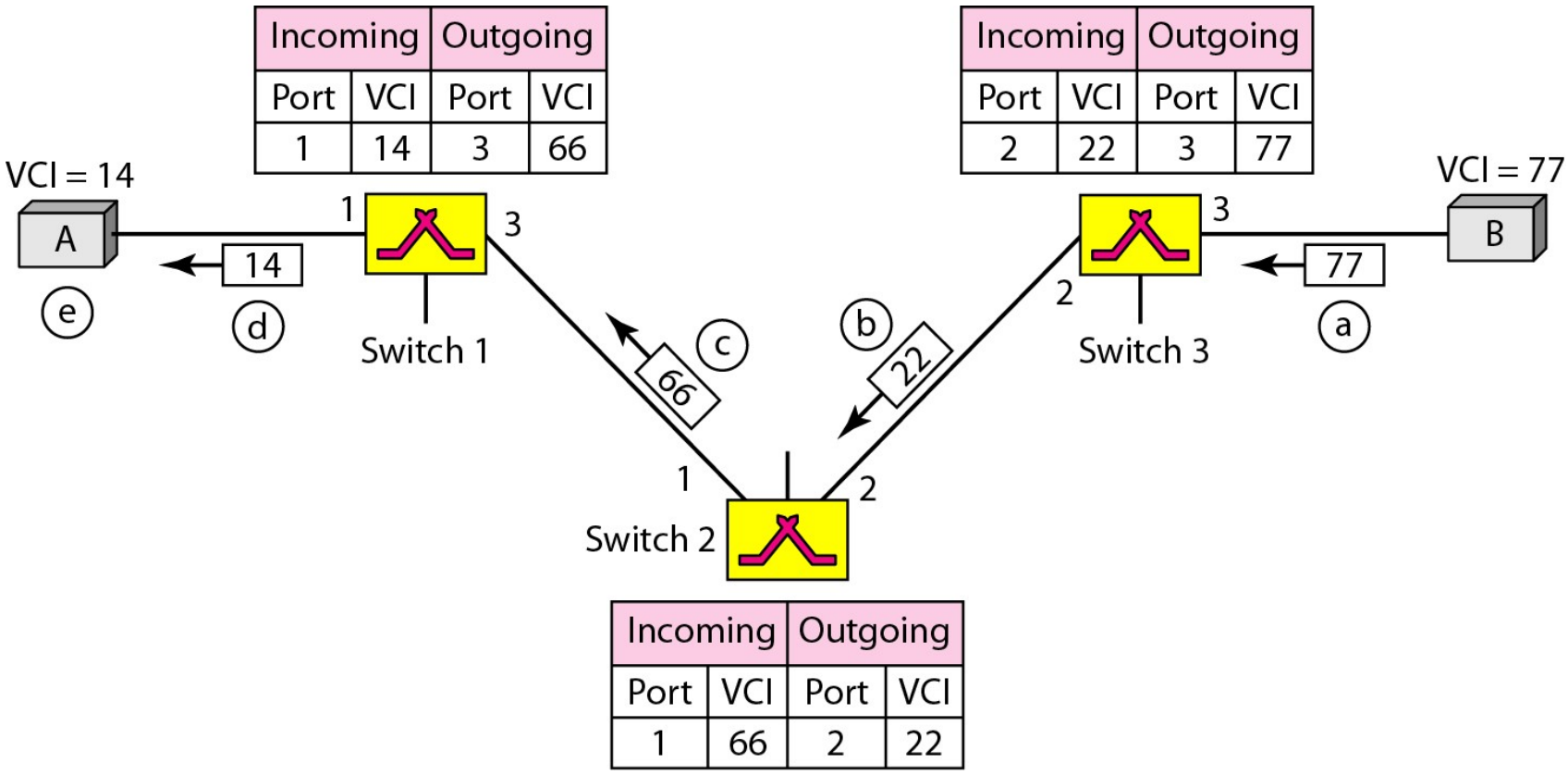


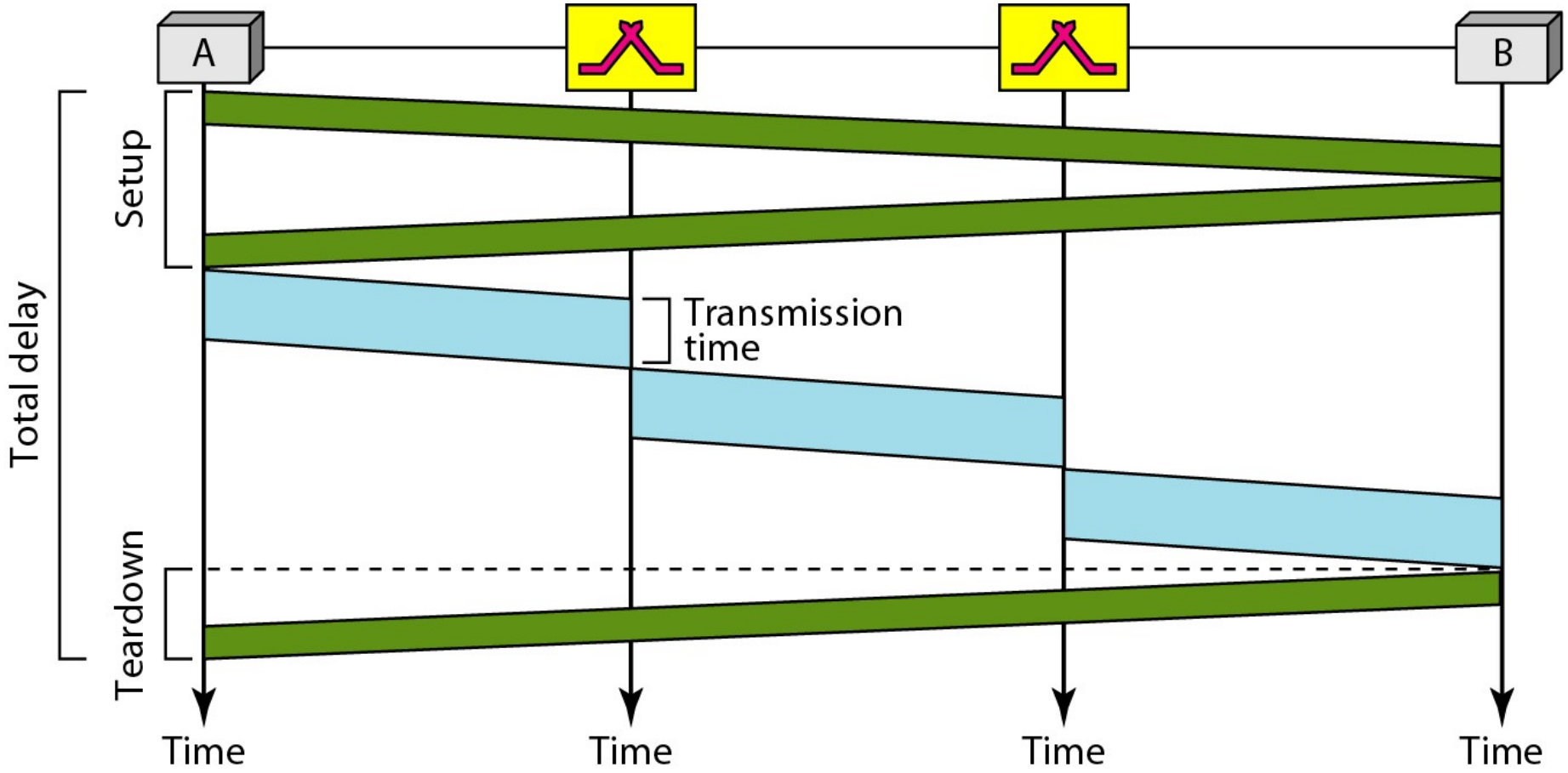
Figure 8.15 *Setup acknowledgment in a virtual-circuit network*



