Switching

Introduction

- Multiple Device ➔ Connection Problem
- Mesh, Star Topology ➔ impractical

  ➔ Wasteful
- Solution: Switching

Figure 1 *Switched network*

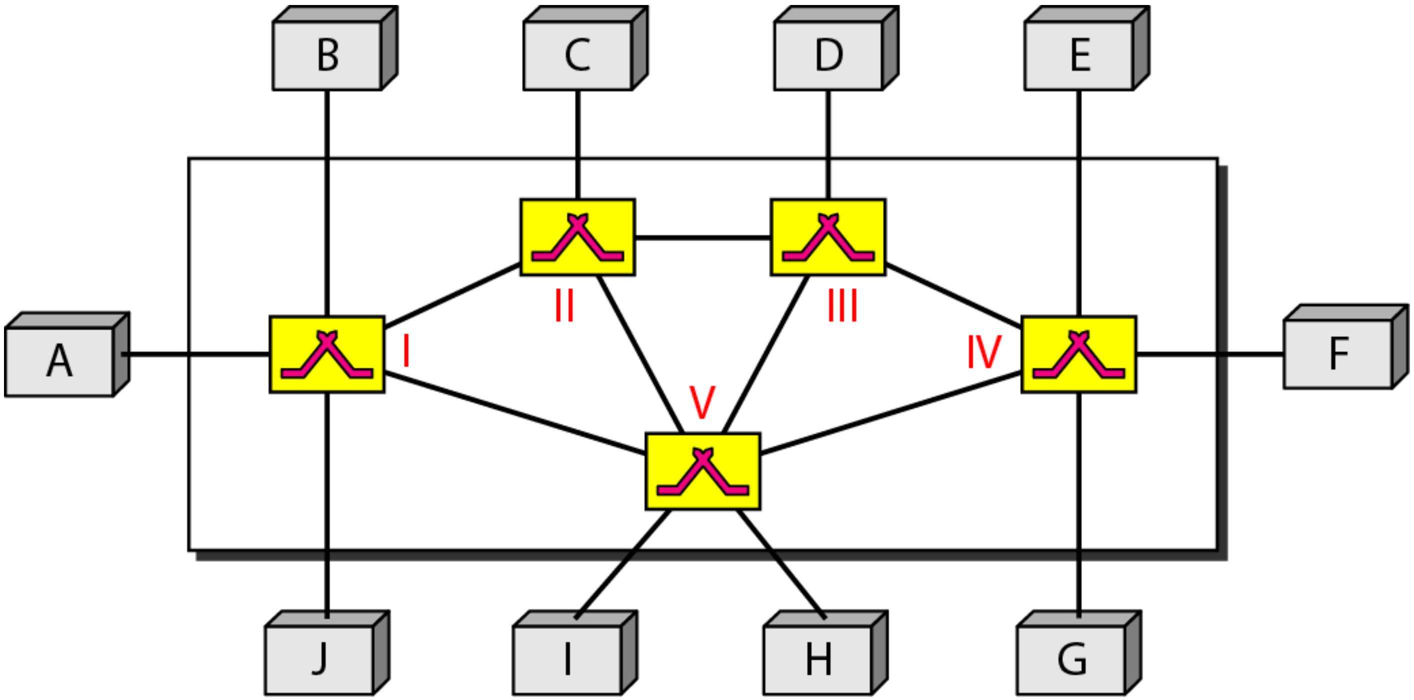
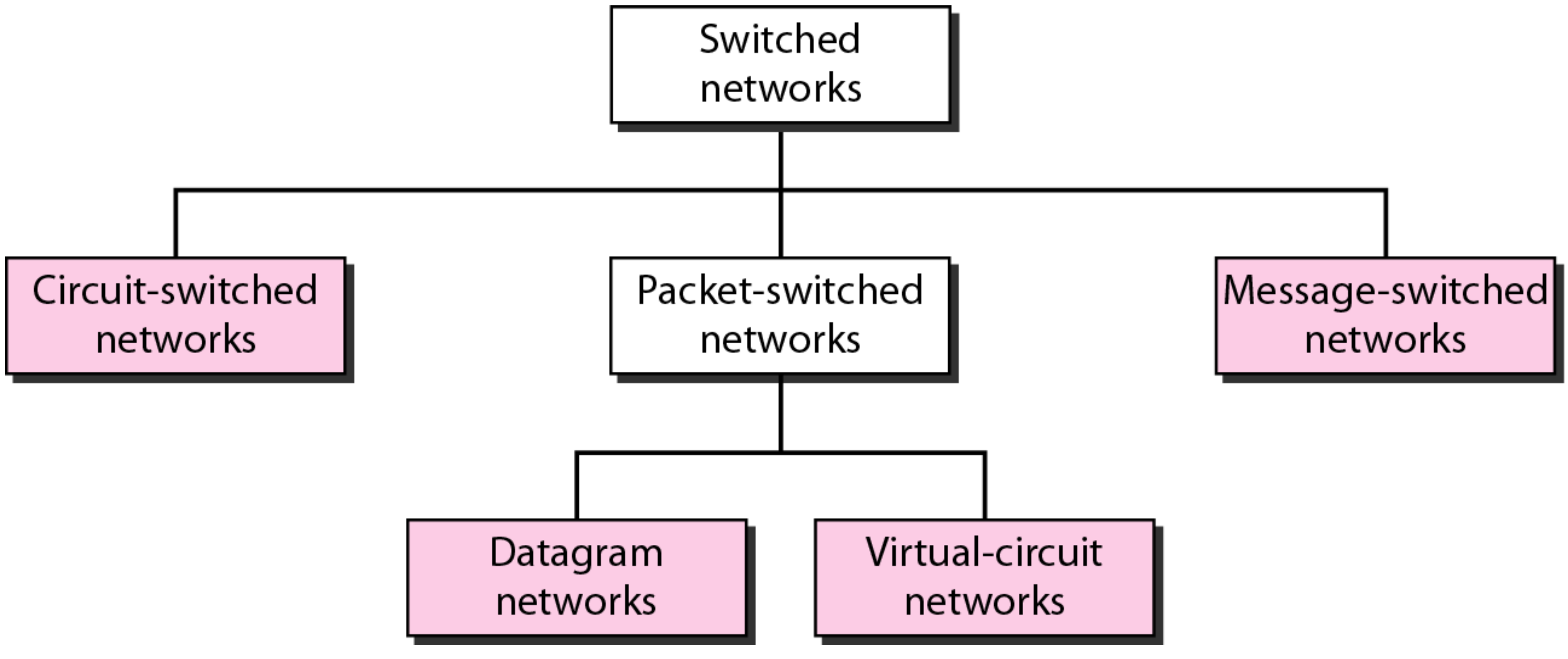


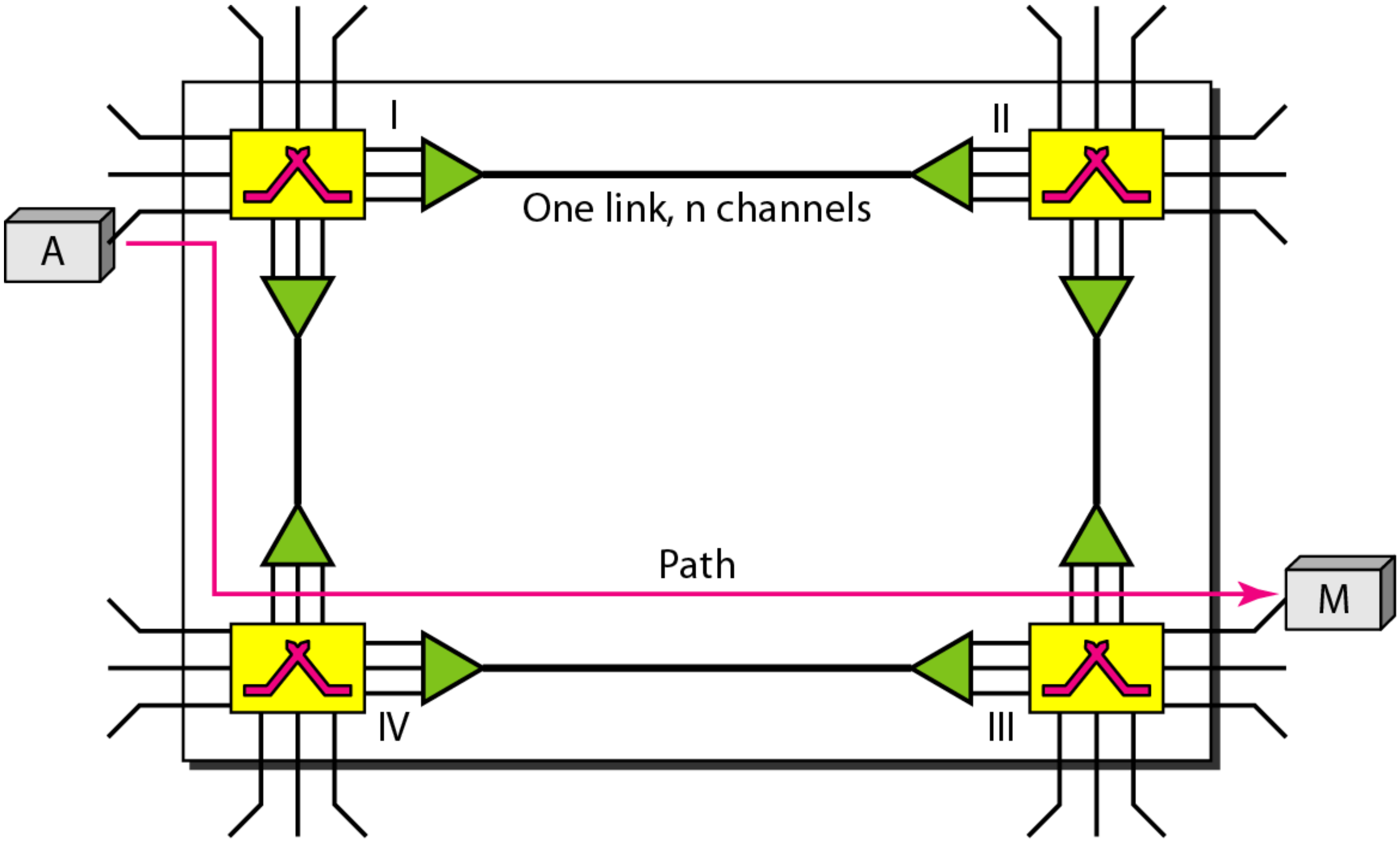
Figure 2 *Taxonomy of switched networks*



CIRCUIT-SWITCHED NETWORKS

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

Figure 3 *circuit-switched network*



circuit-switched network

- Four Switches
- Four links
- Each link divided into 3 channels by FDM or TDM
- Connection request should be accepted by destination as well as intermediate switches.

