Data Communications and Networking Fourth Edition

Forouzan

Chapter 8

Switching

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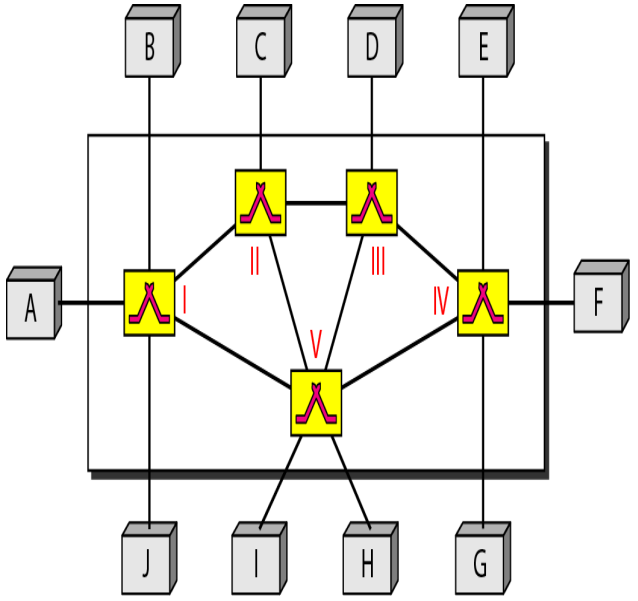
Switched Network

The mechanism for moving data between different computer networks and network segments is called switching.

The end-systems of a computer network are connected to switches, and switches to each other. All network switches perform the following tasks:

- Receive data at their input ports.
- Determine where the data needs to go.
- Move the data to the correct output port.
- Send the data out.



Types of switching elements

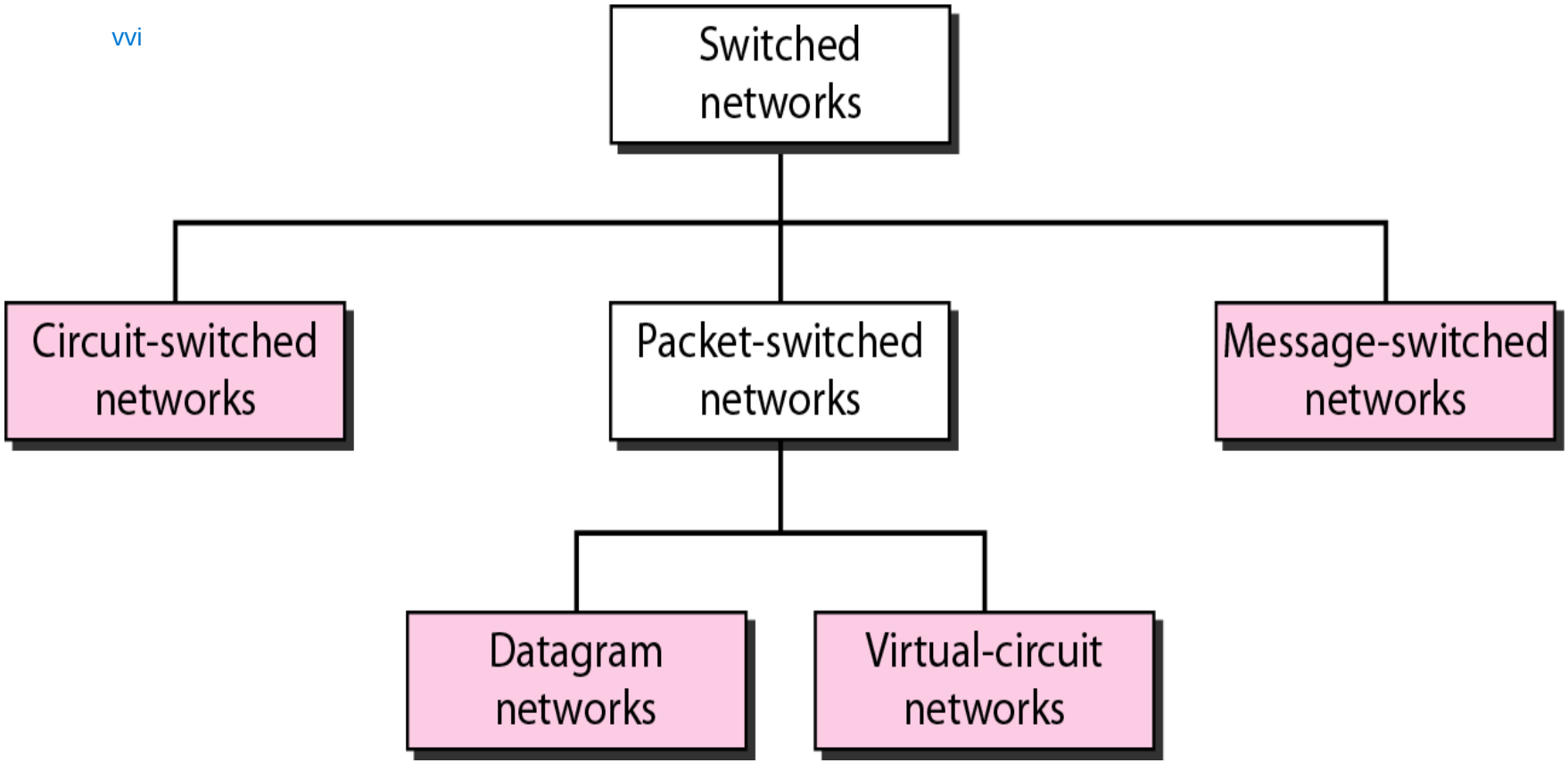
- Telephone switches
  - switch samples
- Datagram routers
  - switch datagrams
- ATM switches
  - switch ATM cells