Note

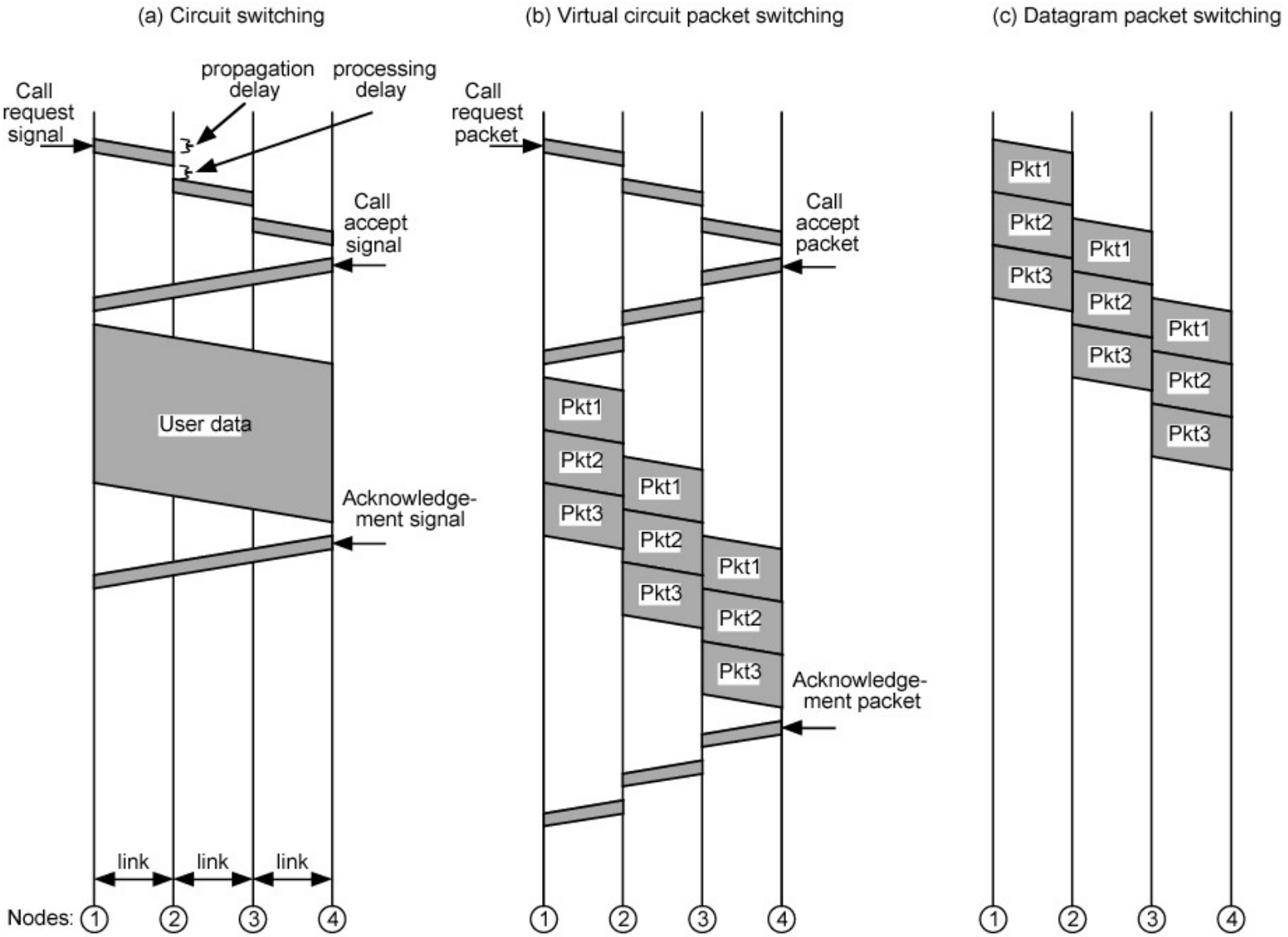
In virtual-circuit switching, all packets belonging to the same source and destination travel the same path; but the packets may arrive at the destination with different delays if resource allocation is on demand.

Figure 8.16 *Delay in a virtual-circuit network*



Note

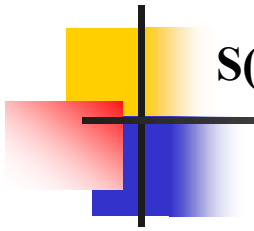
Switching at the data link layer in a switched WAN is normally implemented by using virtual-circuit techniques.


(a) Circuit switching
(b) Virtual circuit packet switching
(c) Datagram packet switching
Call request signal
propagation delay
processing delay
Call accept signal
User data
Acknowledge-ment signal
link
link
link
Nodes: 1 2 3 4
Call request packet
Call accept packet
Acknowledge-ment packet
Pkt1
Pkt2
Pkt3

