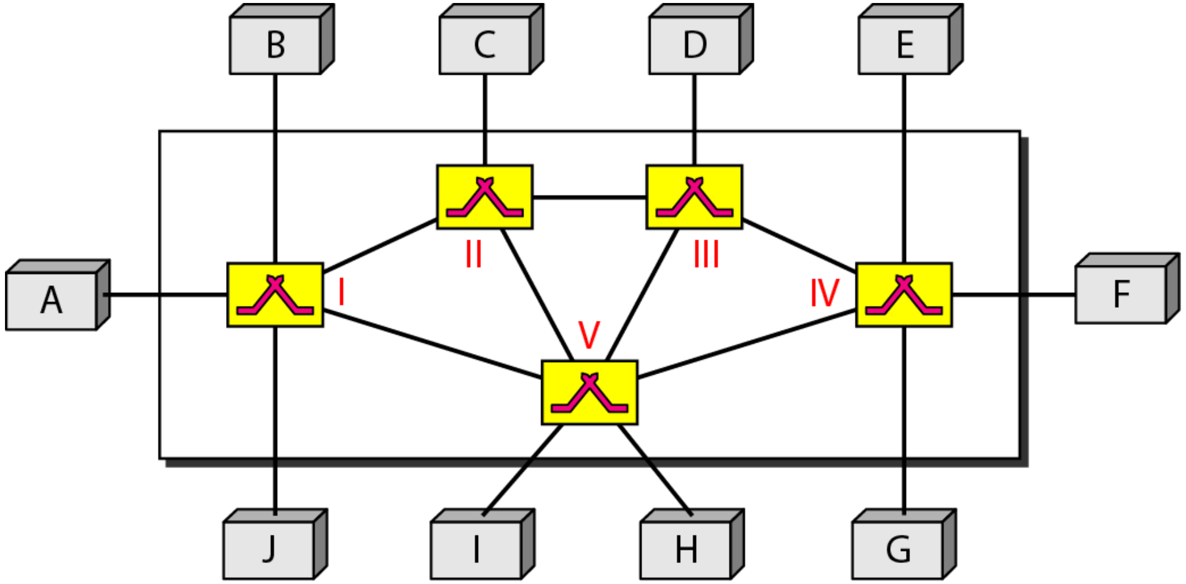
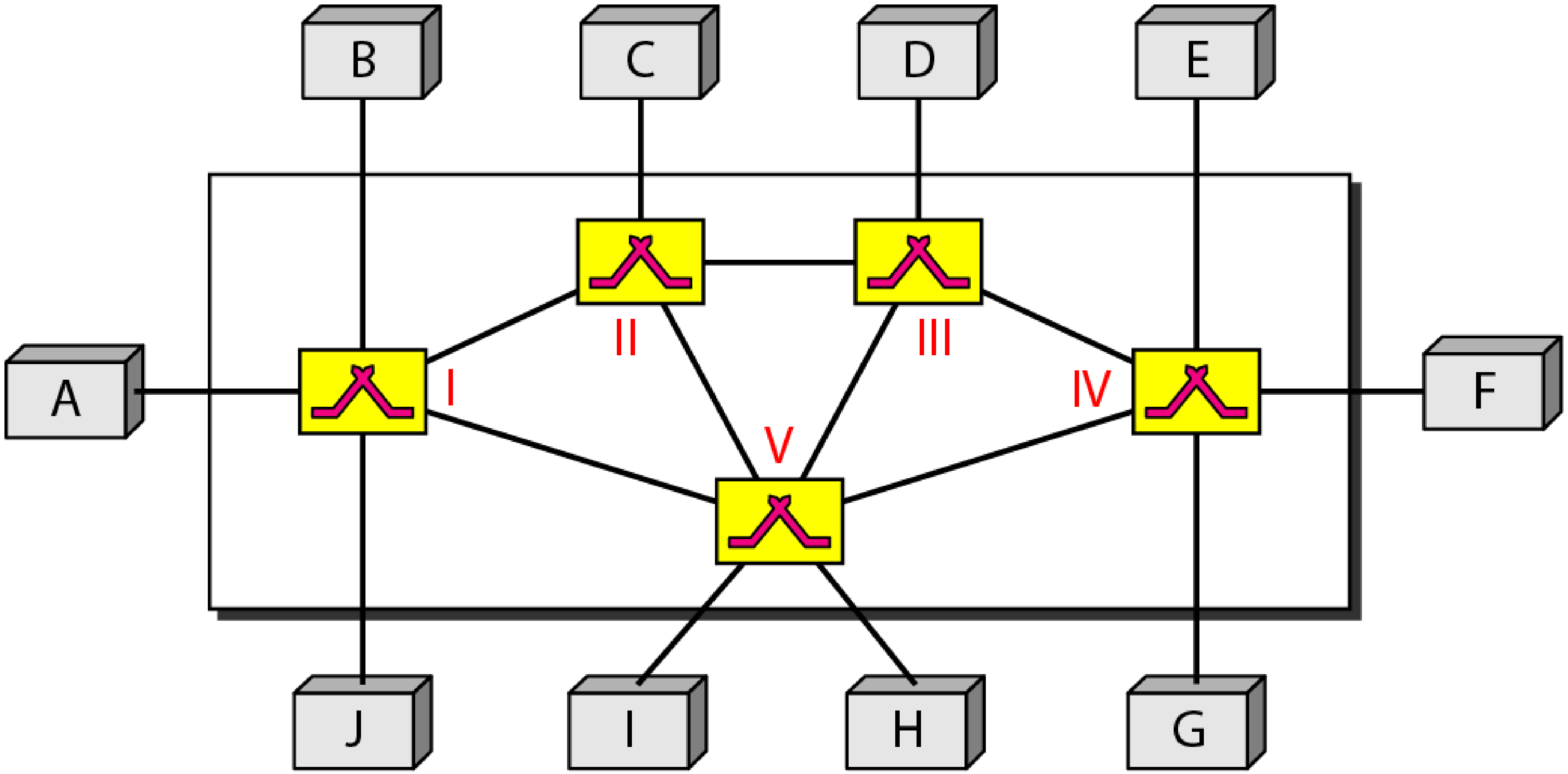


Switching

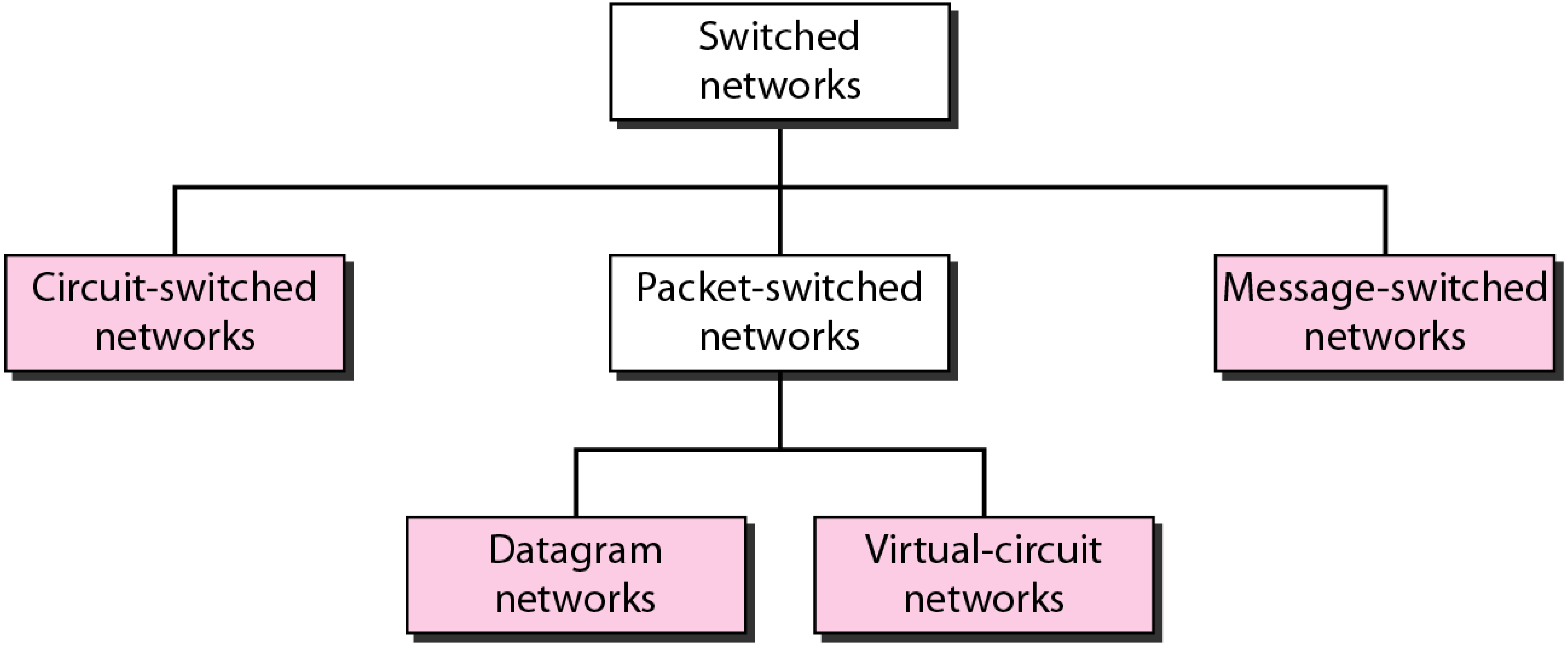
Switching

- A network is a set of connected device
- If we have multiple devices, we have the problem of how to connect them to make one-to-one communication
- solutions are: mesh, star
- if very large networks?
- A better solution is Switching
- A switched network consists of a series of interlinked nodes, called switches.
- Switches are devices capable of creating temporary connections between two or more devices linked to the switch