Other switching element functions

- Participate in routing algorithms
  - to build routing tables
- Resolve contention for output trunks
  - scheduling
- Admission control
  - to guarantee resources to certain streams
- We'll discuss these later
- Here we focus on pure data movement

Taxonomy of Switched Network

vvi



comparison between circuit vs packet vs message

Classification

CT

- Packet vs. circuit switches
  - Data packets (in packet switched networks) have headers and samples (in circuit switched networks) don't have headers.
- Connectionless vs. connection oriented
  - connection oriented switches need a call setup
  - setup is handled in *control plane* by *switch controller*
  - connectionless switches deal with *self-contained* datagrams

	Connectionless (router)	*Connection-oriented (switching system)*
Packet switch	Internet router	ATM switching system
Circuit switch		Telephone switching system

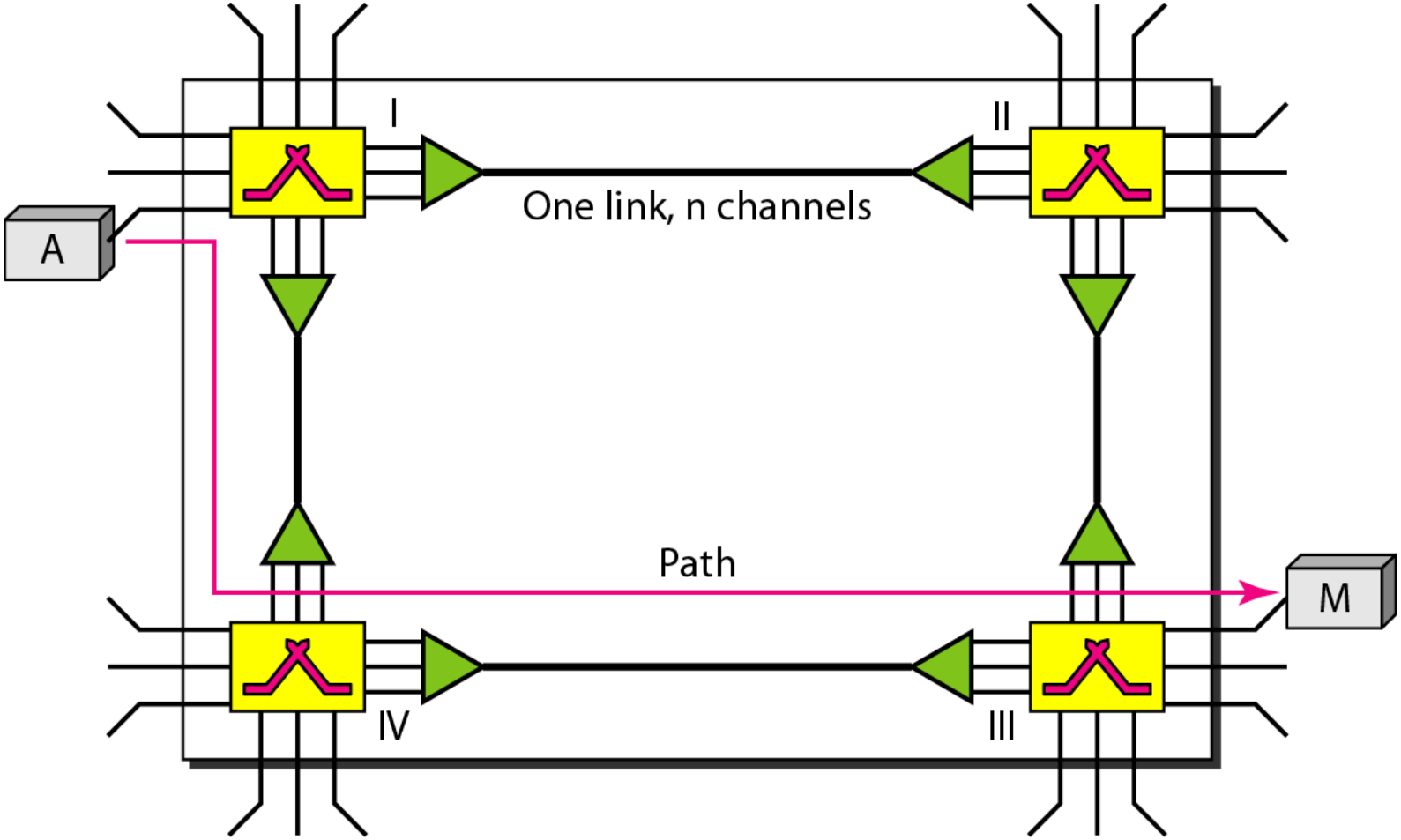
CIRCUIT-SWITCHED NETWORKS

- A circuit-switched network consists of a set of switches connected by physical links, in which each link is divided into n channels using FDM or TDM.

- 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.

- In the traditional telephone network, switching at the physical layer uses the circuit-switching approach.

Fig. 1(8.3): A circuit-switched network



A circuit switch

- A switch that can handle N calls has N logical inputs and N logical outputs
  - N up to 200,000
- In practice, input trunks are multiplexed
  - example: DS3 trunk carries 672 simultaneous calls
- Multiplexed trunks carry *frames* = set of samples
- Goal: extract samples from frame, and depending on position in frame, switch to output
  - each incoming sample has to get to the right output line and the right slot in the output frame
  - demultiplex, switch, multiplex

Example of a circuit-switched network

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.

Fig. 2 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.

Fig. 2: Circuit-switched network (used in previous Example)