circuit-switched network

- At Physical layer
- Continuous flow ➔ although there may be periods of silence
- No addressing

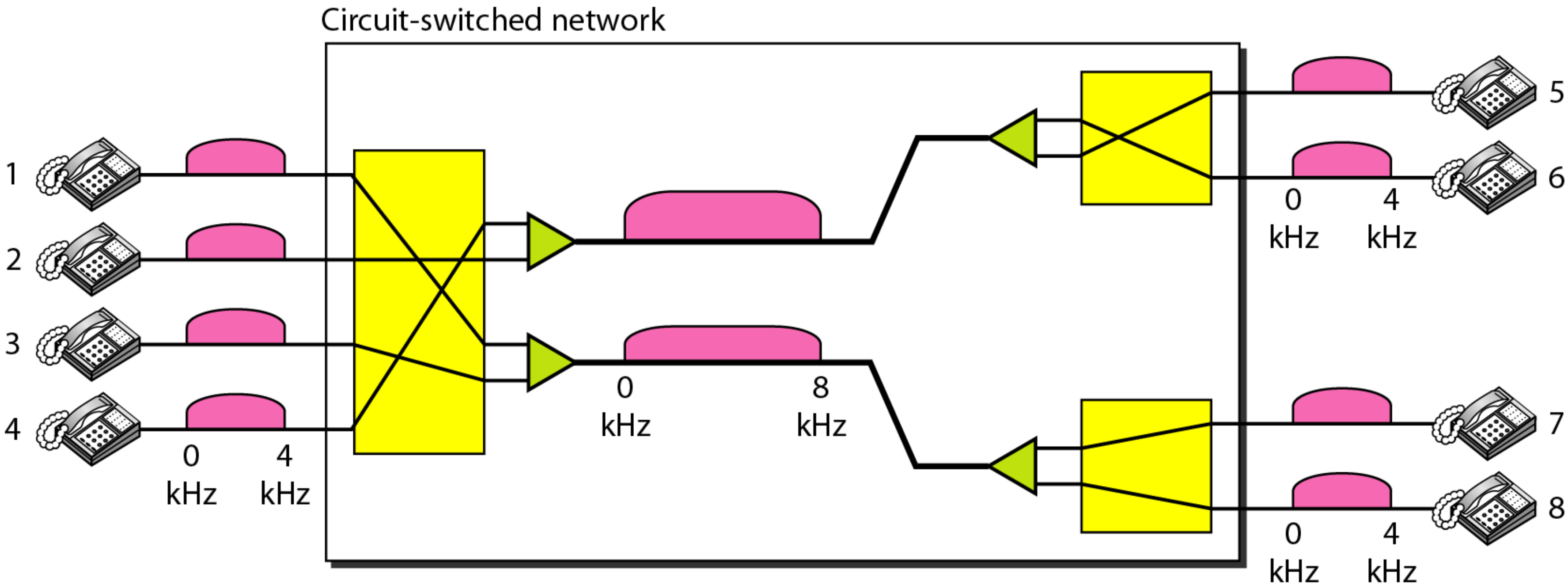
Note

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 1

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 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.

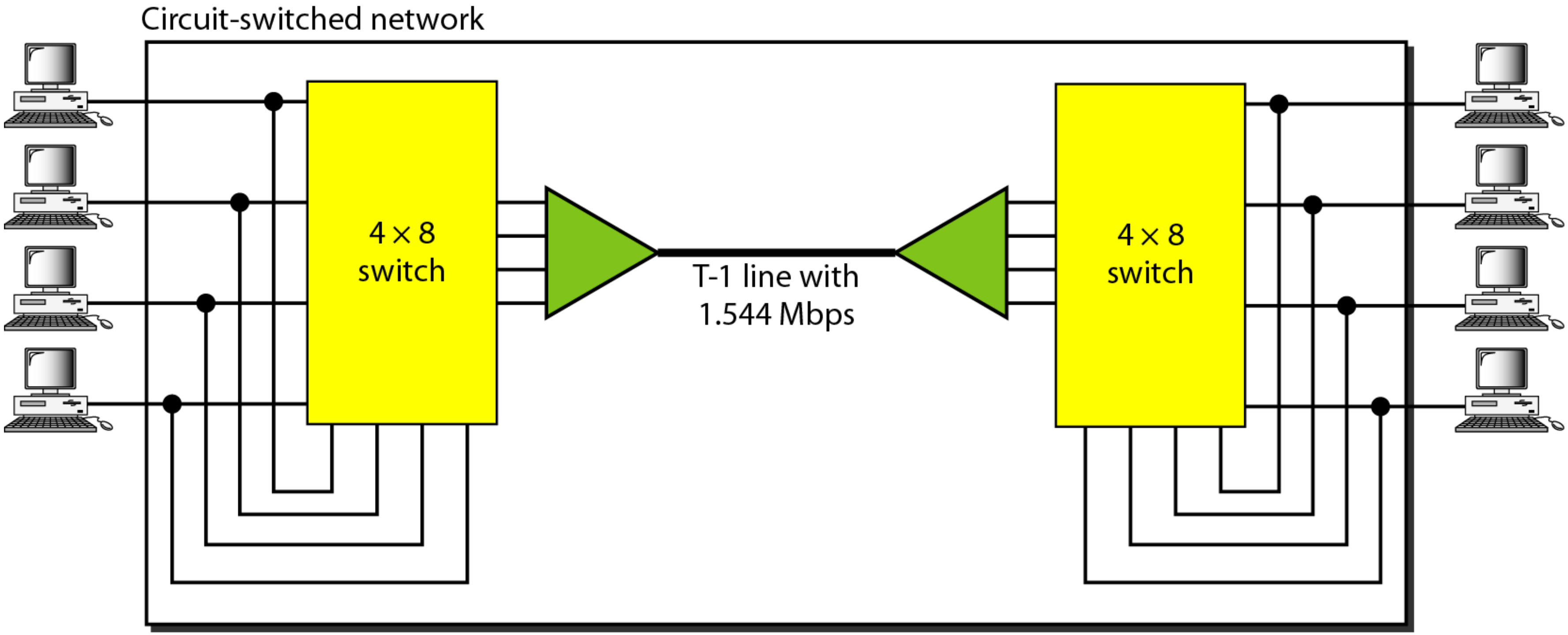
Figure 4 *Circuit-switched network used in Example 1*



Example 2

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 5 shows the situation.

Figure 5 *Circuit-switched network used in Example 2*



circuit-switched network Phases

- Setup Phase
  - Creating dedicated channels between switches
  - Setup request from source to destination
  - Acknowledgment
- Data Transfer Phase
- Teardown Phase
  - One party need to disconnect → signal to release resources

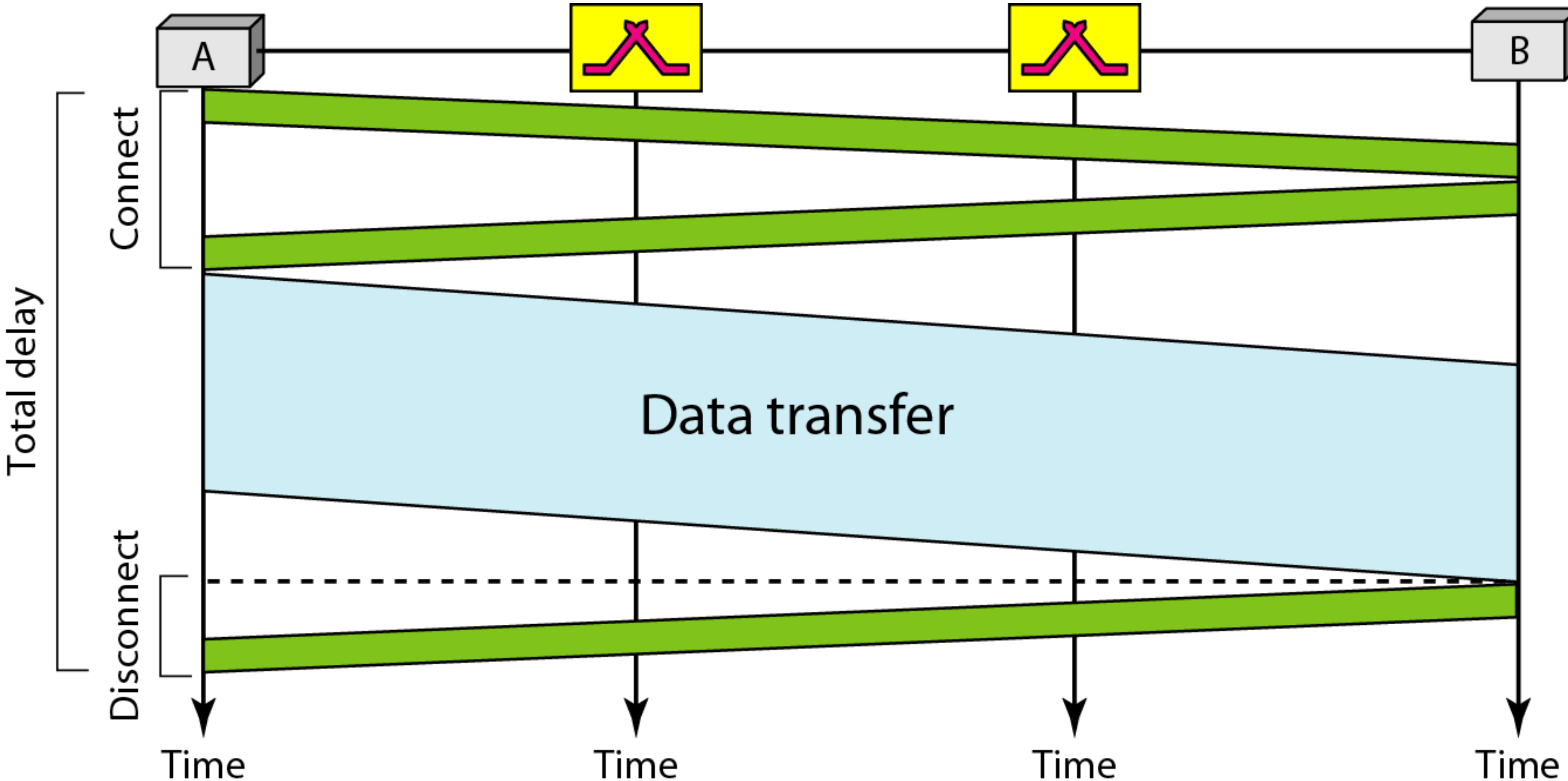
Delay in circuit-switched network

- Minimal
- No waiting time at each switch
- Total Delay = time to create connection

  \+ transfer data

  \+ disconnect circuit

Figure 6 *Delay in a circuit-switched network*



Note

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

DATAGRAM NETWORKS

- Message 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.