8.46

Comparisons

Circuit Switching	Datagram Packet Switching	Virtual Circuit Packet Switching
Dedicated transmission path	No dedicated path	No dedicated path
Continuous transmission of data	Transmission of packets	Transmission of packets
Fast enough for interactive	Fast enough for interactive	Fast enough for interactive
Messages are not stored	Packets may be stored until delivered	Packets stored until delivered
The path is established for entire conversation	Route established for each packet	Route established for entire conversation
Call setup delay; negligible transmission delay	Packet transmission delay	Call setup delay; packet transmission delay
Busy signal if called party busy	Sender may be notified if packet not delivered	Sender notified of connection denial
Overload may block call setup; no delay for established calls	Overload increases packet delay	Overload may block call setup; increases packet delay
Electromechanical or computerized switching nodes	Small switching nodes	Small switching nodes
User responsible for message loss protection	Network may be responsible for individual packets	Network may be responsible for packet sequences
Usually no speed or code conversion	Speed and code conversion	Speed and code conversion
Fixed bandwidth	Dynamic use of bandwidth	Dynamic use of bandwidth
No overhead bits after call setup	Overhead bits in each packet	Overhead bits in each packet



S(witched)VC vs. P(ermanent)VC setup

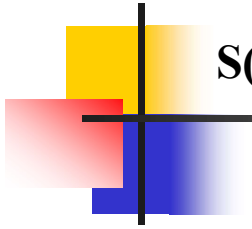
A virtual circuit can be either switched or permanent.

If permanent, an outgoing VCI is given to the source, and an incoming VCI is given to the destination.

The source always uses this VCI to send frames to this particular destination.

The destination knows that the frame is coming from that particular source if the frame carries the corresponding incoming VCI.

If a duplex connection is needed, two virtual circuits are established.



S(witched)VC vs. P(ermanent)VC setup

A PVC has several drawbacks:

1. Always connected, so always paying

2. Connection is between two parties only. If you need a connection to another point, you need another PVC.

Don't like these disadvantages? Use an SVC.

8-4 STRUCTURE OF A SWITCH

We use switches in circuit-switched and packet-switched networks. In this section, we discuss the structures of the switches used in each type of network.

Topics discussed in this section:

Structure of Circuit Switches
Structure of Packet Switches

Figure 8.17 *Crossbar switch with three inputs and four outputs*

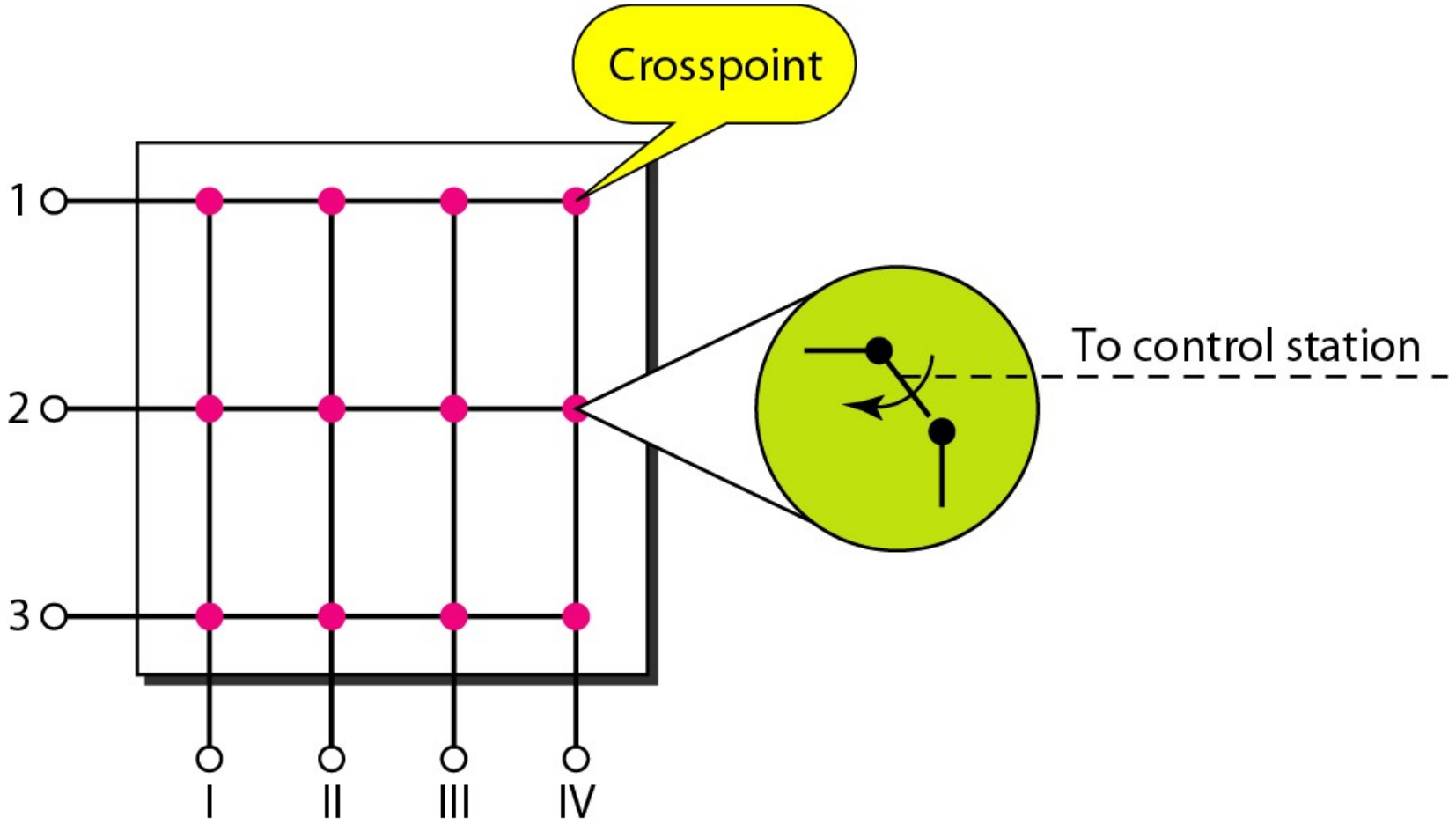
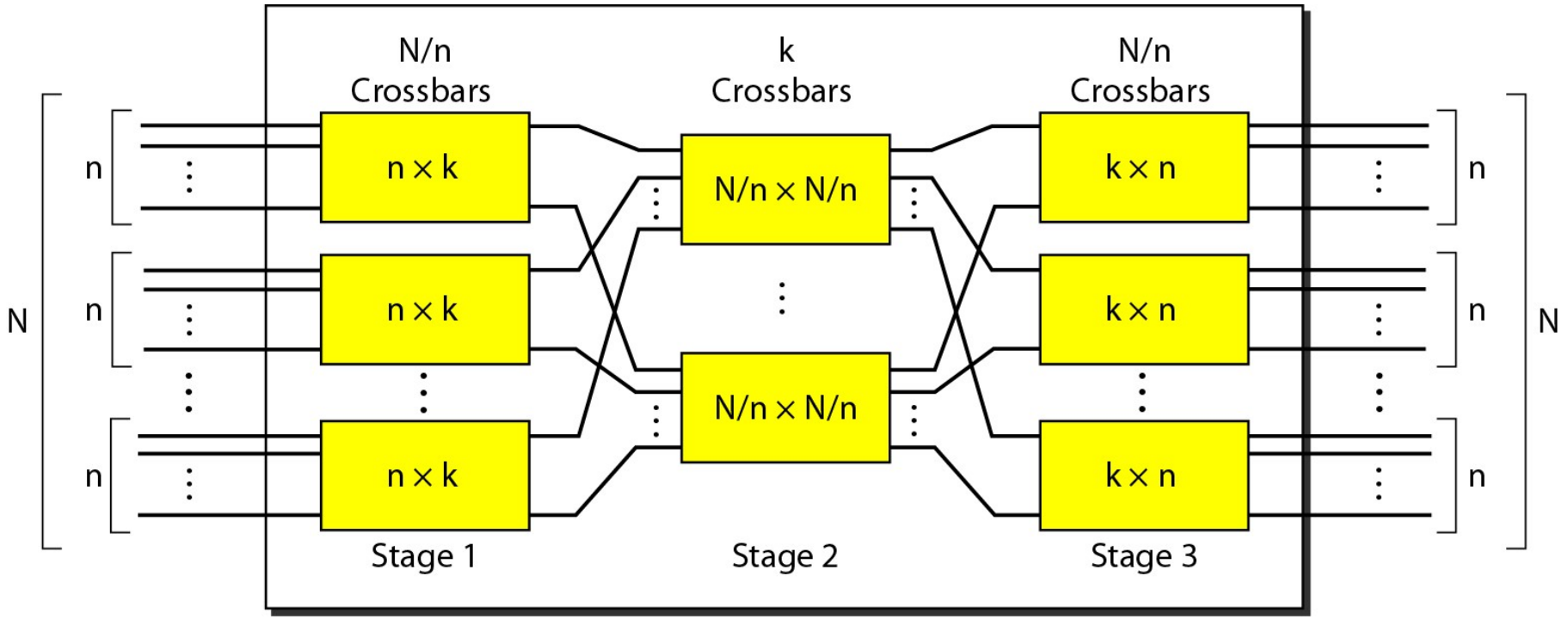