Switch Network



Taxonomy of Switched Network

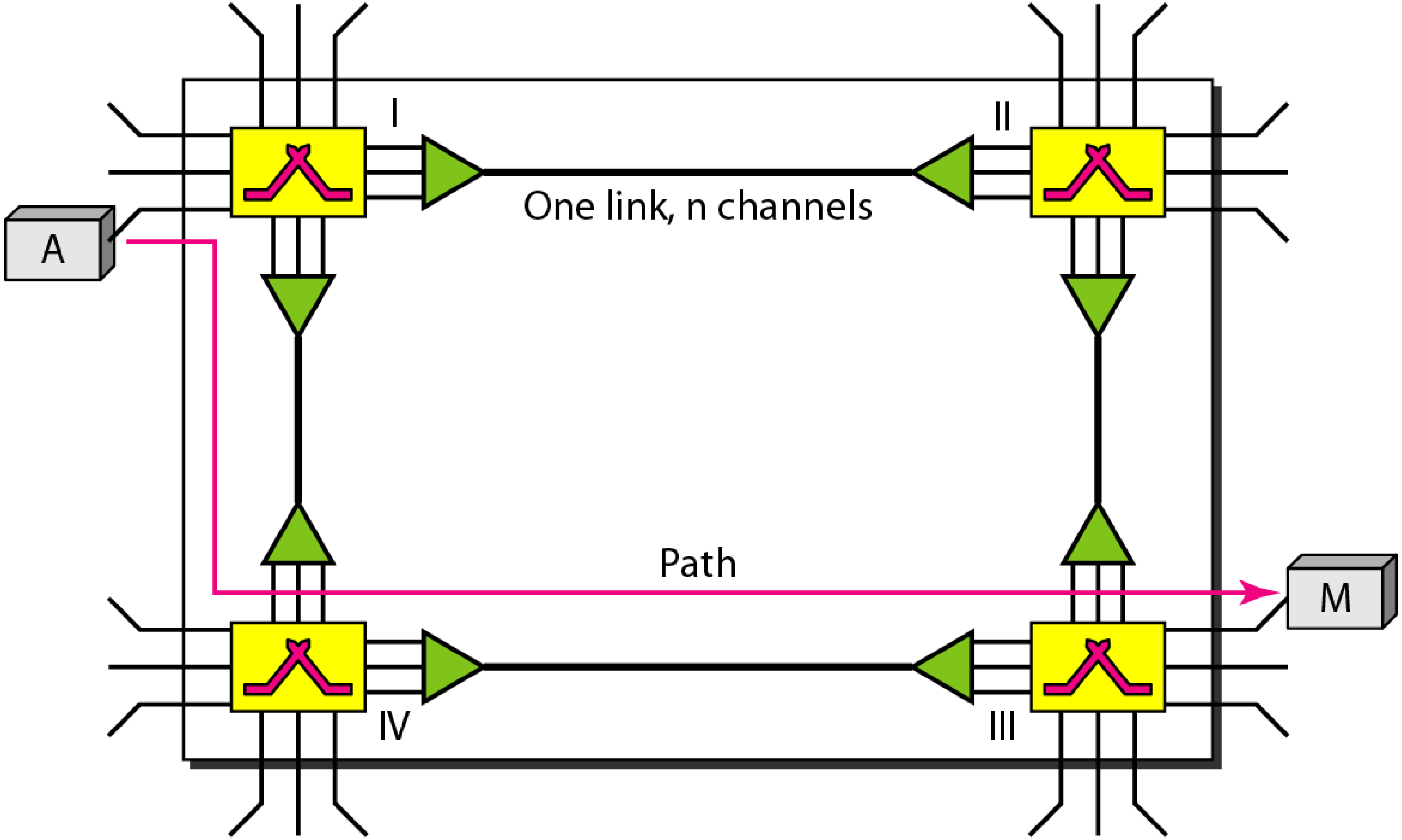


Circuit-Switched Networks

- 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.

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-Switched Networks



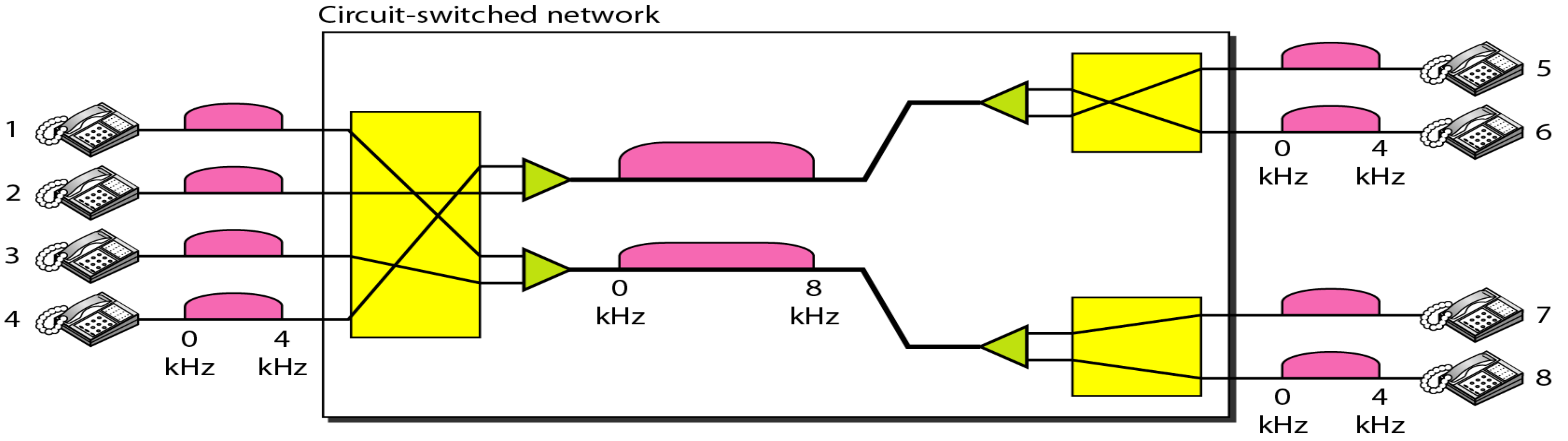
Circuit-Switched Networks

- Circuit switching takes place at the physical layer.
- Before starting communication, the stations must make a reservation for the resources to be used during the communication. These resources, such as channels bandwidth, switch buffers, switch processing time, and switch input/output ports, must remain dedicated during the entire duration of data transfer until the teardown phase.
- Data transferred between the two stations are not packetized
- The data are a continuous flow sent by the source station and received by the destination station, although there may be periods of silence.

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.

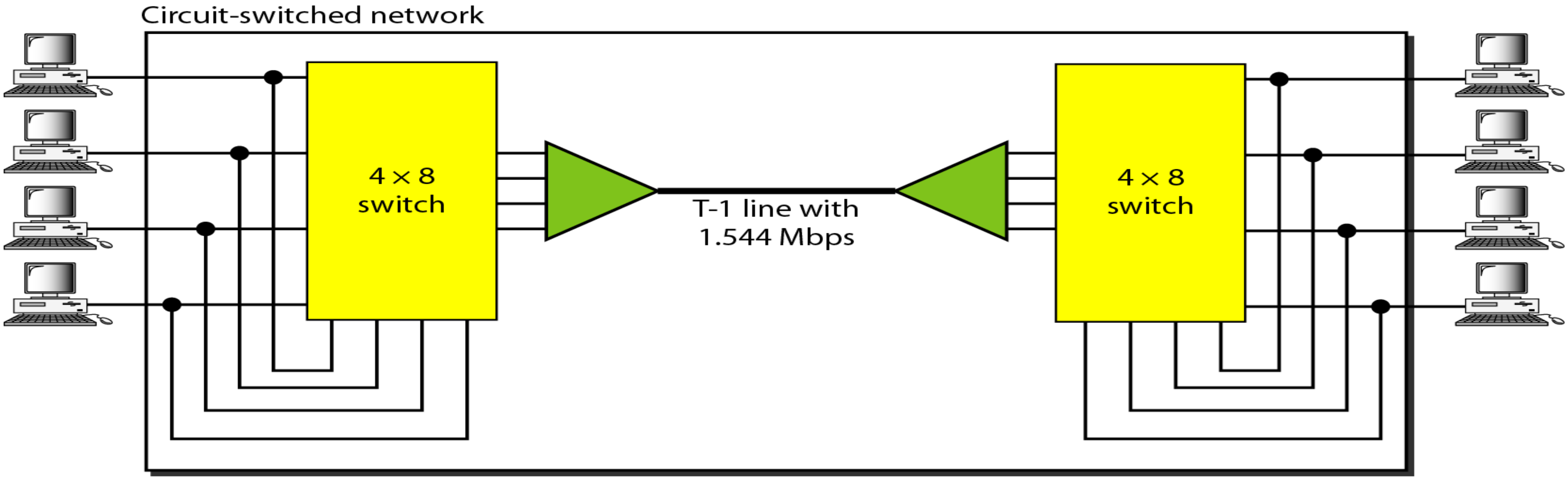
Circuit-switched network used in Example 8.1



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.