Datagram network

- Resources on demand
- First Come First Serve
- Lack of reservation may create delay
- Each packet independently
- Out of order with different delay
- Chances of lost or drop

Figure 7 *A datagram network with four switches (routers)*

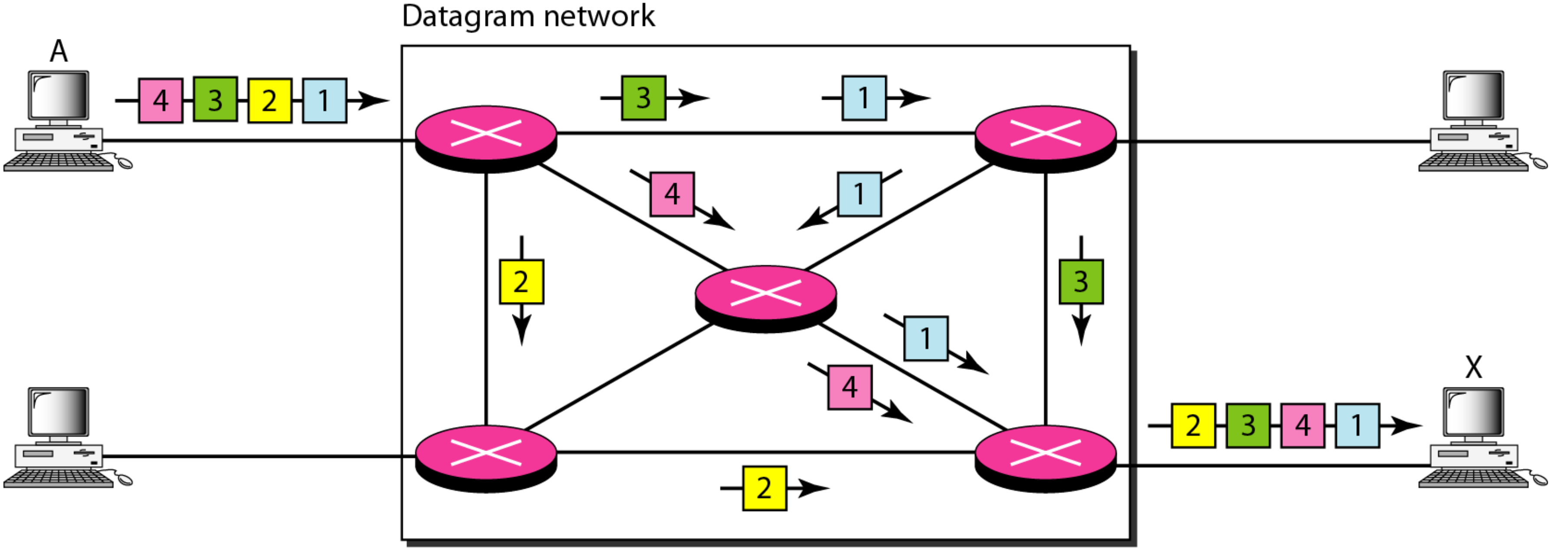
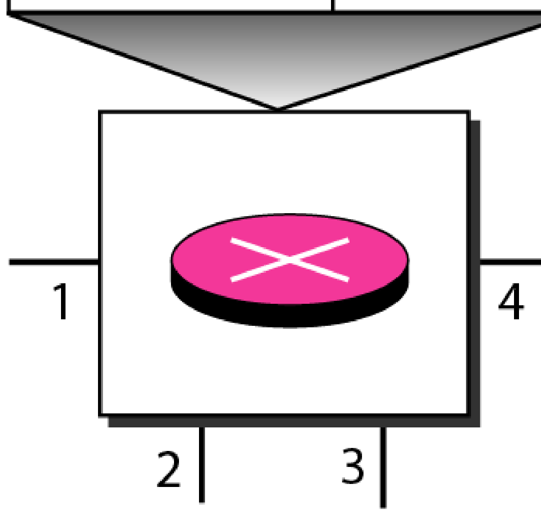


Figure 8 *Routing table in a datagram network*

Destination address	Output port
1232	1
4150	2
⋮	⋮
9130	3



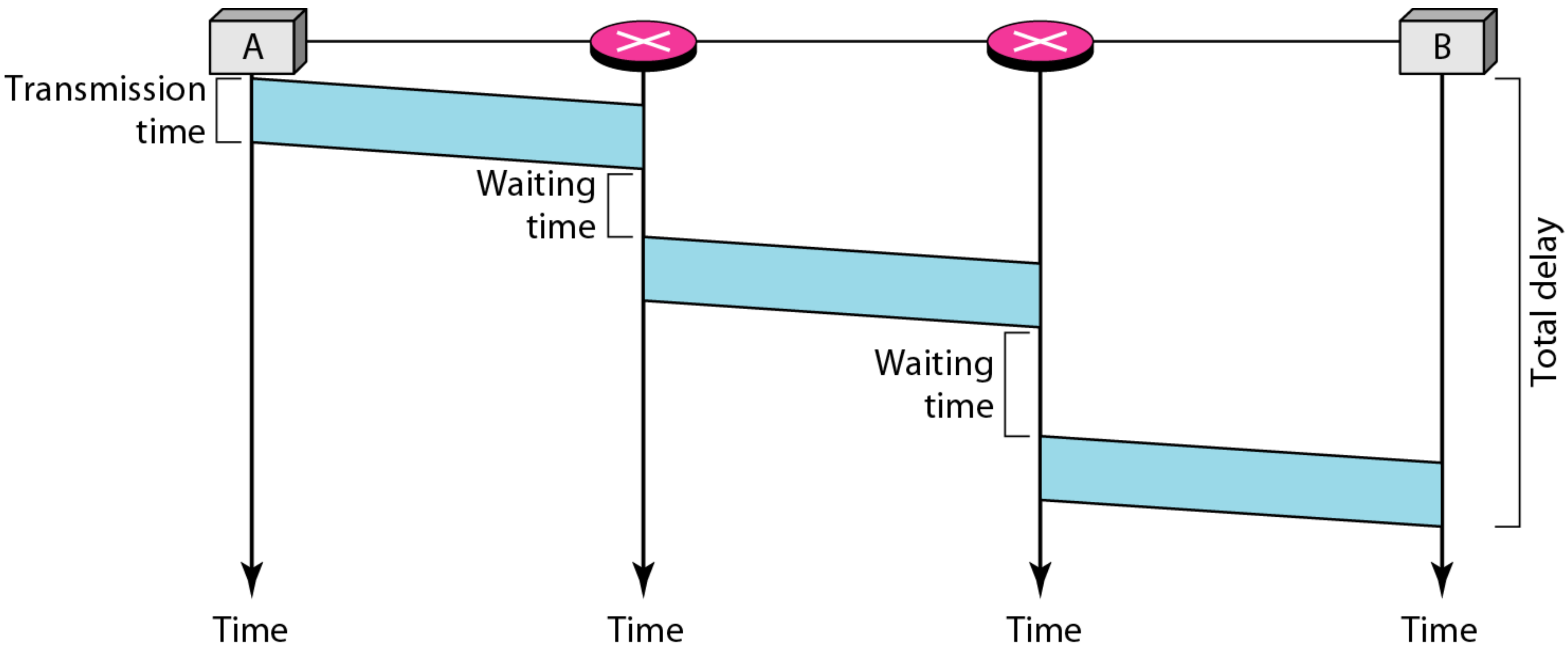
Note

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 9 *Delay in a datagram network*



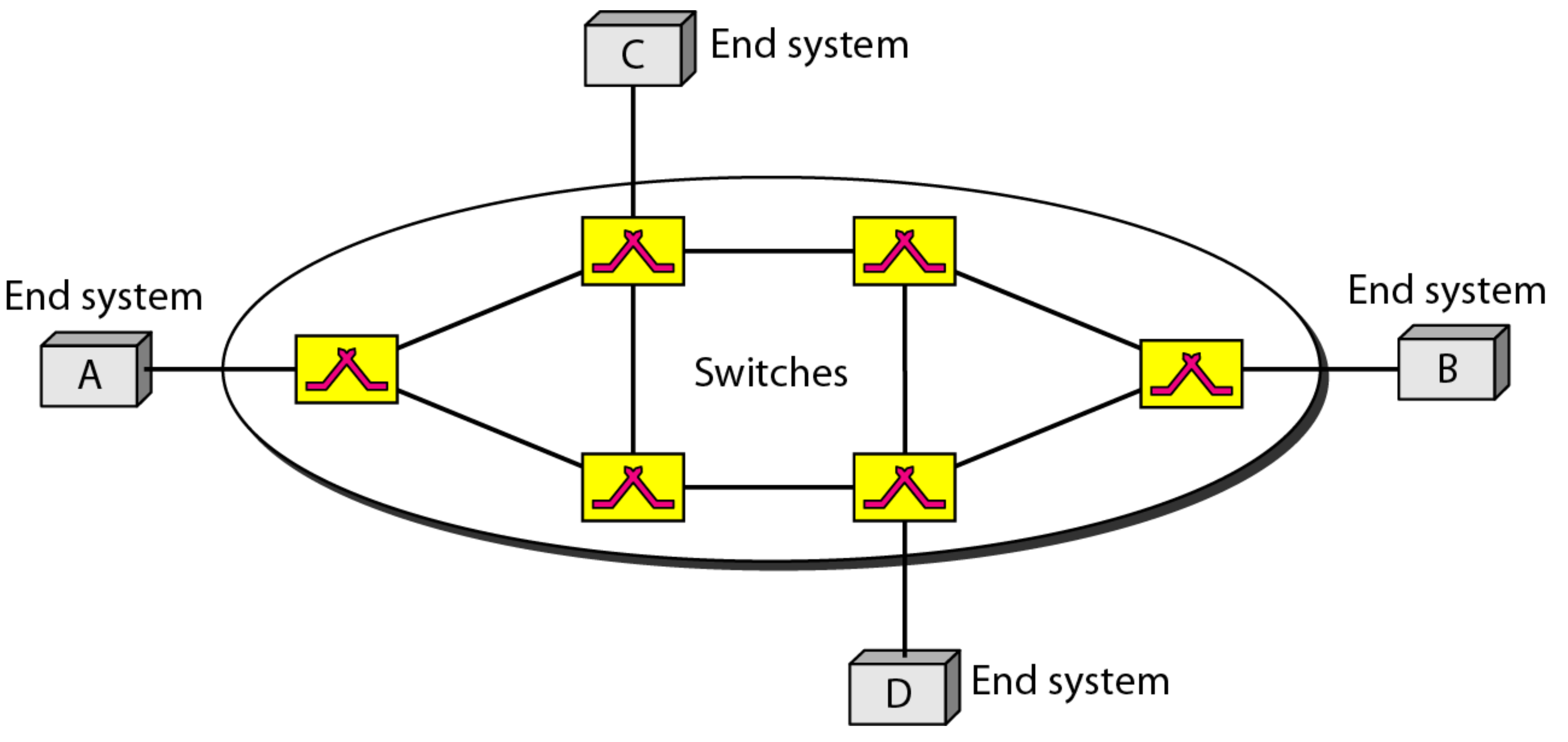
Note

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

VIRTUAL-CIRCUIT NETWORKS

- A virtual-circuit network is a cross between a circuit-switched network and a datagram network.
- At Datalink Layer