Figure 8.18 *Multistage switch*



Three Stage Switch

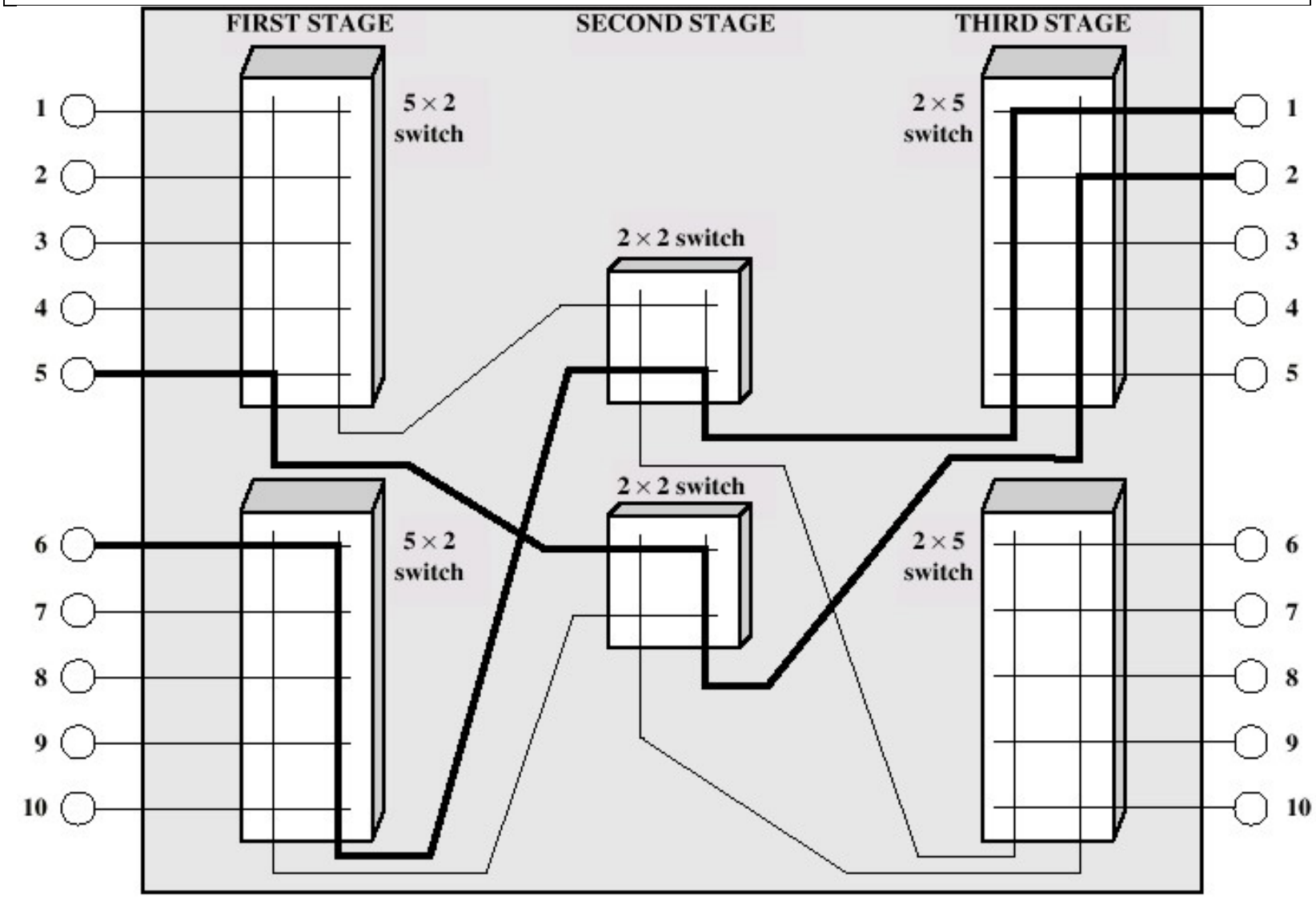


Figure 8.19 *Time-slot interchange*