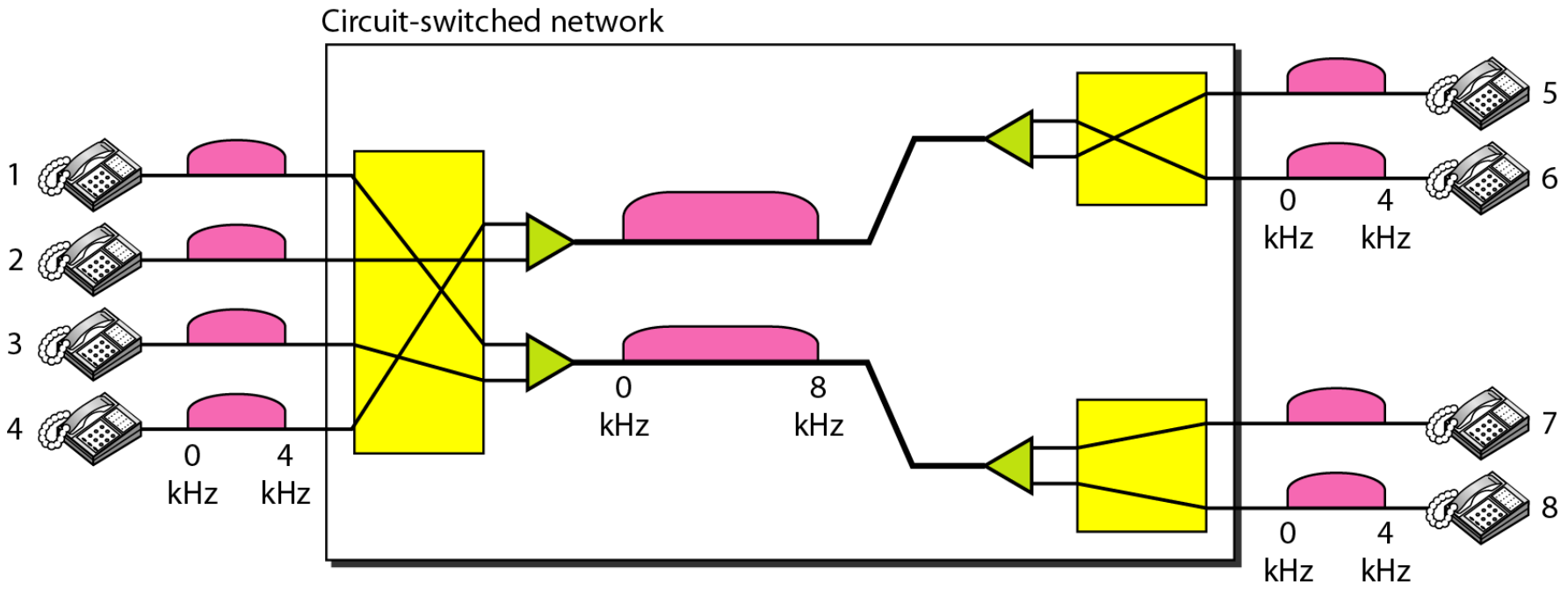