Circuit-switched network used in Example 8.2



Three Phases in Circuit-switched network

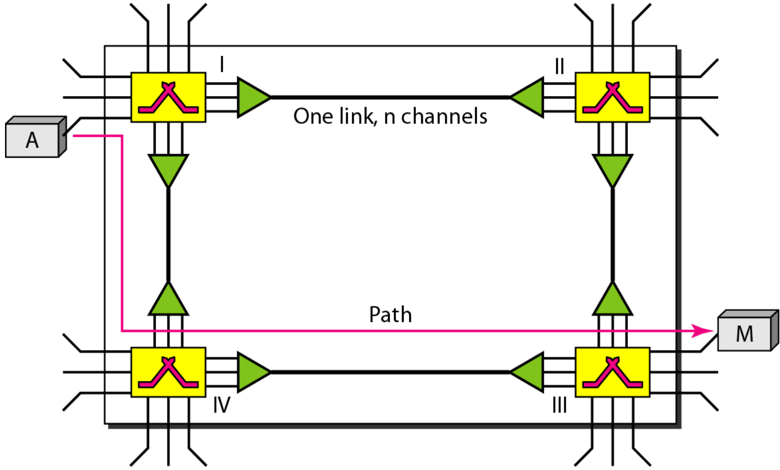
The actual communication in a circuit-switched network requires three phases

- Connection Setup Phase
- Data Transfer
- Connection teardown

Circuit-switched network

Connection Setup Phase

- Before the two parties (or multiple parties in a conference call) can communicate, a dedicated circuit (combination of channels in links) needs to be established.
- The end systems are normally connected through dedicated lines to the switches, so connection setup means creating dedicated channels between the switches
- In the next step to making a connection, an acknowledgment from system **M** needs to be sent in the opposite direction to system **A** .
- Only after system **A** receives this acknowledgment is the connection established.



Circuit-switched network

Data Transfer Phase

- After the establishment of the dedicated circuit (channels), the two parties can transfer data

Teardown Phase

- When one of the parties needs to disconnect, a signal is sent to each switch to release the resources.

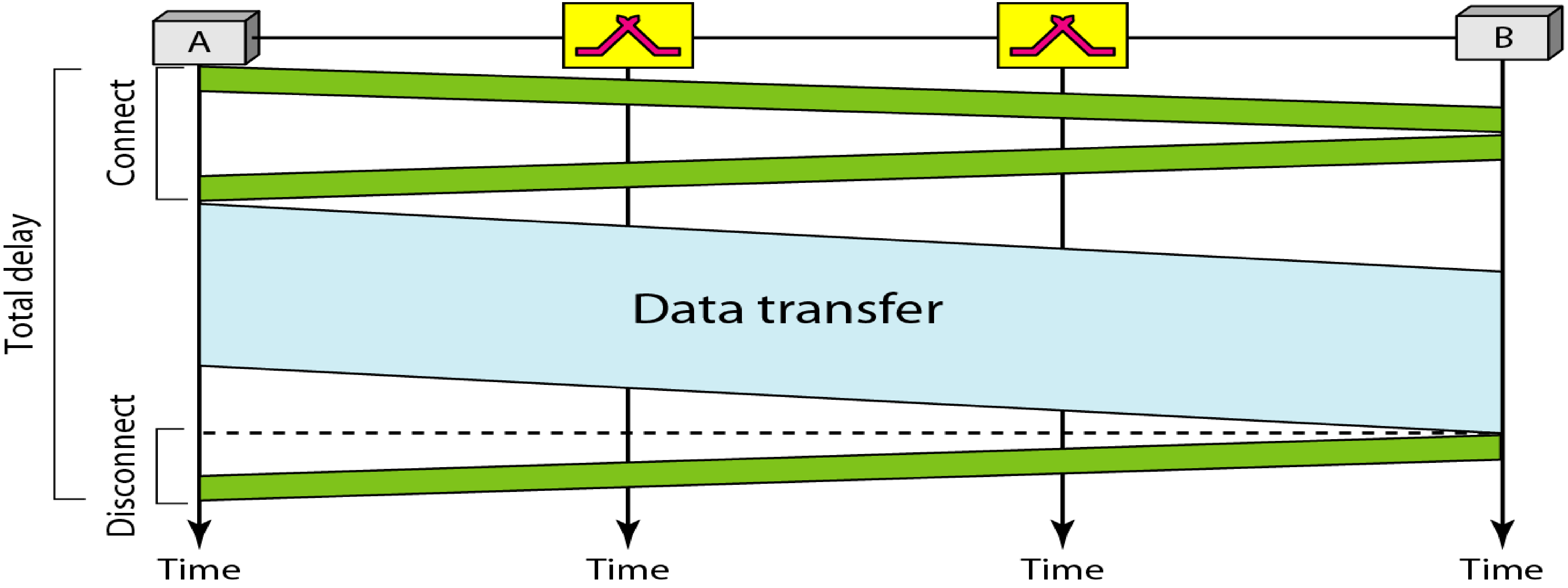
Circuit-switched network

Efficiency

- It can be argued that circuit-switched networks are not as efficient as the other two types of networks because resources are allocated during the entire duration of the connection.
- These resources are unavailable to other connections.
- In a telephone network, people normally terminate the communication when they have finished their conversation.
- However, in computer networks, a computer can be connected to another computer even if there is no activity for a long time. In this case, allowing resources to be dedicated means that other connections are deprived.

Circuit-switched network

Delay



Circuit-switched network

Application

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

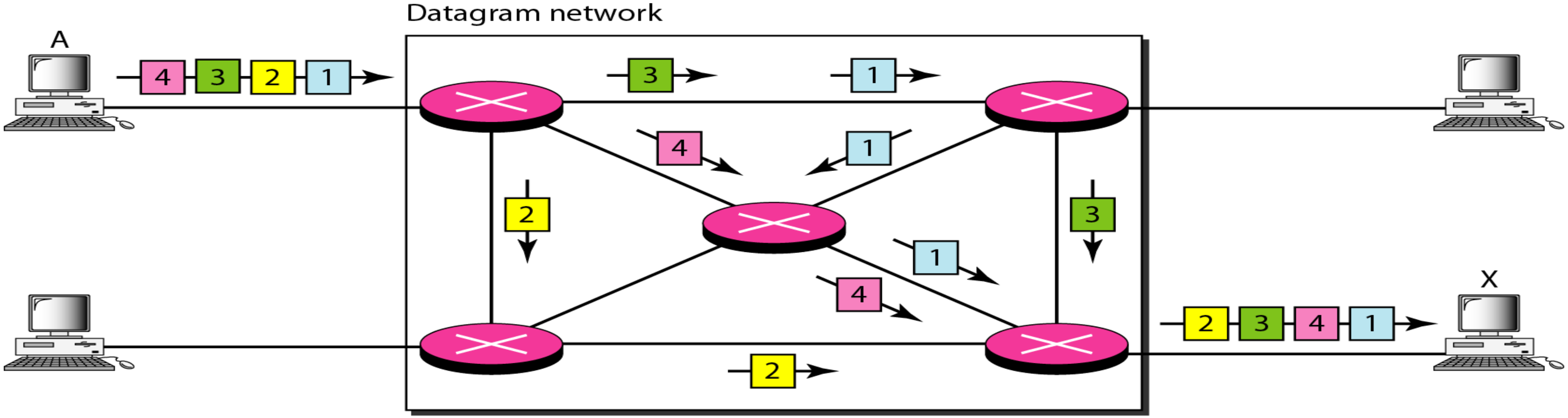
Packet Switching

- 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

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

Datagram Networks

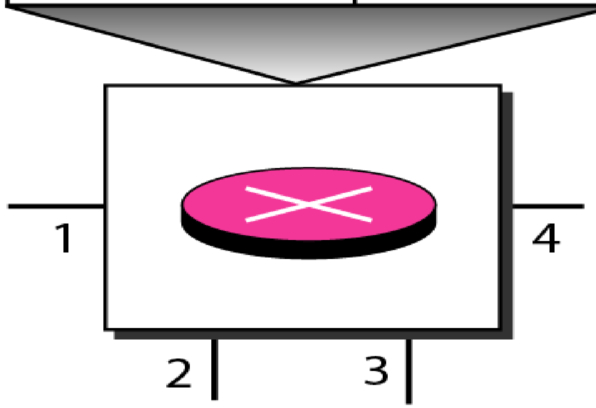
- In a datagram network, each packet is treated independently of all others.
- Even if a packet is part of a multipacket transmission, the network treats it as though it existed alone.
- Packets in this approach are referred to as datagrams.
- Datagram switching is normally done at the network layer.



Routing table in a datagram network

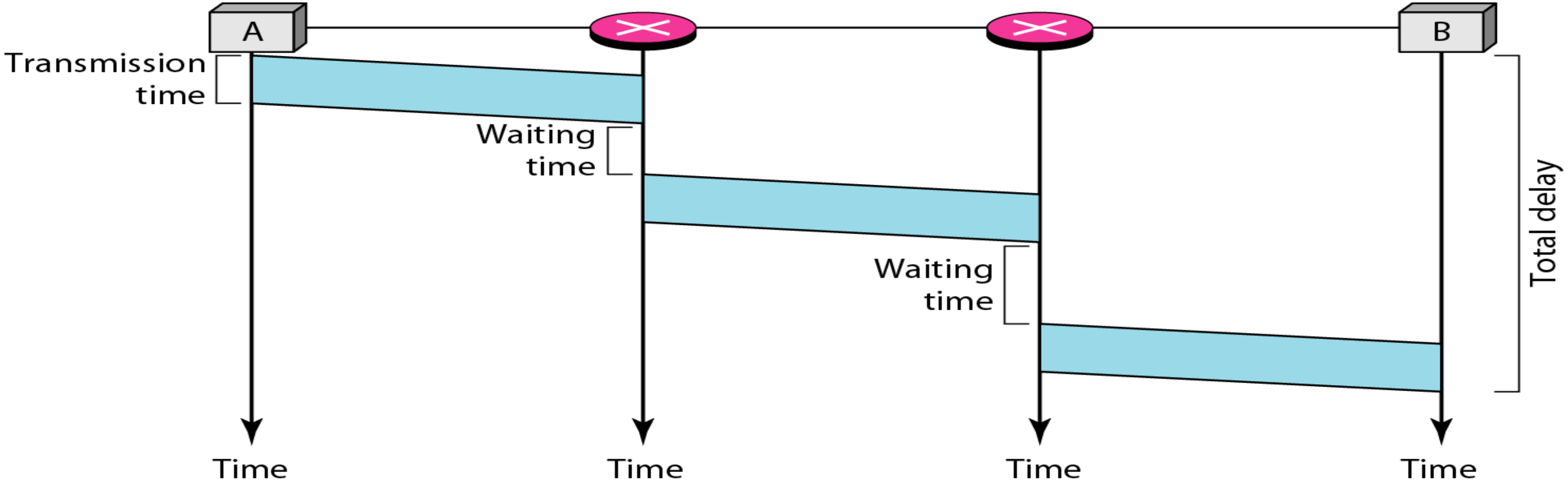
- If there are no setup or teardown phases, how are the packets routed to their destinations in a datagram network?
- In this type of network, each switch (or packet switch) has a routing table which is based on the destination address.
- The routing tables are dynamic and are updated periodically.
- The destination address in the header of a packet in a datagram network remains the same during the entire journey of the packet.