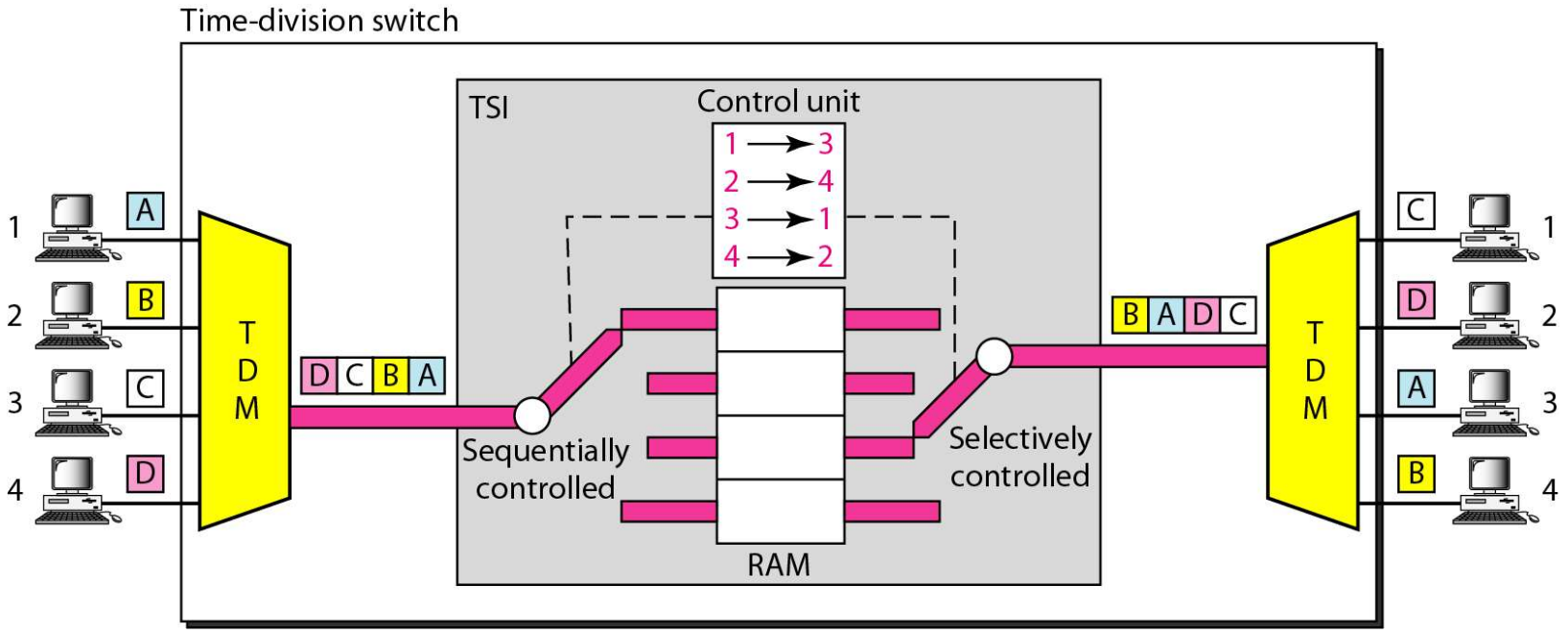


Figure 8.21 *Packet switch components*