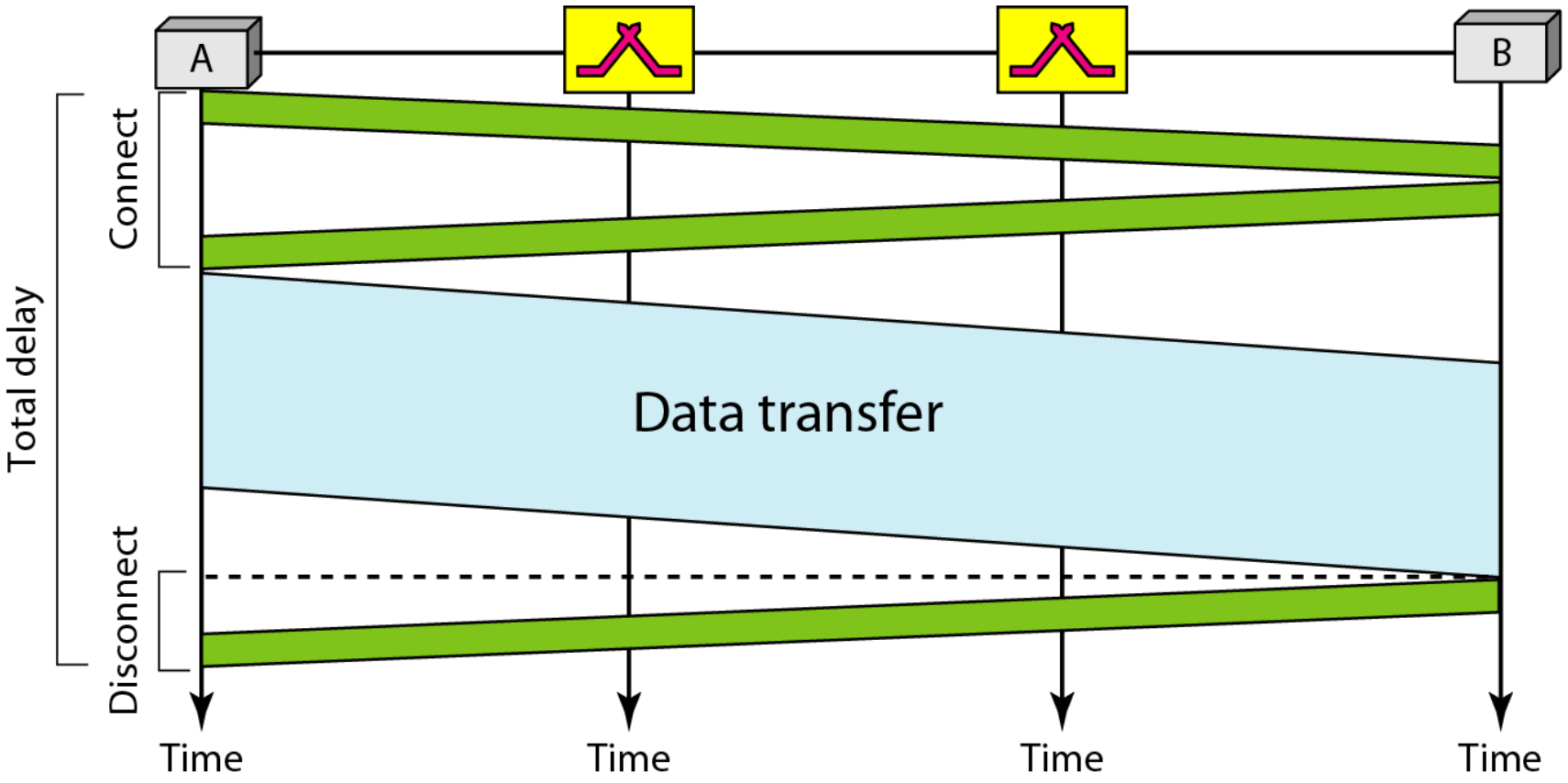