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



Delay in a datagram network

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



The efficiency of a datagram network is better than that of a circuit-switched network; resources are allocated only when there are packets to be transferred.
If a source sends a packet and there is a delay of a few minutes before another packet can be sent, the resources can be reallocated during these minutes for other packets from other sources.

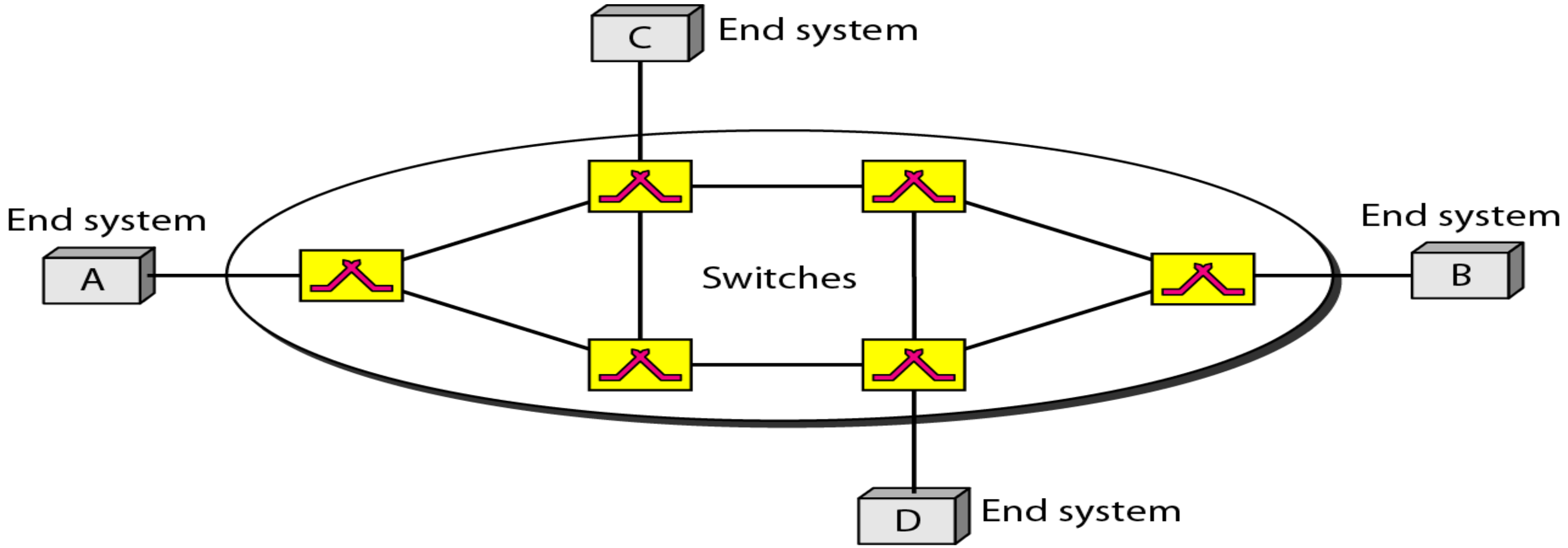
Datagram network

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. It has some characteristics of both.
- As in a circuit-switched network, there are setup and teardown phases in addition to the data transfer phase.
- Resources can be allocated during the setup phase, as in a circuit-switched network, or on demand, as in a datagram network.
- As in a datagram network, data are packetized and each packet carries an address in the header. However, the address in the header has local jurisdiction (it defines what the next switch should be and the channel on which the packet is being carried), not end-to-end jurisdiction. The reader may ask how the intermediate switches know where to send the packet if there is no final destination address carried by a packet.
- As in a circuit-switched network, all packets follow the same path established during the connection.

Virtual Circuit Networks



- The network has switches that allow traffic from sources to destinations.
- A source or destination can be a computer, packet switch, bridge, or any other device that connects other networks.

Virtual Circuit Networks

Addressing

- global and local (virtual-circuit identifier) addressing .

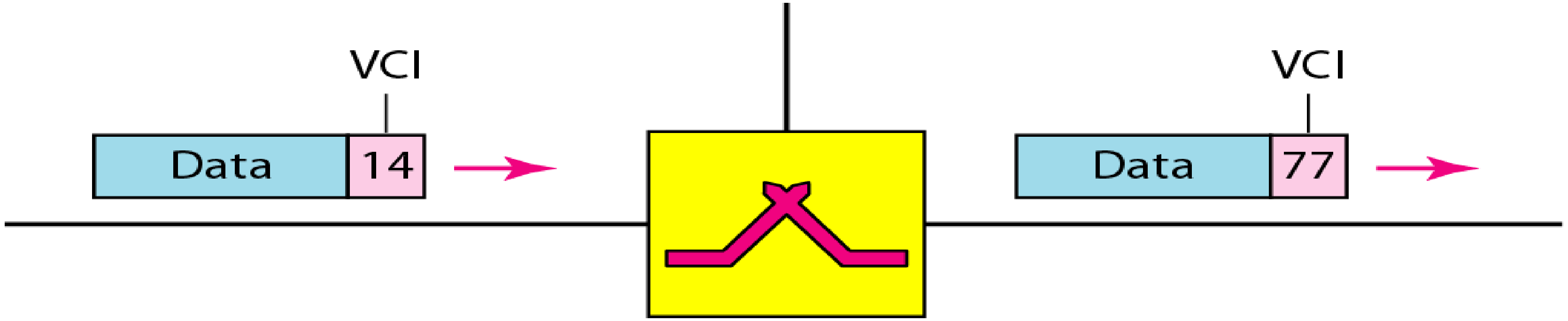
Global Addressing

- A source or a destination needs to have a global address—an address that can be unique in the scope of the network or internationally if the network is part of an international network.

Virtual Circuit Networks

Virtual-Circuit Identifier

- The identifier that is actually used for data transfer is called the virtual-circuit identifier (VCI) or the label.
- A VCI, unlike a global address, is a small number that has only switch scope;
- it is used by a frame between two switches.
- When a frame arrives at a switch, it has a VCI; when it leaves, it has a different VCI.



Three Phases in Virtual-Circuit Network

The actual communication in a circuit-switched network requires three phases

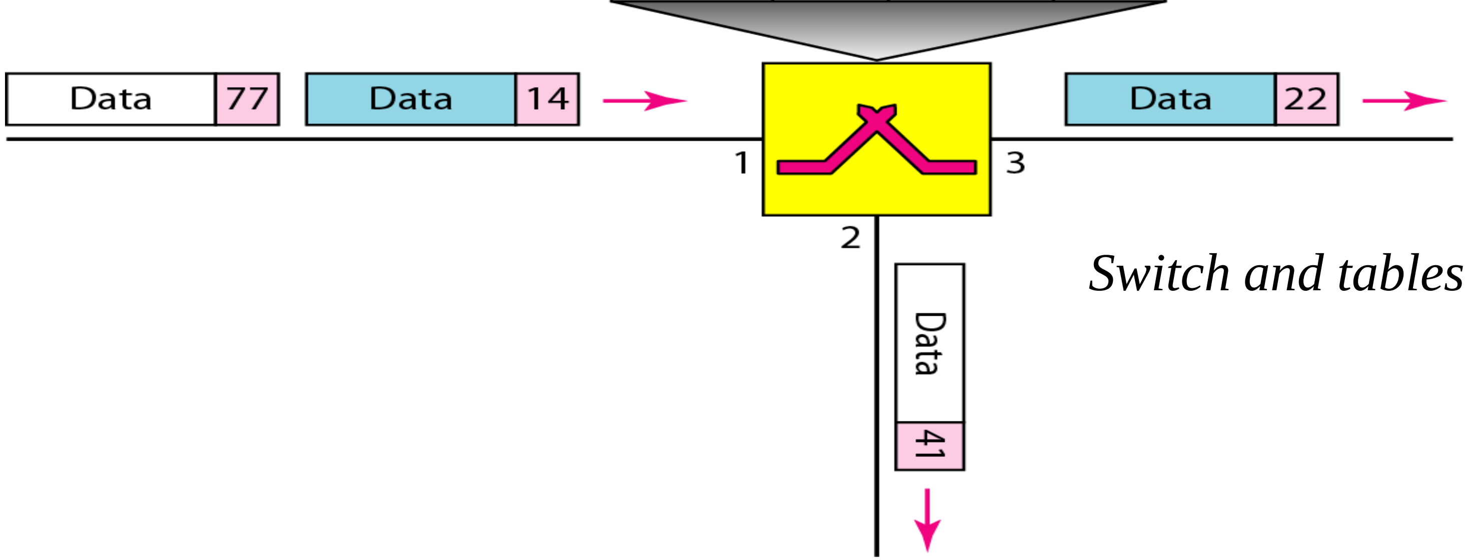
- Connection Setup Phase
- Data Transfer
- Connection teardown