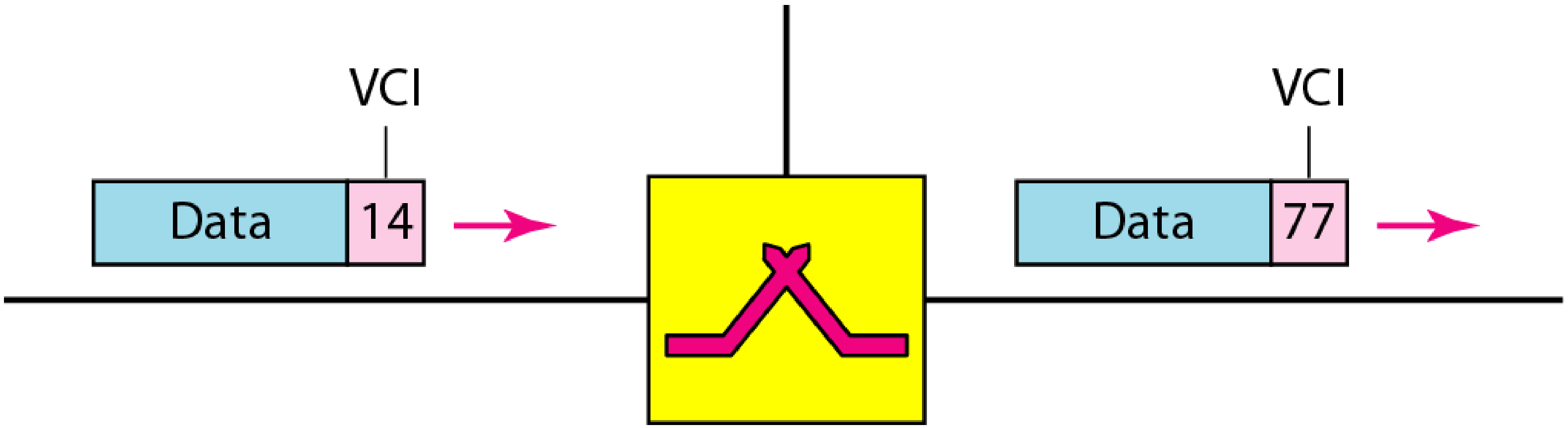
Figure 10 *Virtual-circuit network*



Addressing

- Two Types
  - Global
    - Source or destination ➔ unique
  - Local (Virtual Circuit Identifier)
    - Small number ➔ only switch scope
    - Used by frame between two switches
    - Different VCI when leave switch

Figure 11 *Virtual-circuit identifier*



Three Phases

- Setup
  - Switch creates entry for virtual circuit
  - Two steps:
    - Setup request
    - acknowledgment
- Data transfer
- Teardown

Figure 12 *Switch and tables in a virtual-circuit network*

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

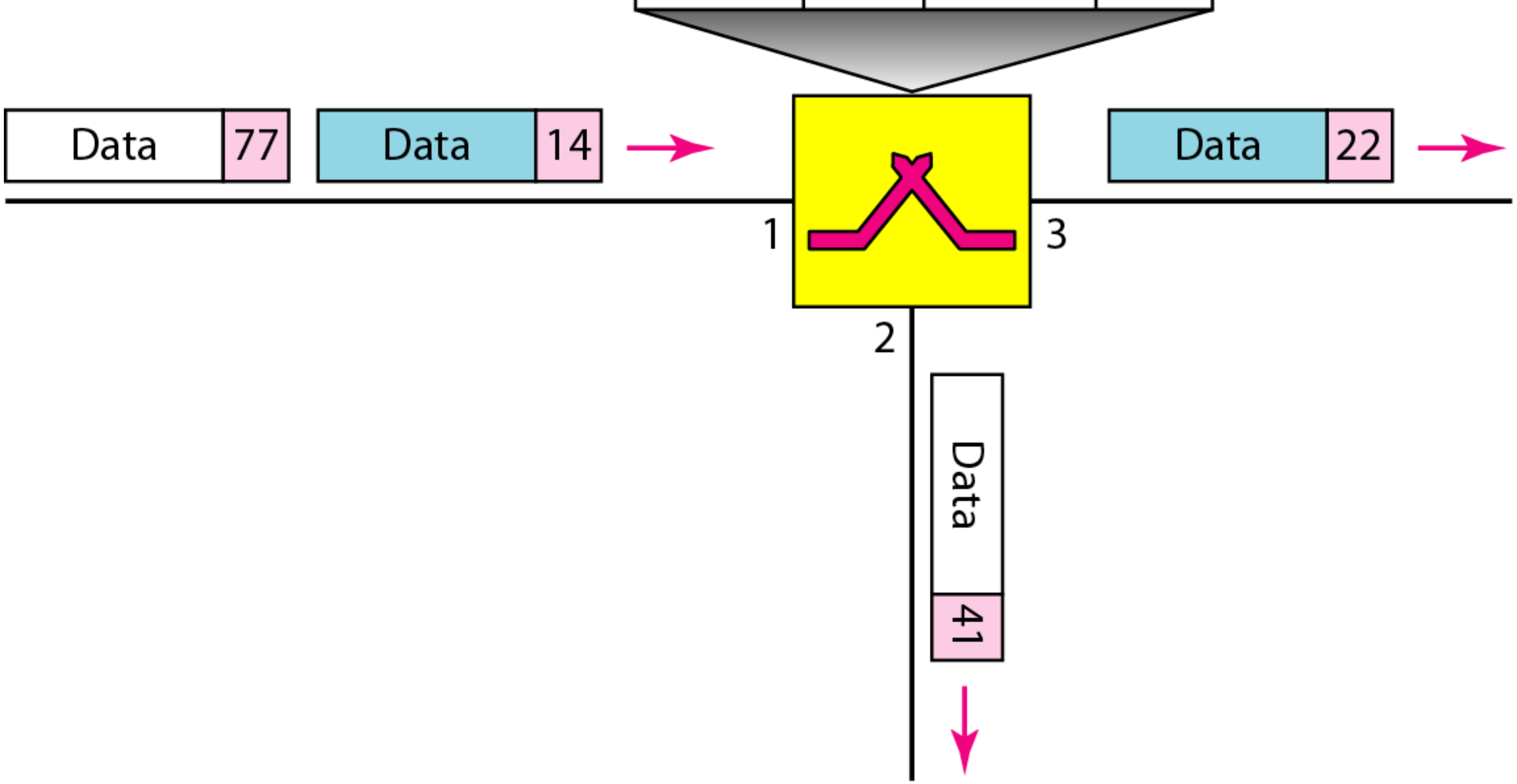
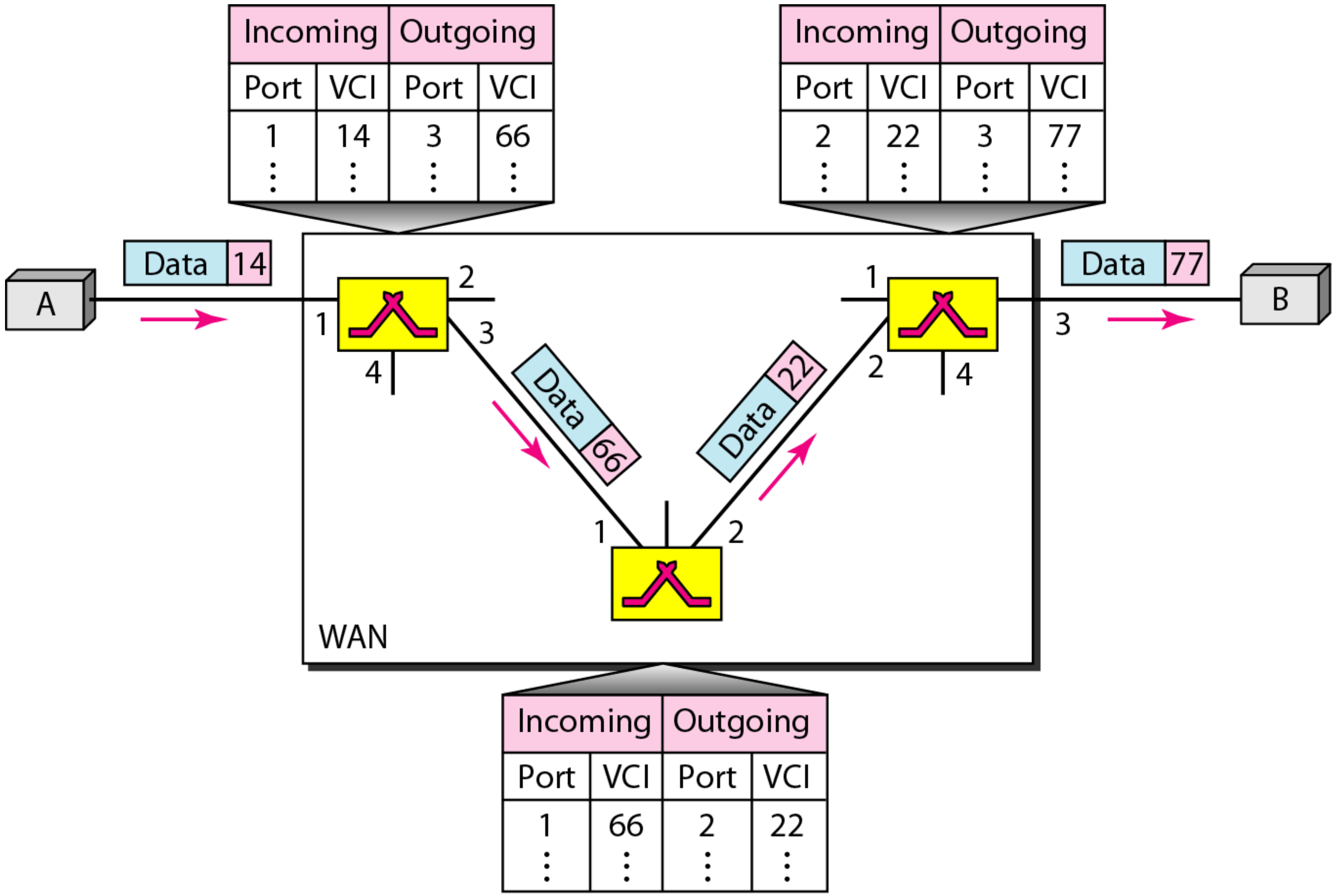