Fig. 2: Circuit-switched network connection setup

- The actual communication in a circuit-switched network requires three phases:
  - Connection setup,
  - Data transfer, and
  - Connection teardown.
- Connection setup means creating dedicated channels between the switches.
- After the establishment of the dedicated circuit (channels), the two parties can transfer data.
- When one of the parties needs to disconnect, a signal is sent to each switch to release the resources.

Fig. 3: Delay in a circuit-switched network

VVI



PACKET SWITCHED NETWORKS :DATAGRAM NETWORKS

In data communications, we need to send messages from one end system to another.

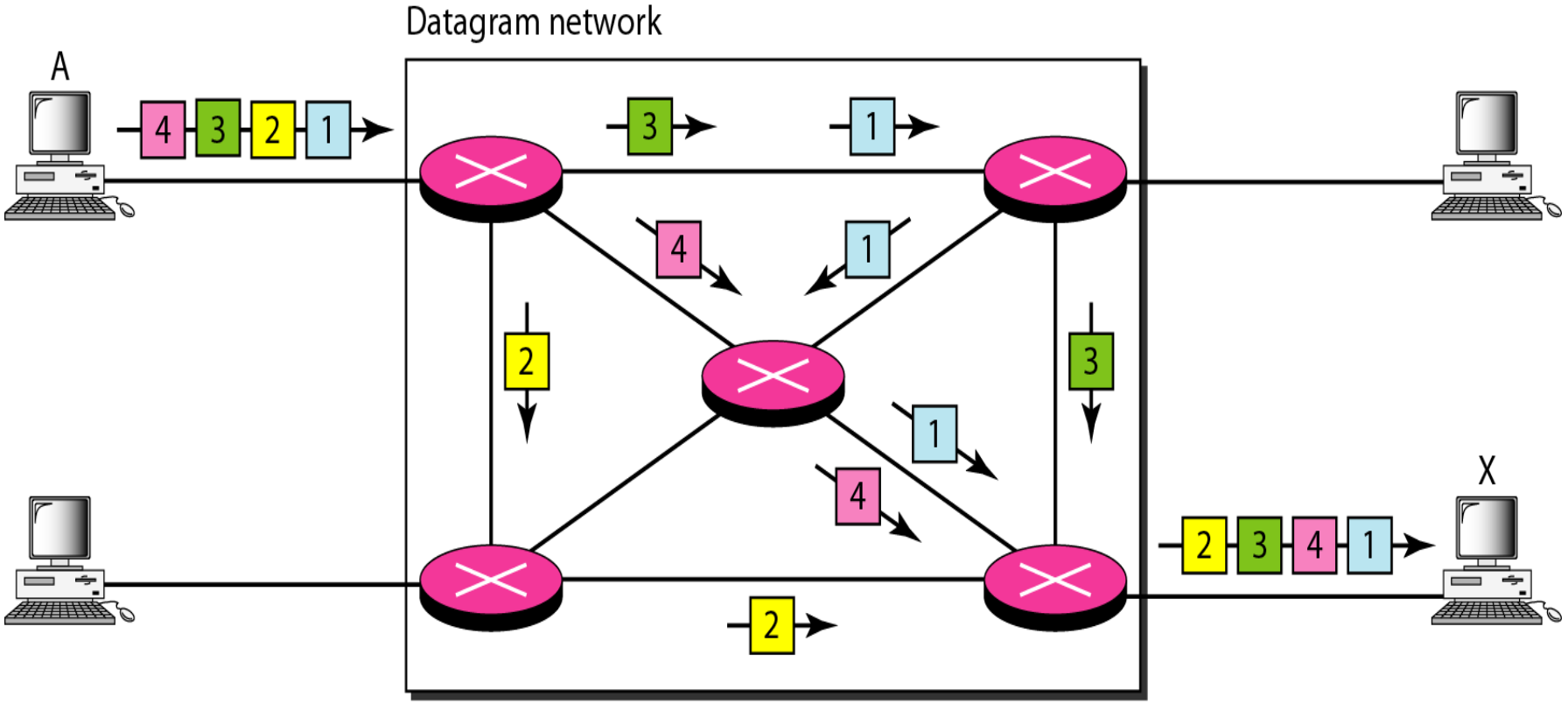
If the message is going to pass through a packet-switched network, it needs to be divided into packets of fixed or variable size.