Virtual – Circuit network

Setup Phase

- In the setup phase, the source and destination use their global addresses to help switches make table entries for the connection

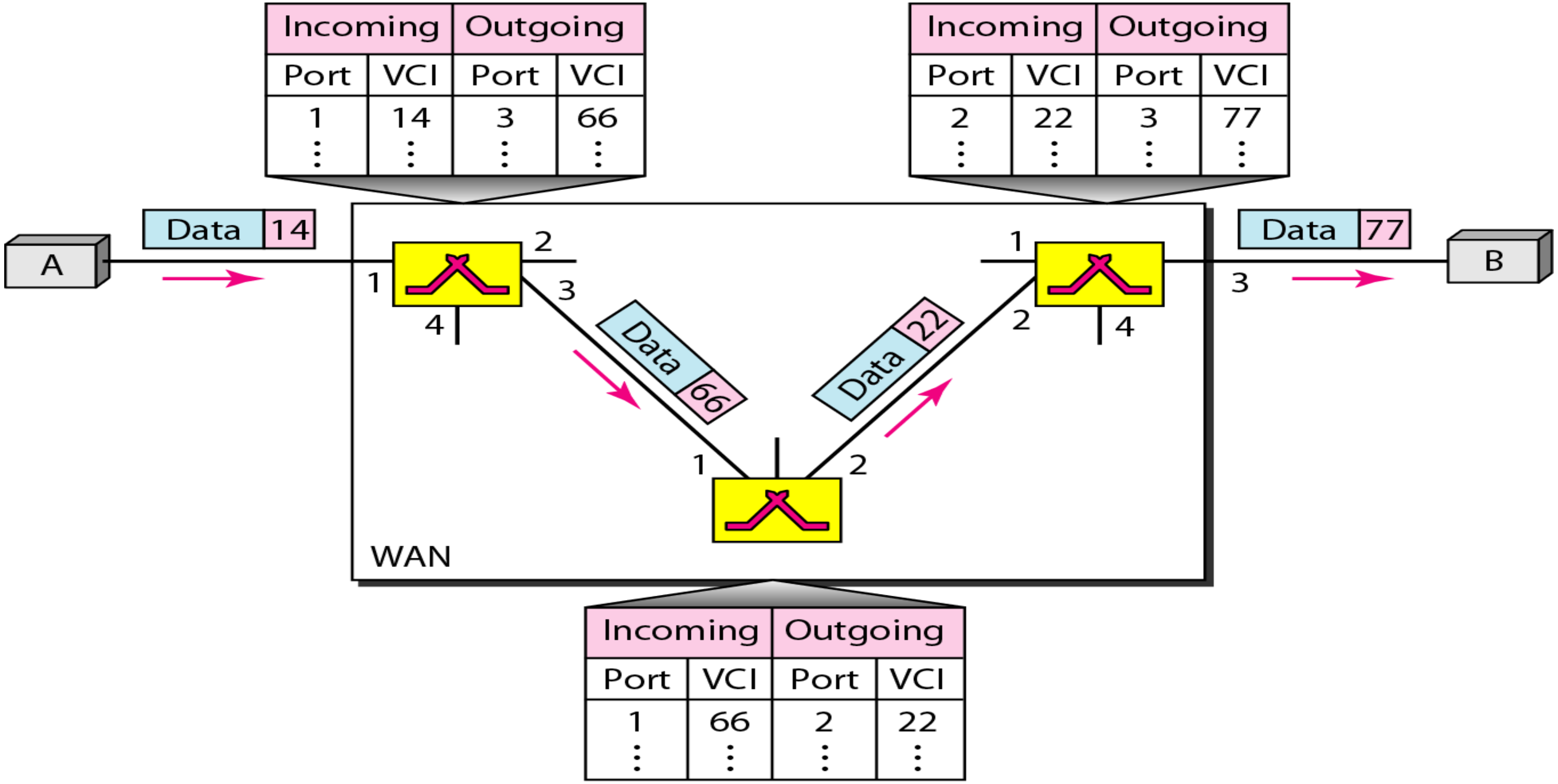
Incoming		Outgoing	
Port	VCI	Port	VCI
1	14	3	22
1	77	2	41