Figure 13 *Source-to-destination data transfer in a virtual-circuit network*



Setup Request

- Switch fill three out of four column
  - Incoming port
  - Choose available incoming VCI
  - Outgoing port
- Not know outgoing VCI
  - Found during acknowledgment

Figure 14 *Setup request in a virtual-circuit network*

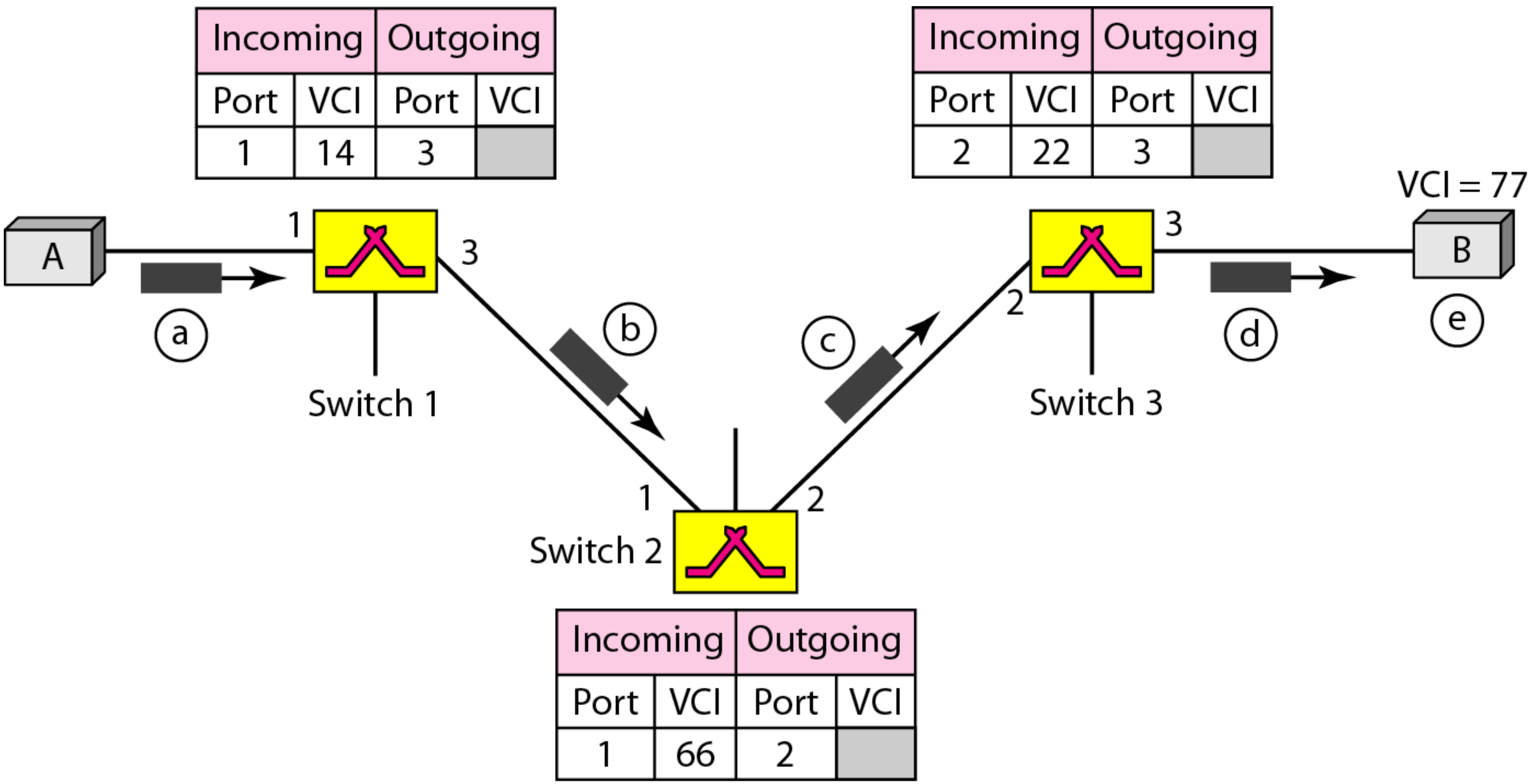
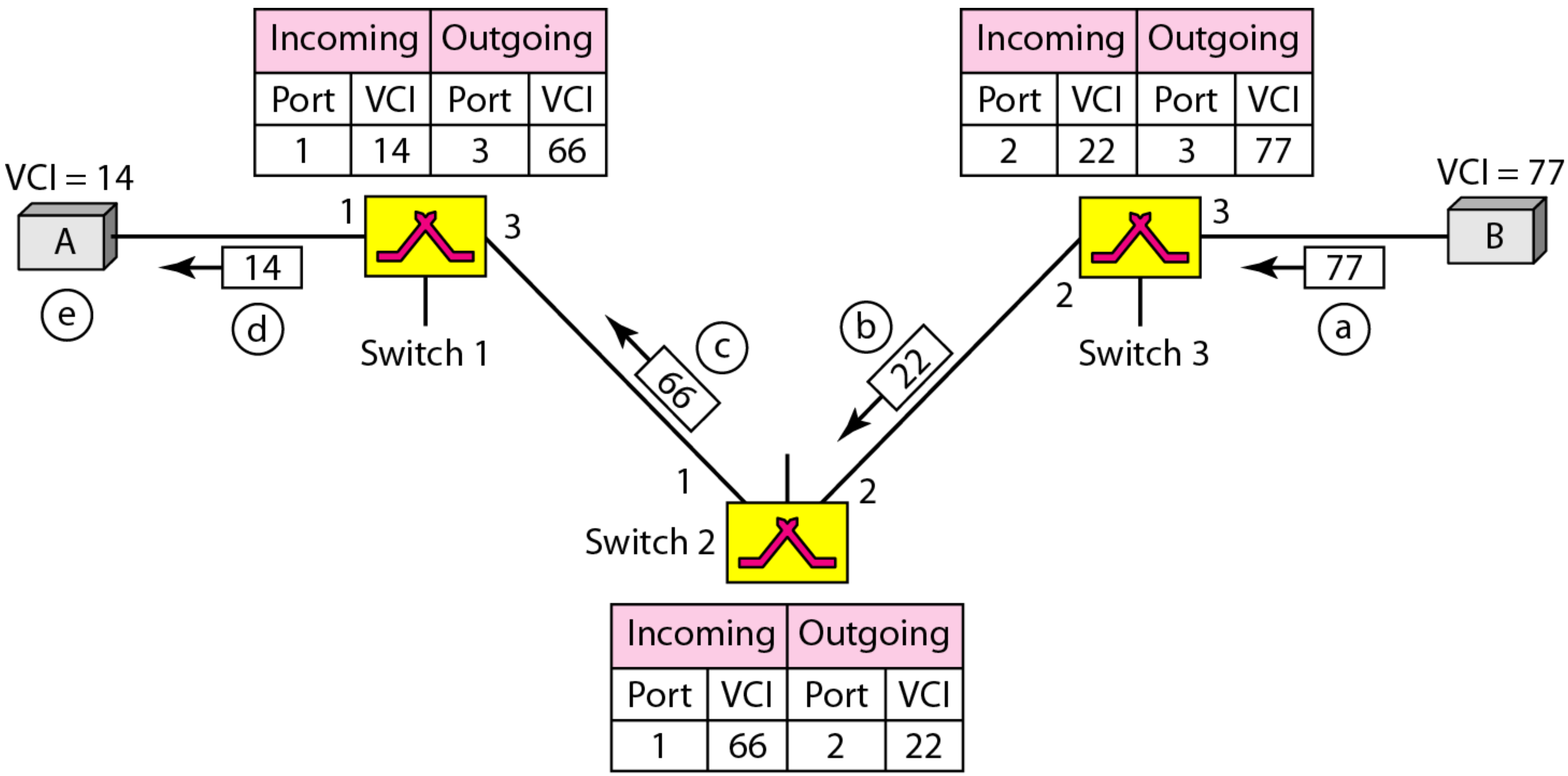


Figure 15 *Setup acknowledgment in a virtual-circuit network*



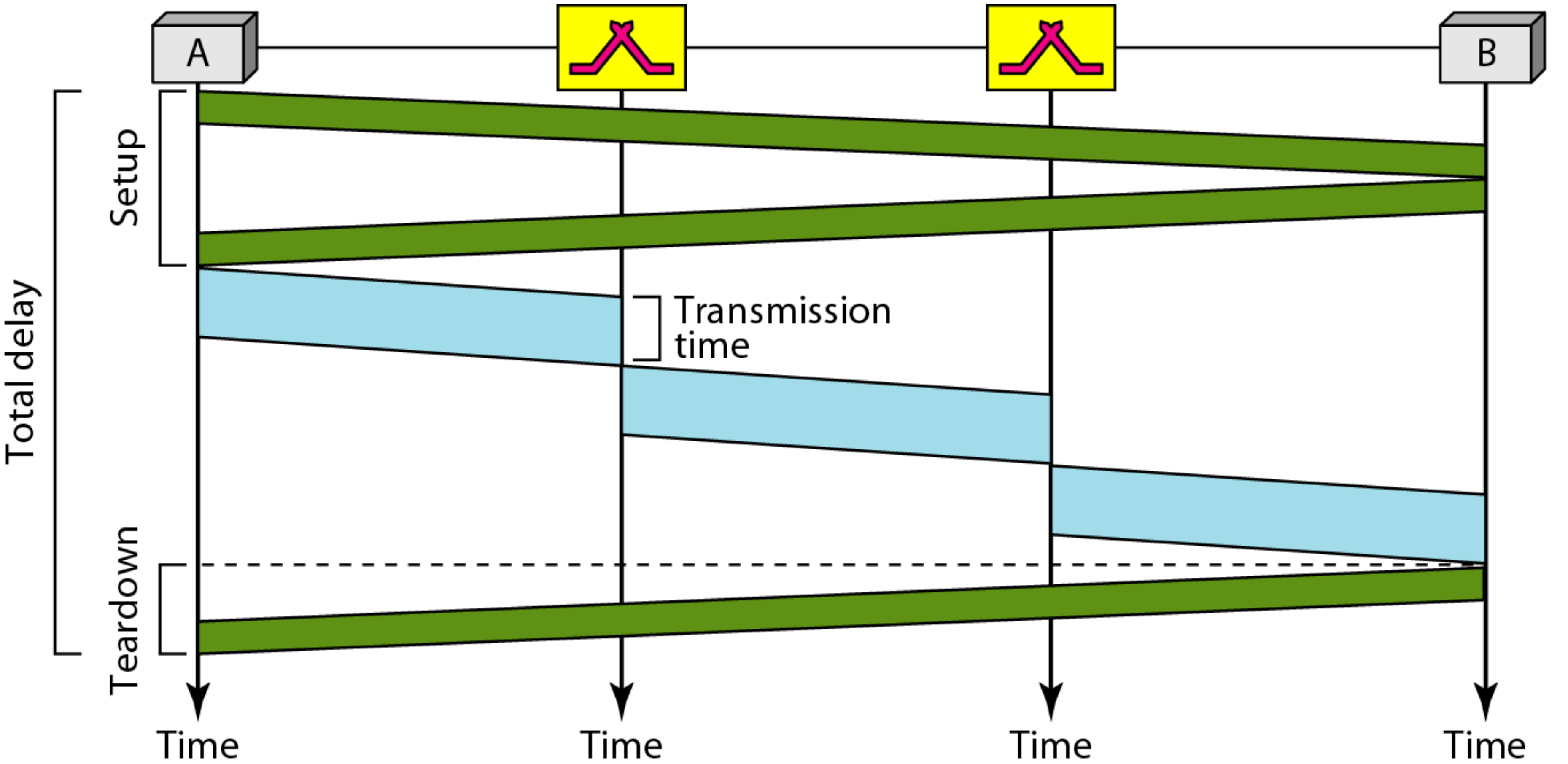
Note

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.