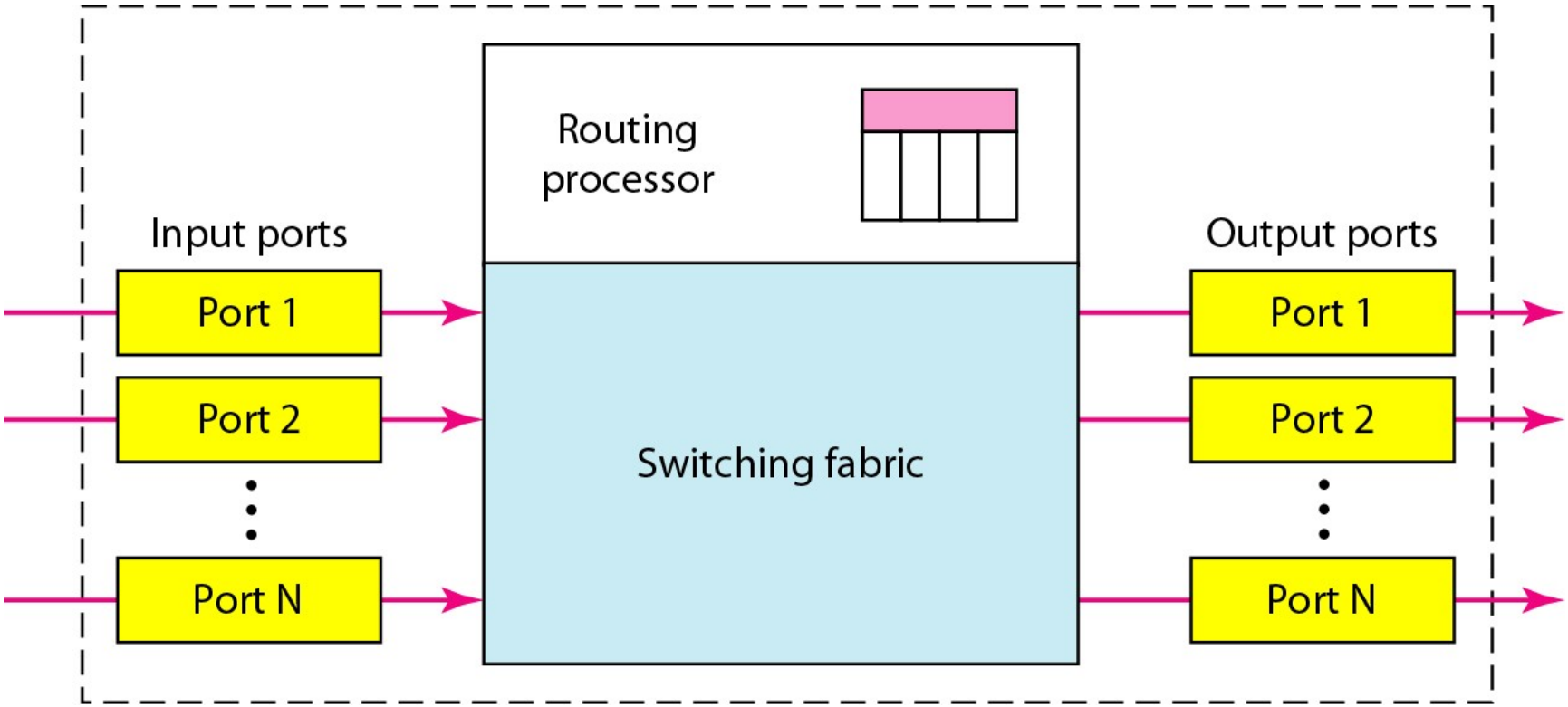


Figure 8.22 *Input port*

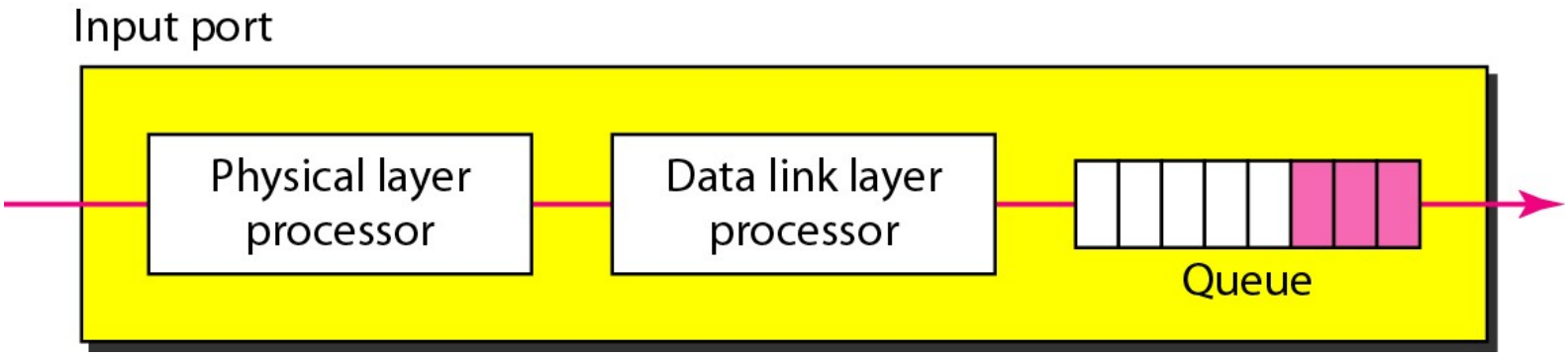


Figure 8.23 *Output port*