Switch and tables in a virtual-circuit network

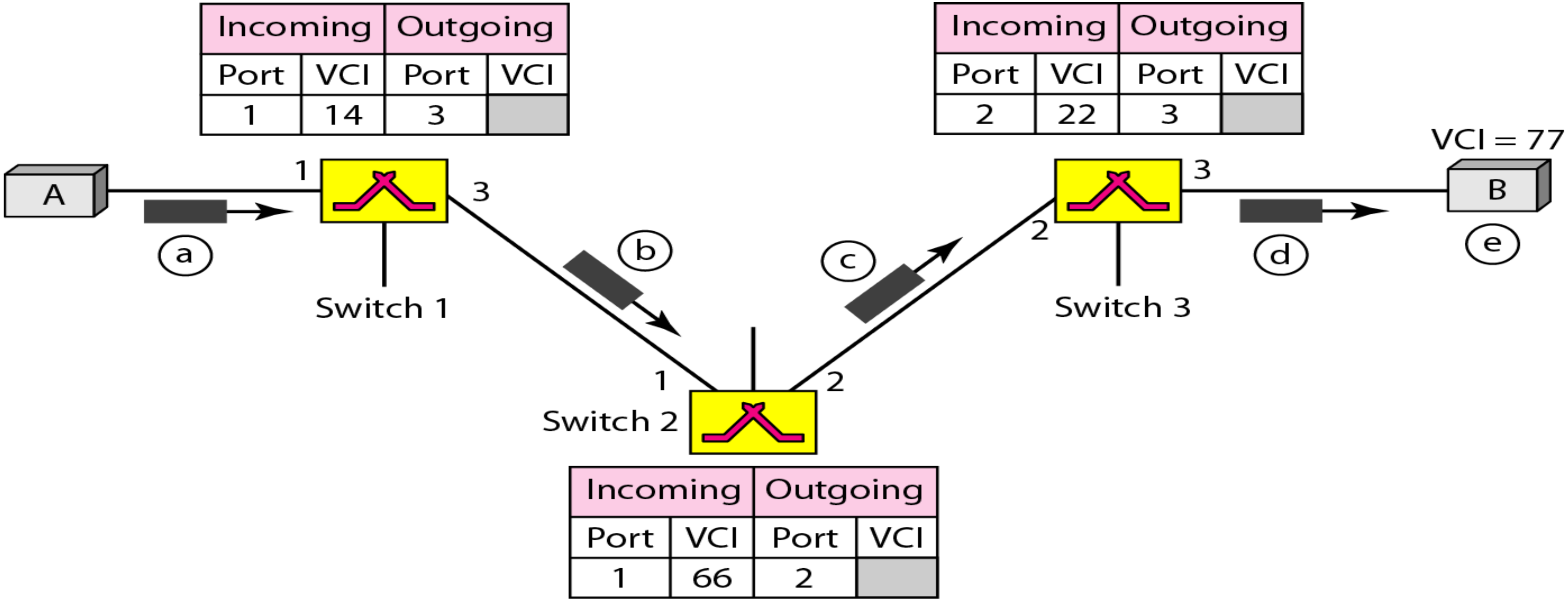
Virtual – Circuit network

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



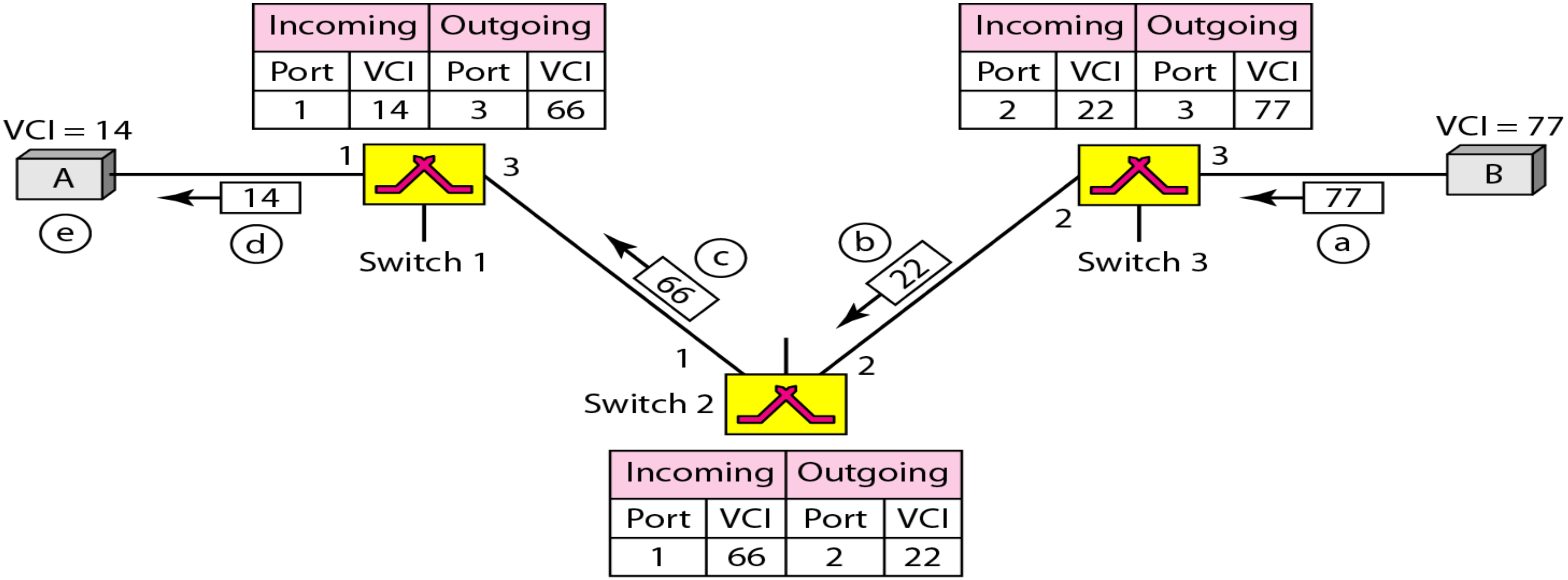
Virtual – Circuit network

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



Virtual – Circuit network

- *Setup acknowledgment in a virtual-circuit network*



Virtual – Circuit network

Teardown Phase

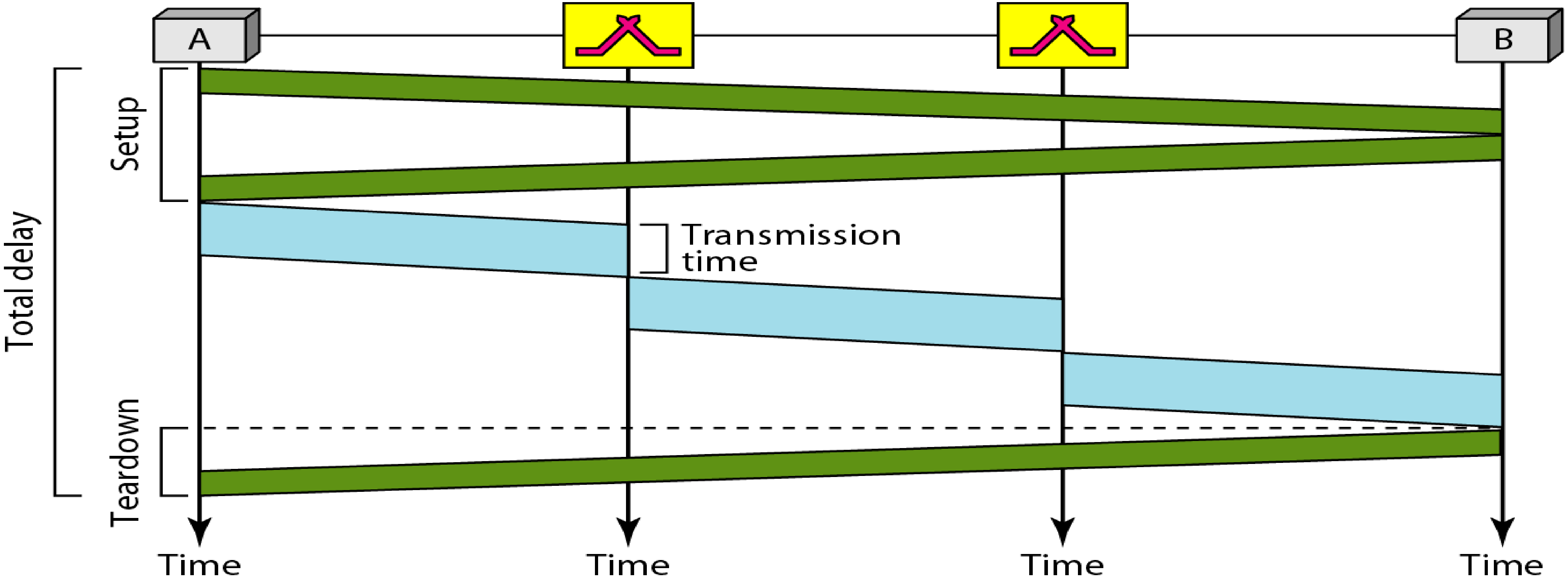
- In the this phase source A, after sending all frames to B, sends a special frame called a teardown request.
- Destination B responds with a teardown confirmation frame. All switches delete the corresponding entry from their tables.

Virtual – Circuit network

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.

Virtual – Circuit network

Delay



Total delay = 3*T* + *3τ* + *setup delay* + *teardown delay*

Structure of 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.
- Circuit switching today can use either of two technologies:
  - Space-division switch
  - Time-division switch

Space – Division Switch

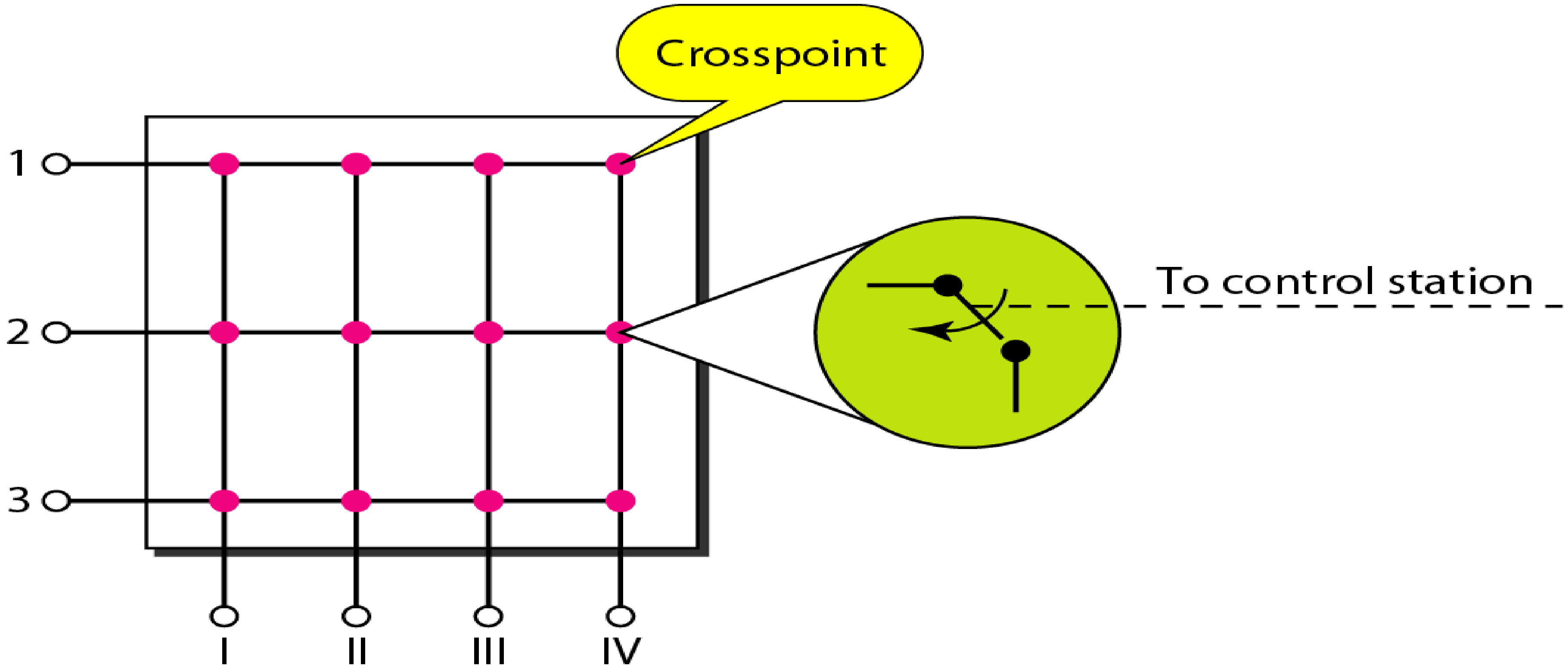
- In space-division switching, the paths in the circuit are separated from one another spatially.
- This technology was originally designed for use in analog networks but is used currently in both analog and digital networks

Crossbar Switch

- Crossbar switch connects n inputs to m outputs in a grid, using electronic microswitches (transistors) at each crosspoint
- The major limitation of this design is the number of crosspoints required
- To connect n inputs to m outputs using acrossbar switch requires $n \times m$ crosspoints.
- For example, to connect 1000 inputs to 1000 outputs requires a switch with 1,000,000 crosspoints.

Crossbar Switch

- Crossbar switch [?] with this number of crosspoints is impractical.
- Such a switch is also inefficient because statistics show that, in practice, fewer than 25 percent of the crosspoints are in use at any given time. The rest are idle

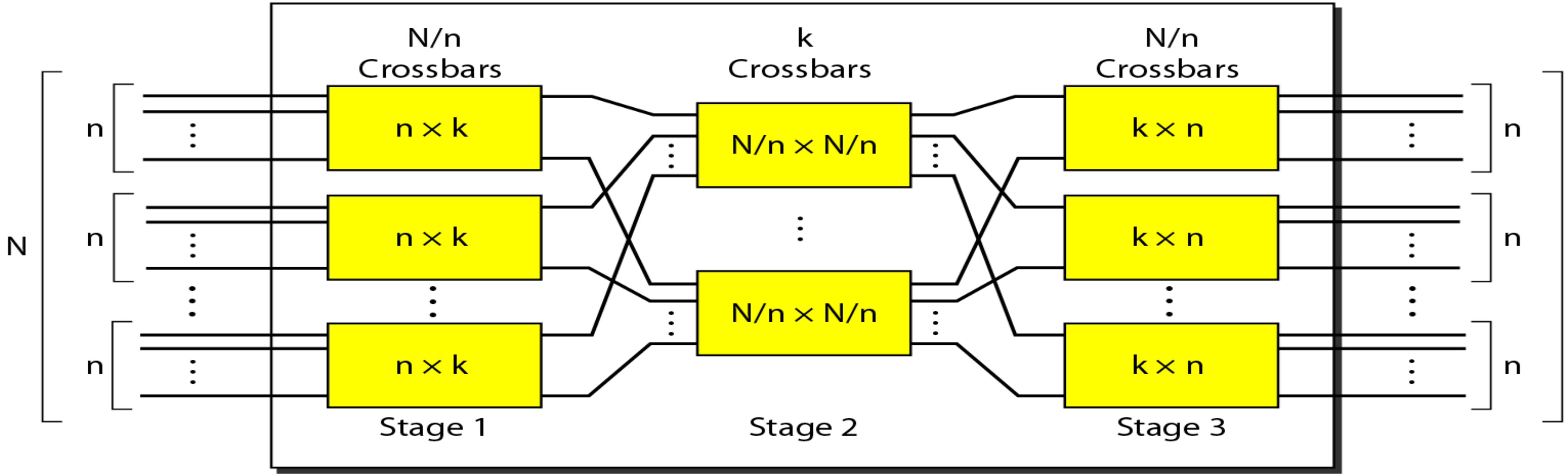


Multistage crossbar switch:

To design a three-stage switch, we follow these steps:

- 1. We divide the N input lines into groups, each of n lines. For each group, we use one crossbar of size $n \times k$, where k is the number of crossbars in the middle stage. In other words, the first stage has N/n crossbars of $n \times k$ cross points.
- 2. We use k crossbars, each of size $(N/n) \times (N/n)$ in the middle stage.
- 3. We use N/n crossbars, each of size $k \times n$ at the third stage.