Teardown Phase

- Special frame called teardown request
- All switch delete corresponding entry from their tables

Figure 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.

STRUCTURE OF A SWITCH

Two technologies:

- Space-division switch
- Time-division switch

Crossbar Switch

- n inputs → m output
- Electronic microswitches at each crosspoints
- 1000 input to 1000 output → 1000000 crosspoints
- Impractical
- 25% used at a time → rest idle

Figure 17 *Crossbar switch with three inputs and four outputs*

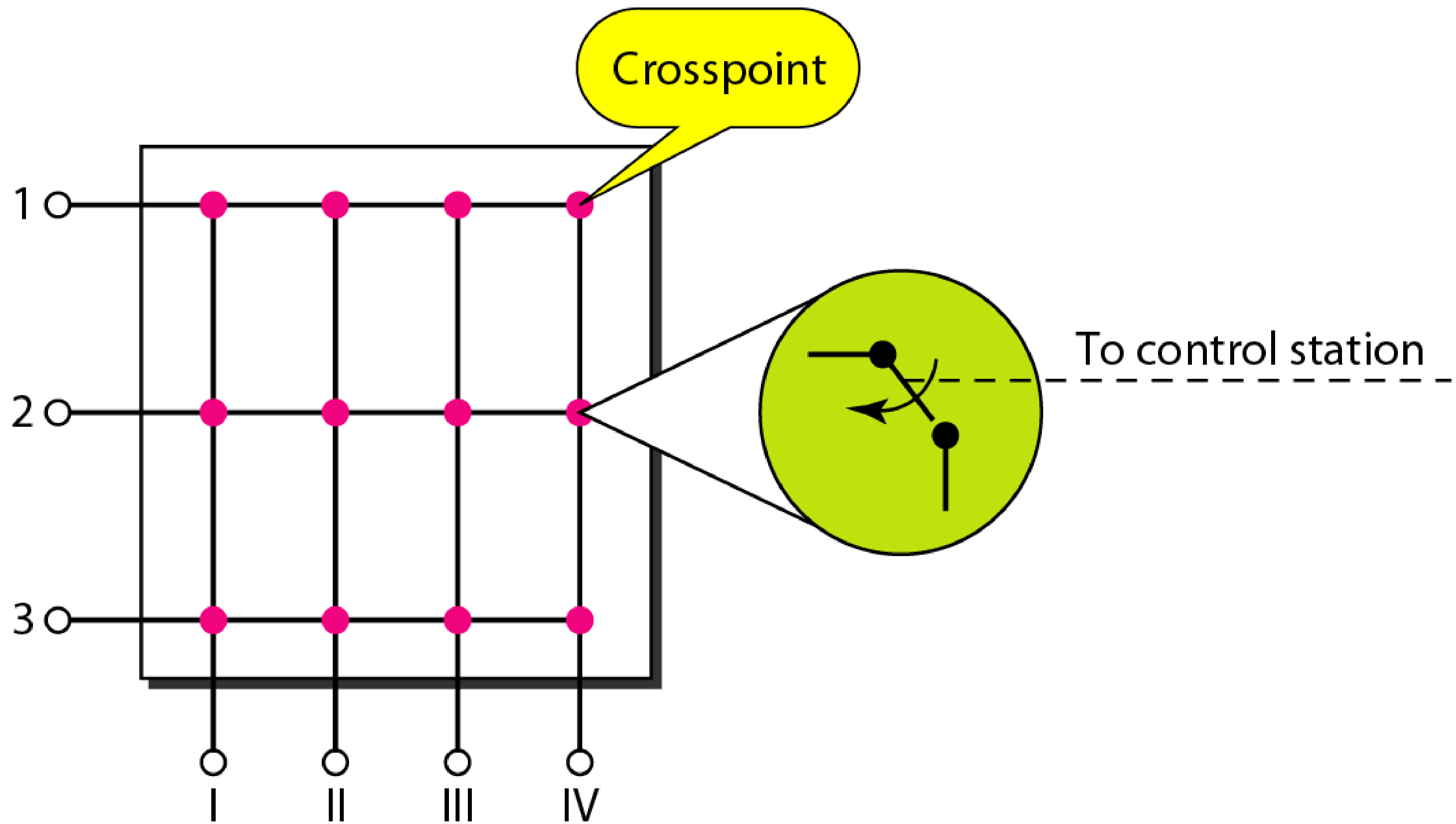
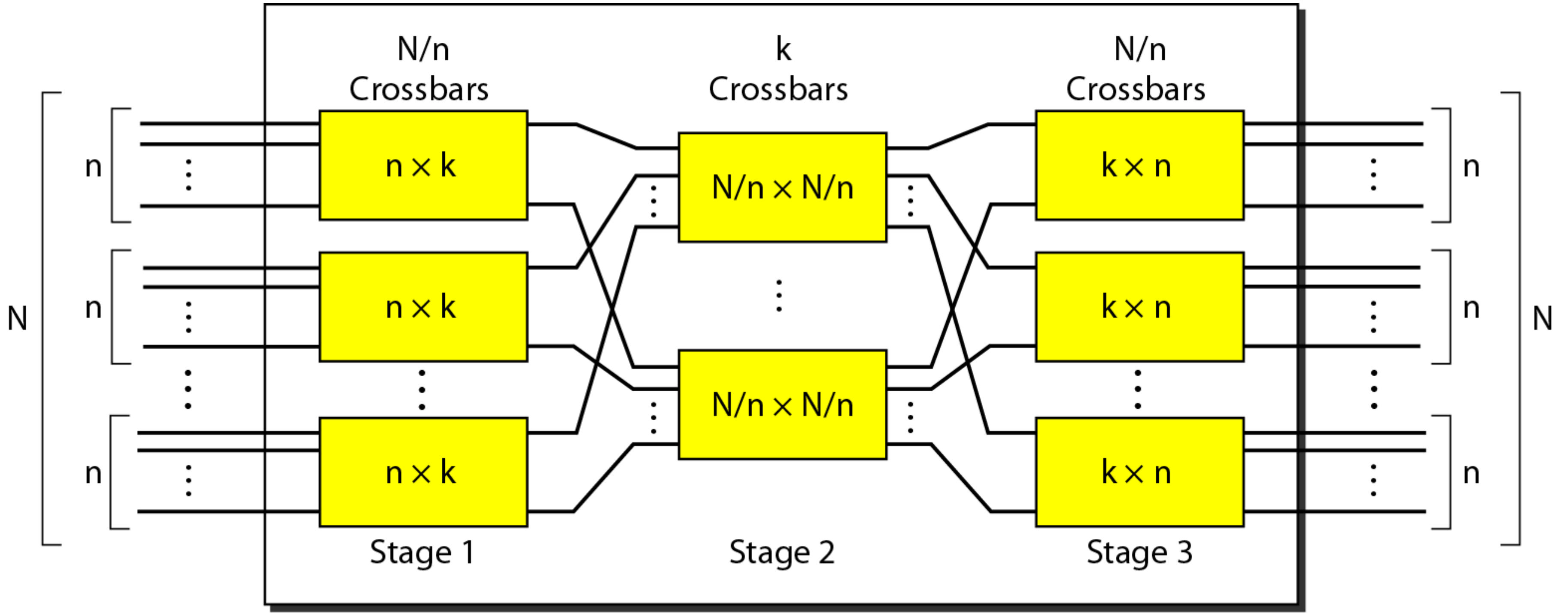


Figure 18 *Multistage switch*



Note

In a three-stage switch, the total number of crosspoints is

$2kN + k(N/n)^2$

which is much smaller than the number of crosspoints in a single-stage switch (N^2).

Example 3

Design a three-stage, 200 × 200 switch ($N = 200$) with $k = 4$ and $n = 20$.

Solution

In the first stage we have N/n or 10 crossbars, each of size 20 × 4. In the second stage, we have 4 crossbars, each of size 10 × 10. In the third stage, we have 10 crossbars, each of size 4 × 20. The total number of crosspoints is $2kN + k(N/n)^2$, or 2000 crosspoints. This is 5 percent of the number of crosspoints in a single-stage switch (200 × 200 = 40,000).

Note

According to the Clos criterion:

$n = (N/2)^{1/2}$

$k > 2n - 1$

Crosspoints $\geq 4N\,[(2N)^{1/2} - 1]$

Example 4

Redesign the previous three-stage, 200 × 200 switch, using the Clos criteria with a minimum number of crosspoints.

Solution

We let $n = (200/2)^{1/2}$, or $n = 10$. We calculate $k = 2n - 1 = 19$. In the first stage, we have 200/10, or 20, crossbars, each with 10 × 19 crosspoints. In the second stage, we have 19 crossbars, each with 10 × 10 crosspoints. In the third stage, we have 20 crossbars each with 19 × 10 crosspoints. The total number of crosspoints is 20(10 × 19) + 19(10 × 10) + 20(19 ×10) = 9500.

Crossbar Switch

- Still need huge number of crosspoints
- 100000 telephones in city → needs 200 million crosspoints
- Company uses Time division switching

Figure 19 *Time-slot interchange*

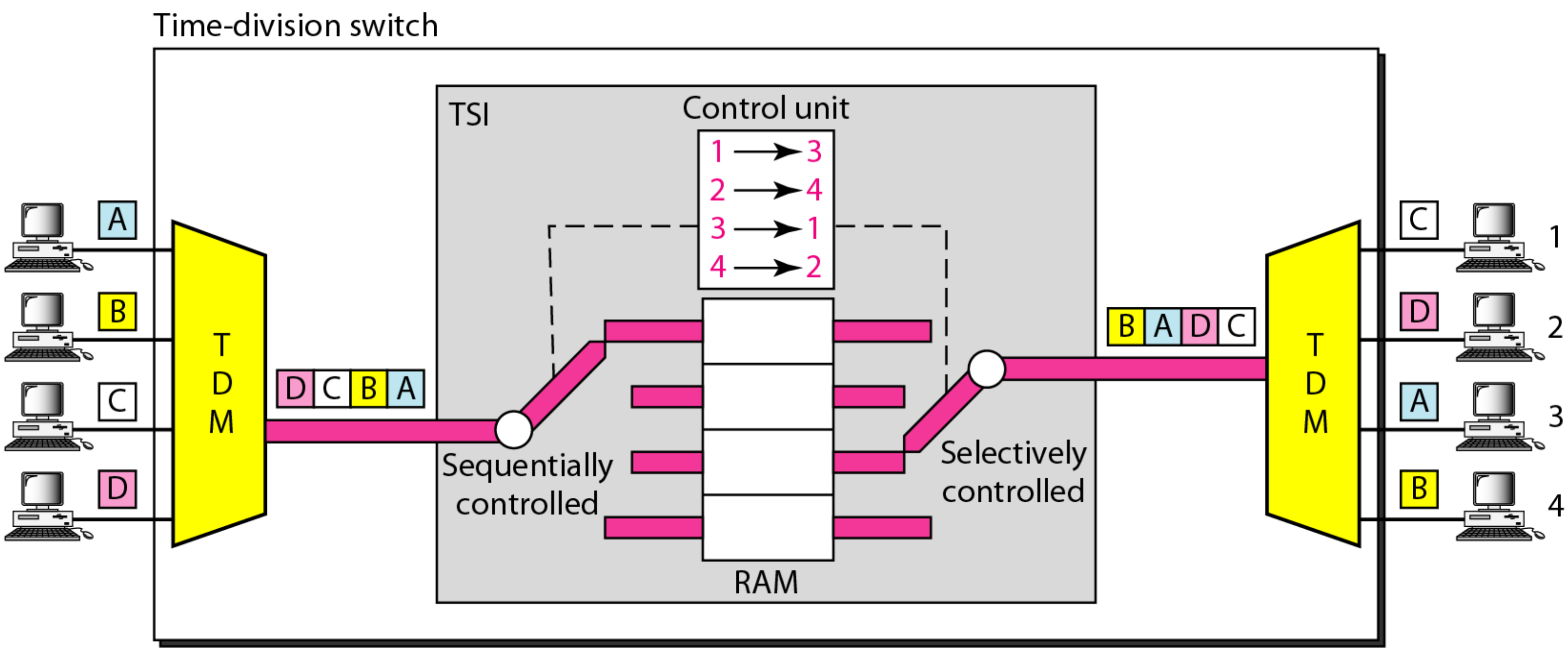


Figure 20 *Time-space-time switch*

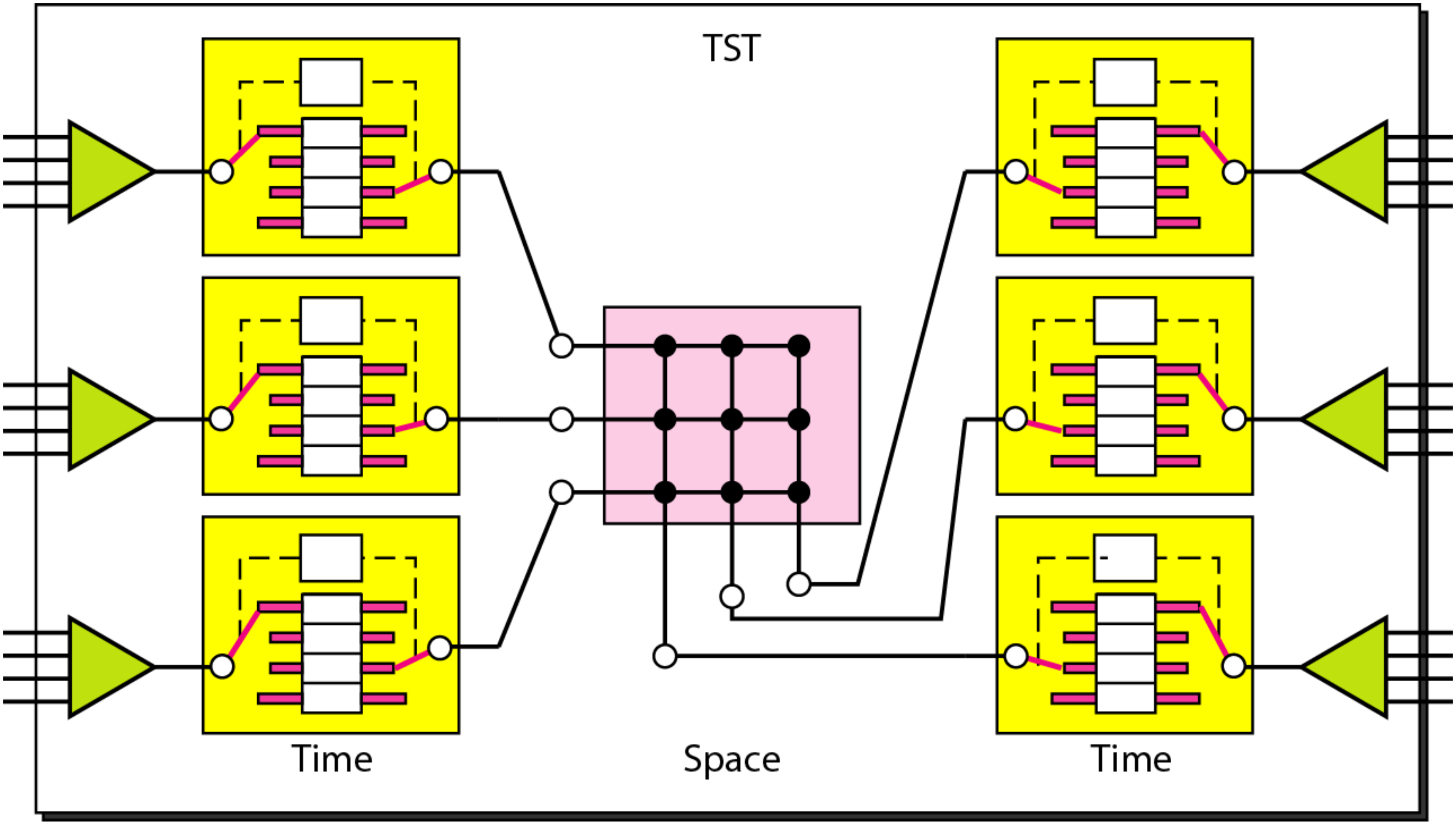


Figure 21 *Packet switch components*

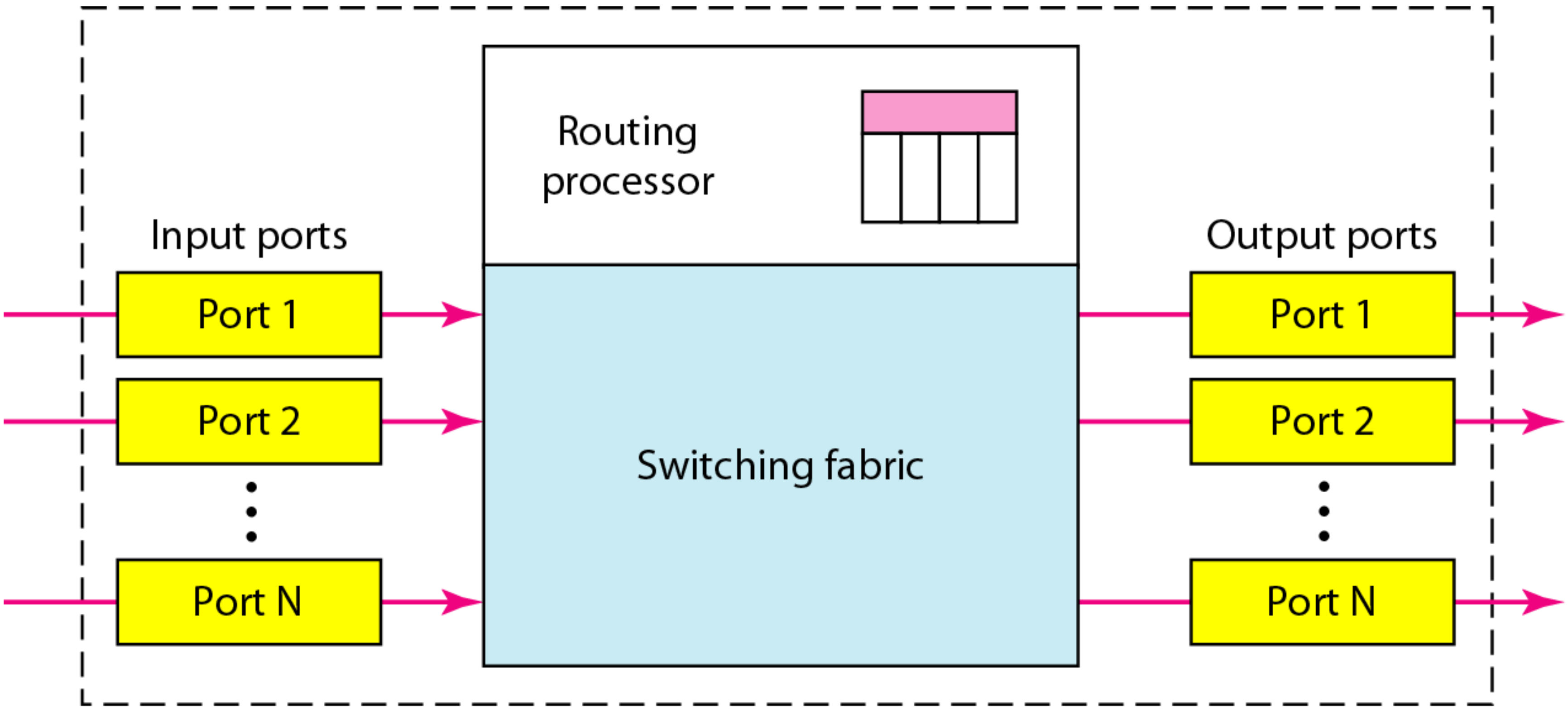


Figure 22 *Input port*

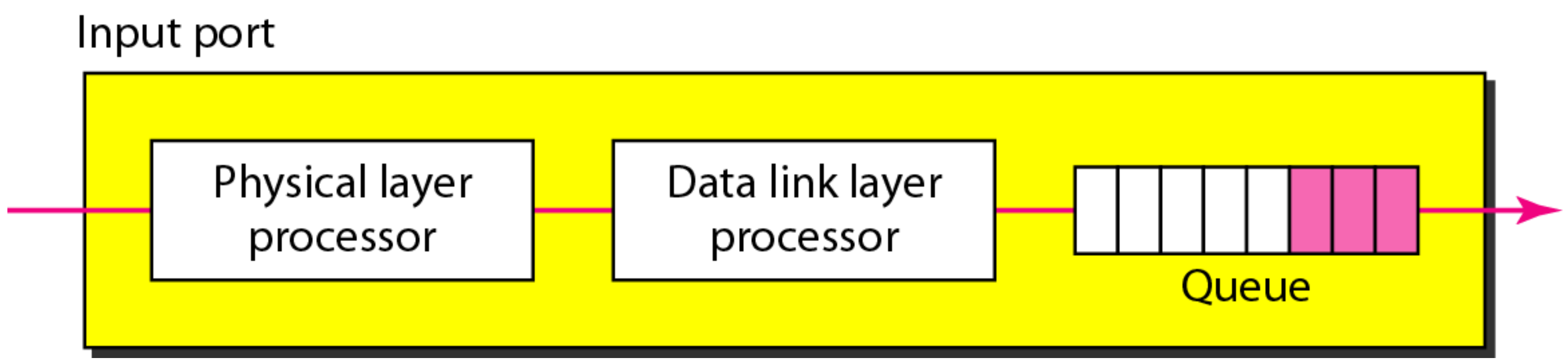