Multistage Crossbar switch



$$\frac{N}{n}(n \times k) + k\left(\frac{N}{n} \times \frac{N}{n}\right) + \frac{N}{n}(k \times n) = 2kN + k\left(\frac{N}{n}\right)^2$$

Example 8.3

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).

Example 8.4

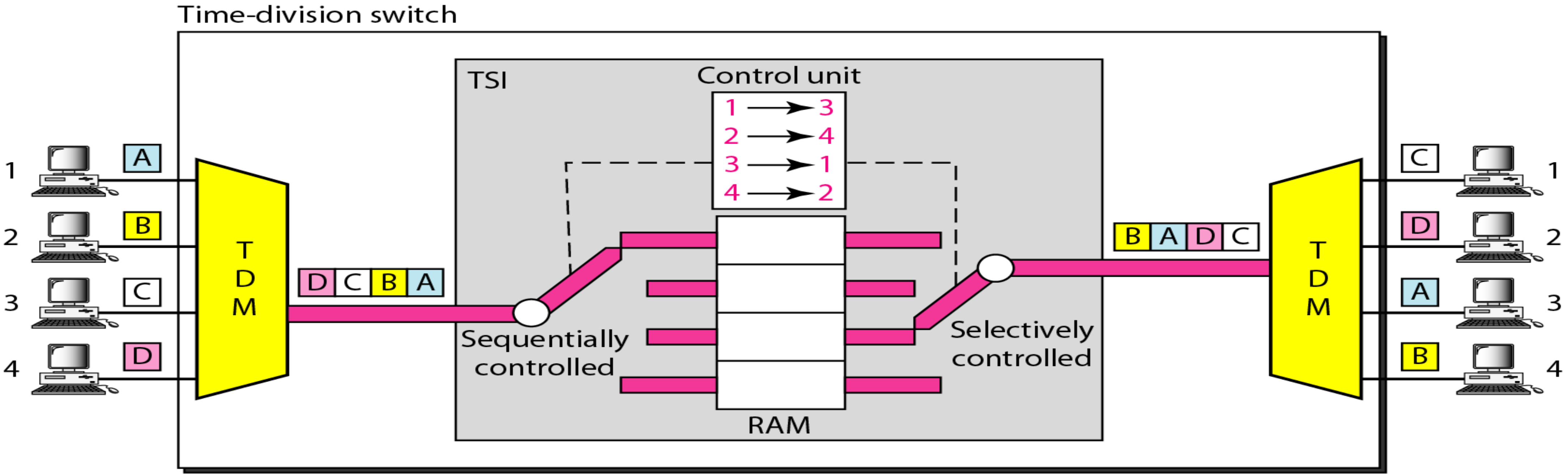
Redesign the previous three-stage, 200 × 200 switch, using the Clos criteria with a minimum number of crosspoints.

Solution

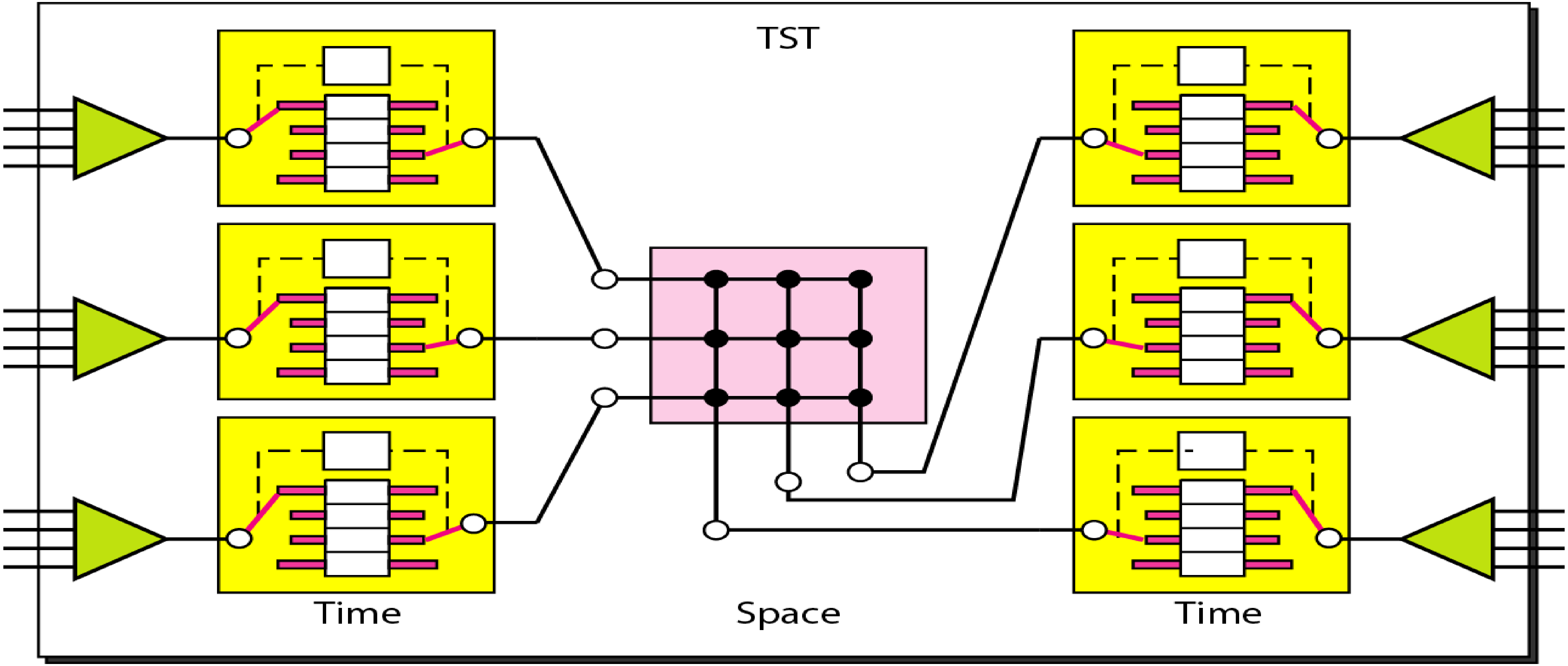
We let $n = (200/2)^{1/2}$, or $n = 10$. We calculate $k = 2n - 1 = 19$. In the first stage, we have 200/10, or 20, crossbars, each with 10 × 19 crosspoints. In the second stage, we have 19 crossbars, each with 10 × 10 crosspoints. In the third stage, we have 20 crossbars each with 19 × 10 crosspoints.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

Time – Division Switch

- Time-division switching uses time-division multiplexing (TDM) inside a switch.
- The most popular technology is called the time-slot interchange (TSI).

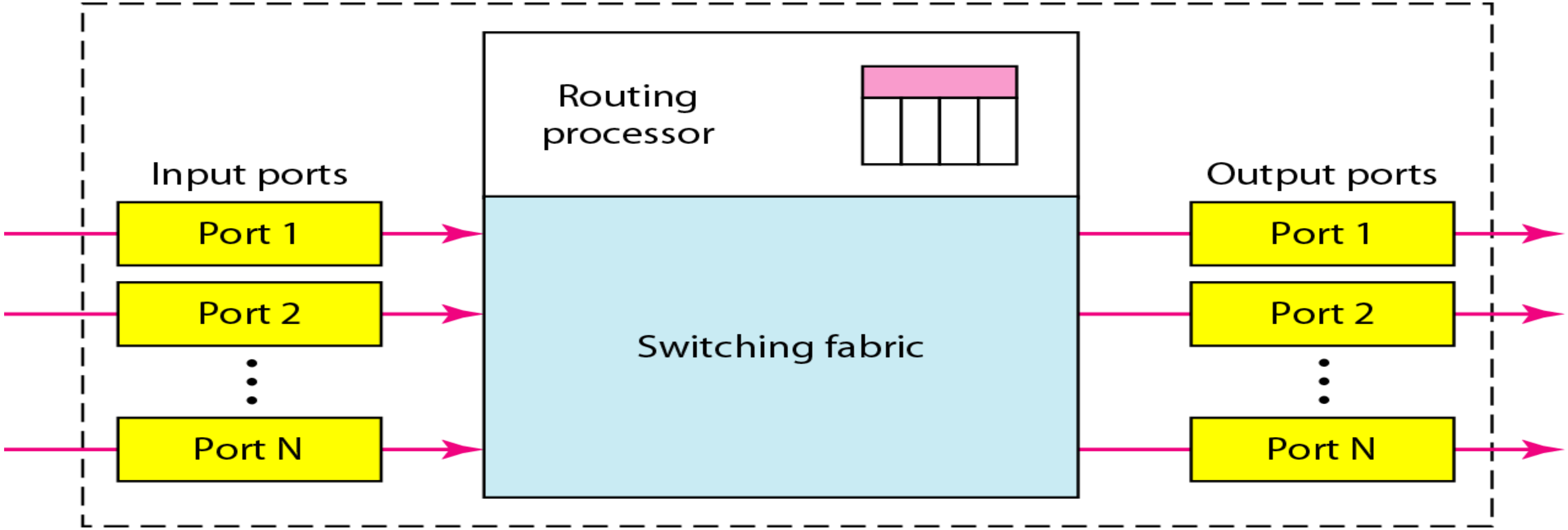


Time-space-time switch



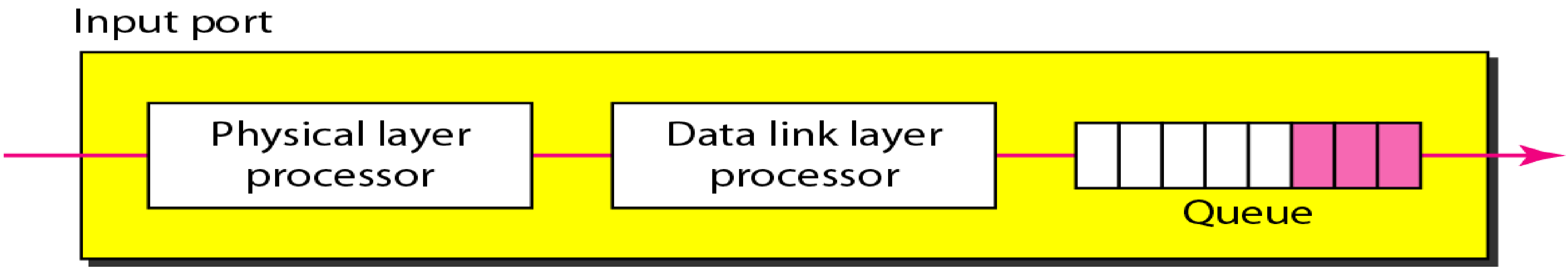
Structure of Packet switch

- A switch used in a packet-switched network has a different structure from a switch used in a circuit-switched network.
- Packet switch has four components: input ports, output ports, the routing processor, and the switching fabric



Structure of Packet switch

- An input port performs the physical and data-link functions of the packet switch.
- The bits are constructed from the received signal.
- The packet is decapsulated from the frame. Errors are detected and corrected.
- The packet is now ready to be routed by the network layer.
- In addition to a physical-layer processor and a data-link processor, the input port has buffers (queues) to hold the packet before it is directed to the switching fabric.



Structure of Packet switch

Routing processor

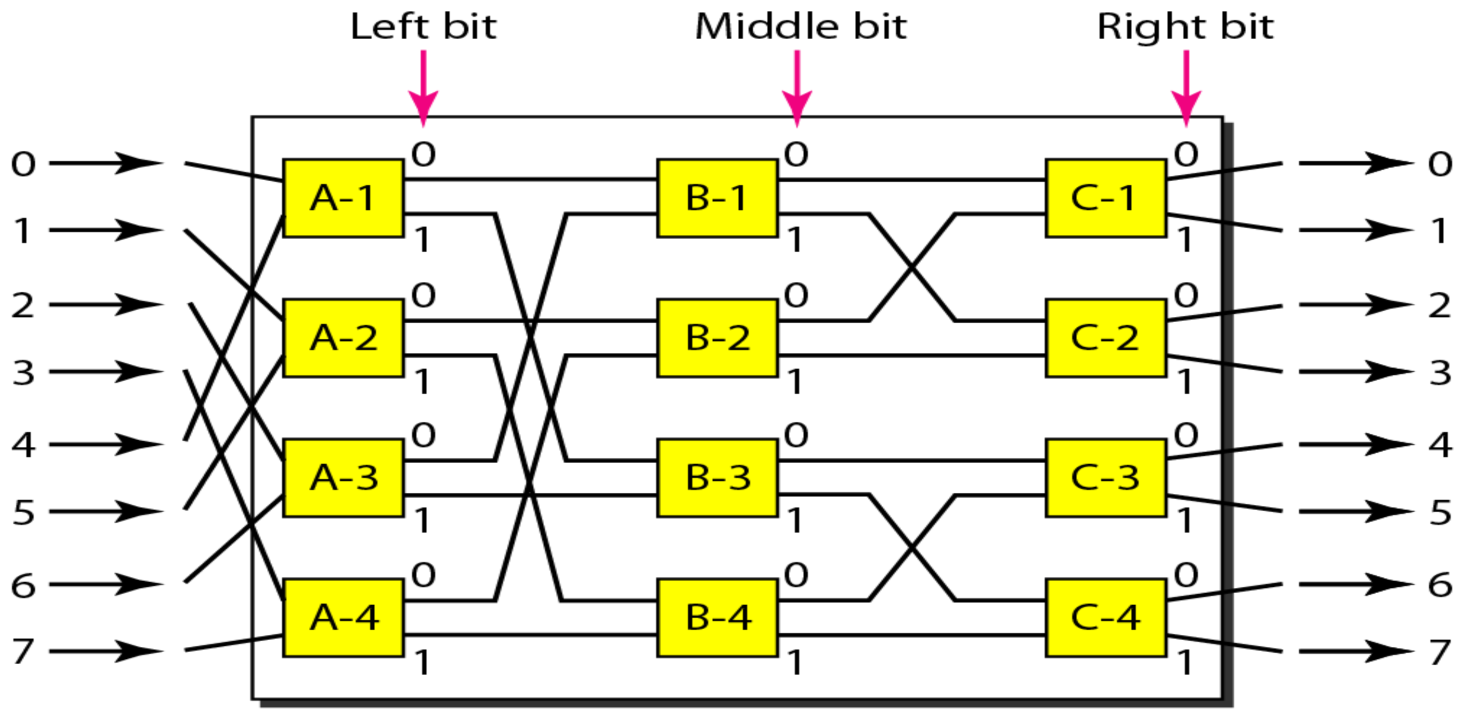
- The routing processor performs the functions of the network layer. The destination
- address is used to find the address of the next hop and, at the same time, the output port number from which the packet is sent out.
- This activity is sometimes referred to as table lookup because the routing processor searches the routing table

Structure of Packet switch

Switching fabrics

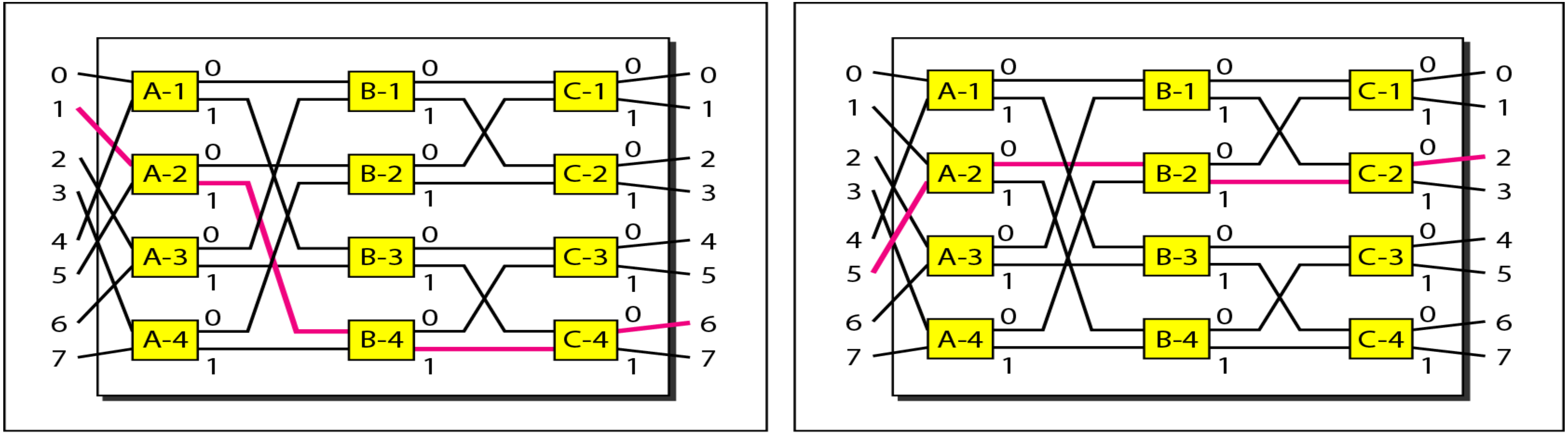
- This activity is sometimes referred to as table lookup because the routing processor searches the routing table
- The most difficult task in a packet switch is to move the packet from the input queue to the output queue.
- The speed with which this is done affects the size of the input/output queue and the overall delay in packet delivery.
- In the past, when a packet switch was actually a dedicated computer, the memory of the computer or a bus was used as the switching fabric.
- The input port stored the packet in memory; the output port retrieved the packet from memory.
- Today, packet switches are specialized mechanisms that use a variety of switching fabrics

A banyan switch – switching fabric



- For n inputs and n outputs, we have log2n stages with n/2 microswitches at each stage.
- The first stage routes the packet based on the high-order bit of the binary string.
- The second stage routes the packet based on the second high-order bit, and so on.

A banyan switch – switching fabric



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

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

Batcher-banyan switch

- The problem with the banyan switch is the possibility of internal collision even when two packets are not heading for the same output port.
- We can solve this problem by sorting the arriving packets based on their destination port.