Figure 23 *Output port*

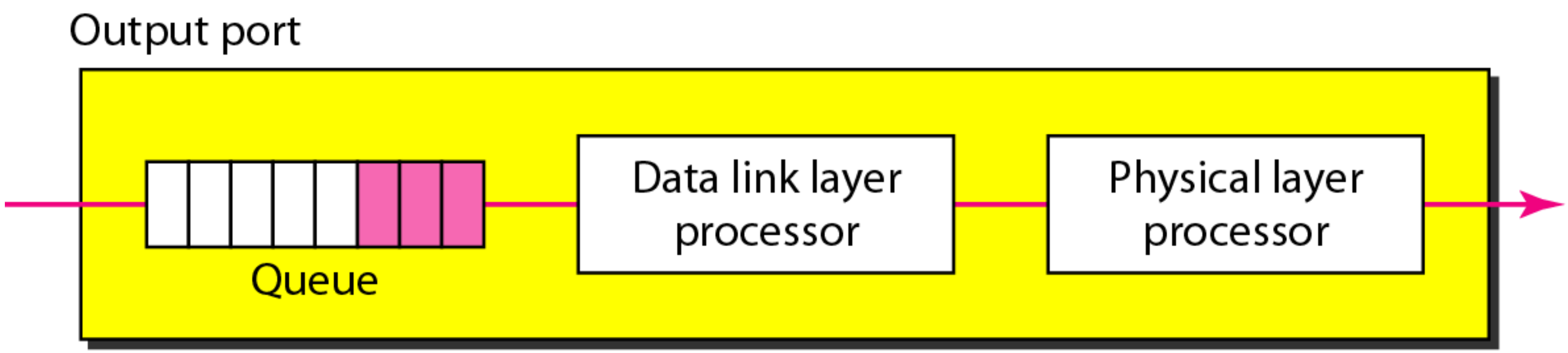
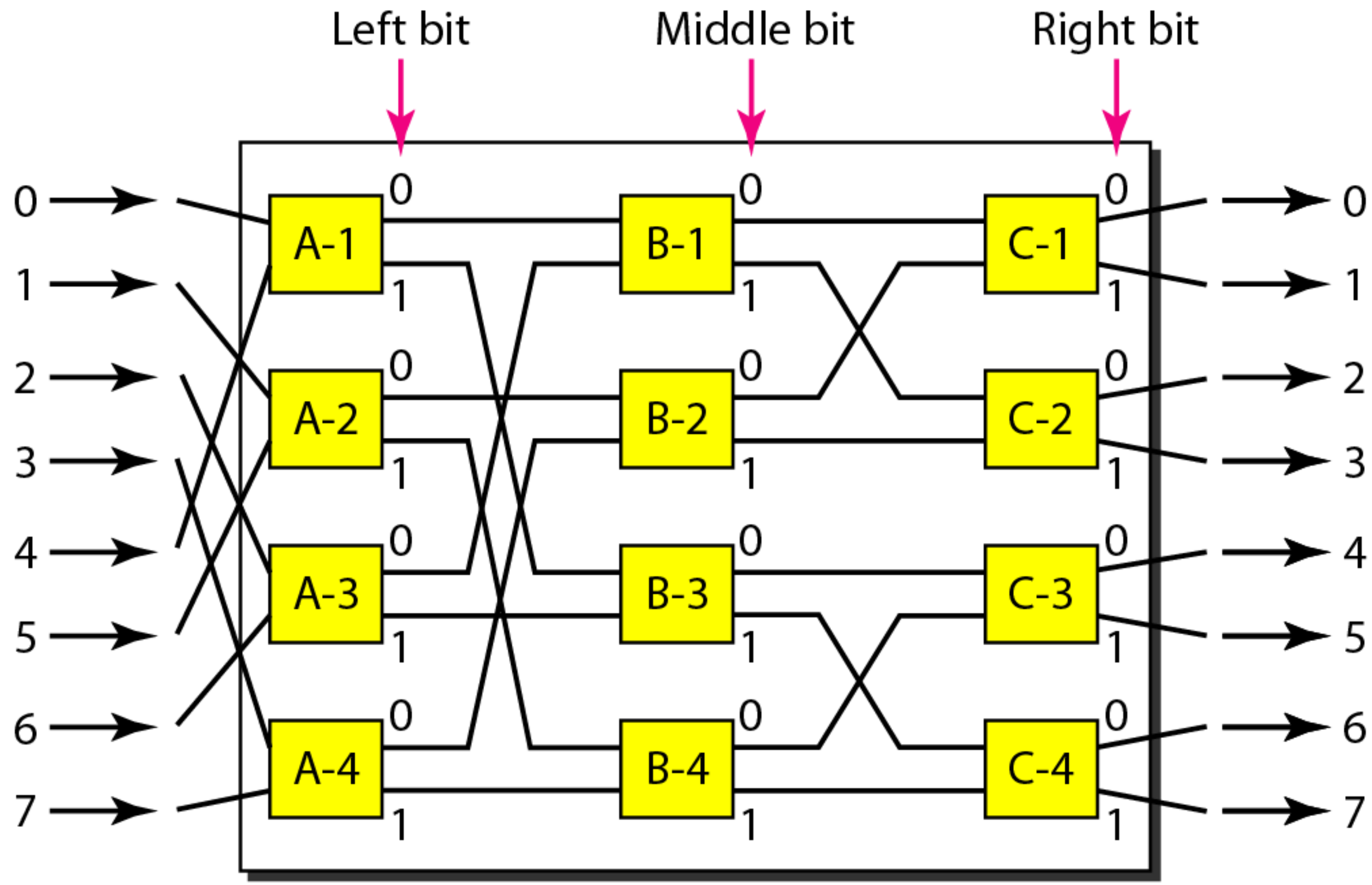


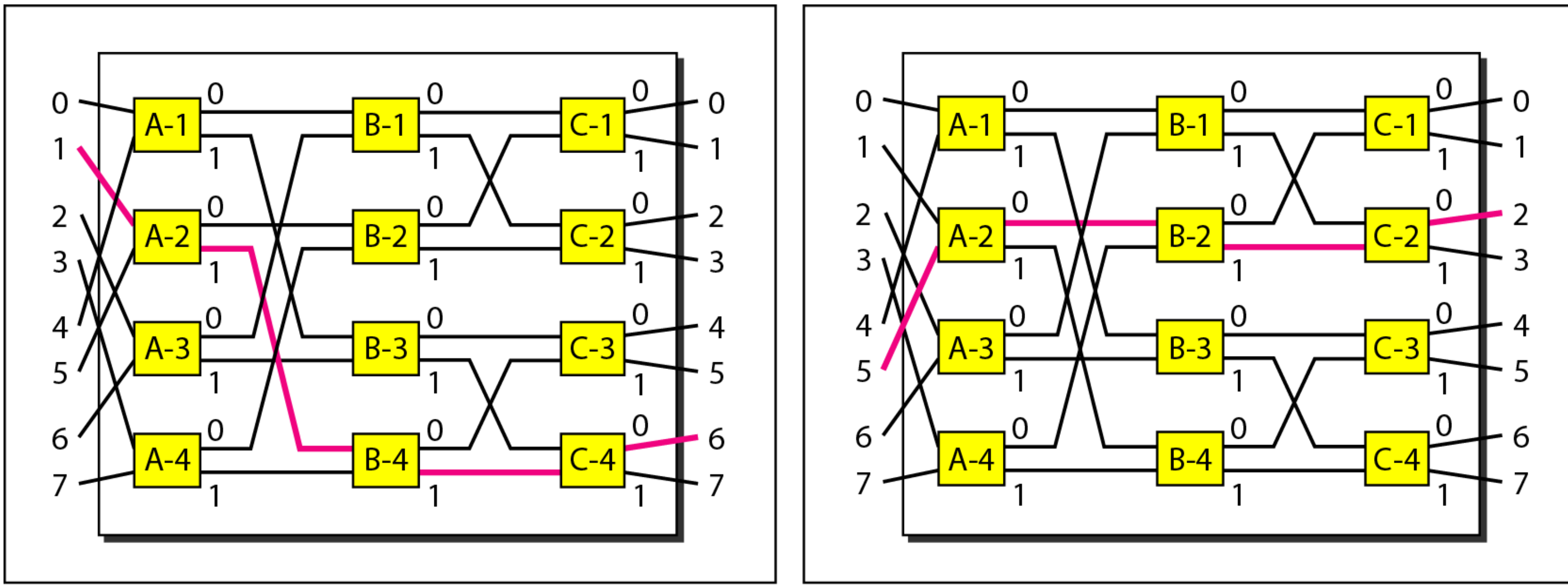
Figure 24 *A banyan switch*



A banyan switch

- n inputs and n outputs
- $\log_2 n$ stages
- n/2 microswitches at each stage

Figure 25 *Examples of routing in a banyan switch*



a. Input 1 sending a cell to output 6 (110)

b. Input 5 sending a cell to output 2 (010)

Figure 26 *Batcher-banyan switch*