The size of the packet is determined by the network and the governing protocol.

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

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

Fig. 4: A datagram network with four switches (routers)



- Connectionless network
- Perform operation at network layer
- The efficiency of a datagram network is better than that of a circuit-switched network
- The Internet has chosen the datagram approach to switching at the network layer. It uses the universal addresses defined in the network layer to route packets

Routing table in a datagram network

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

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

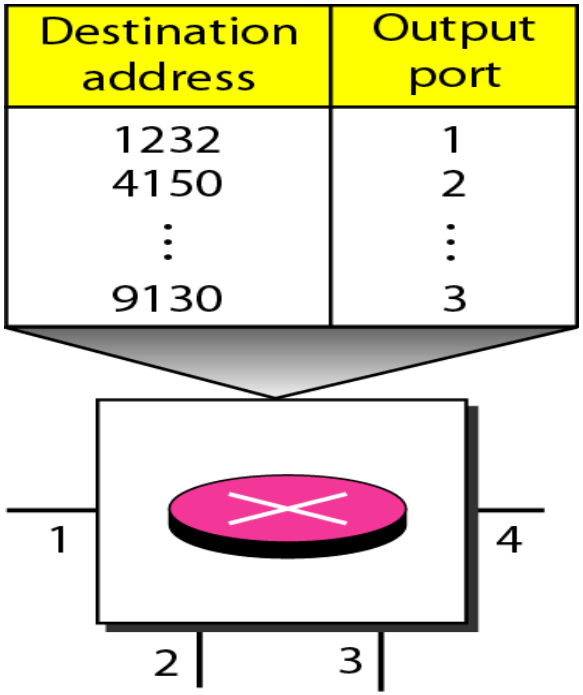
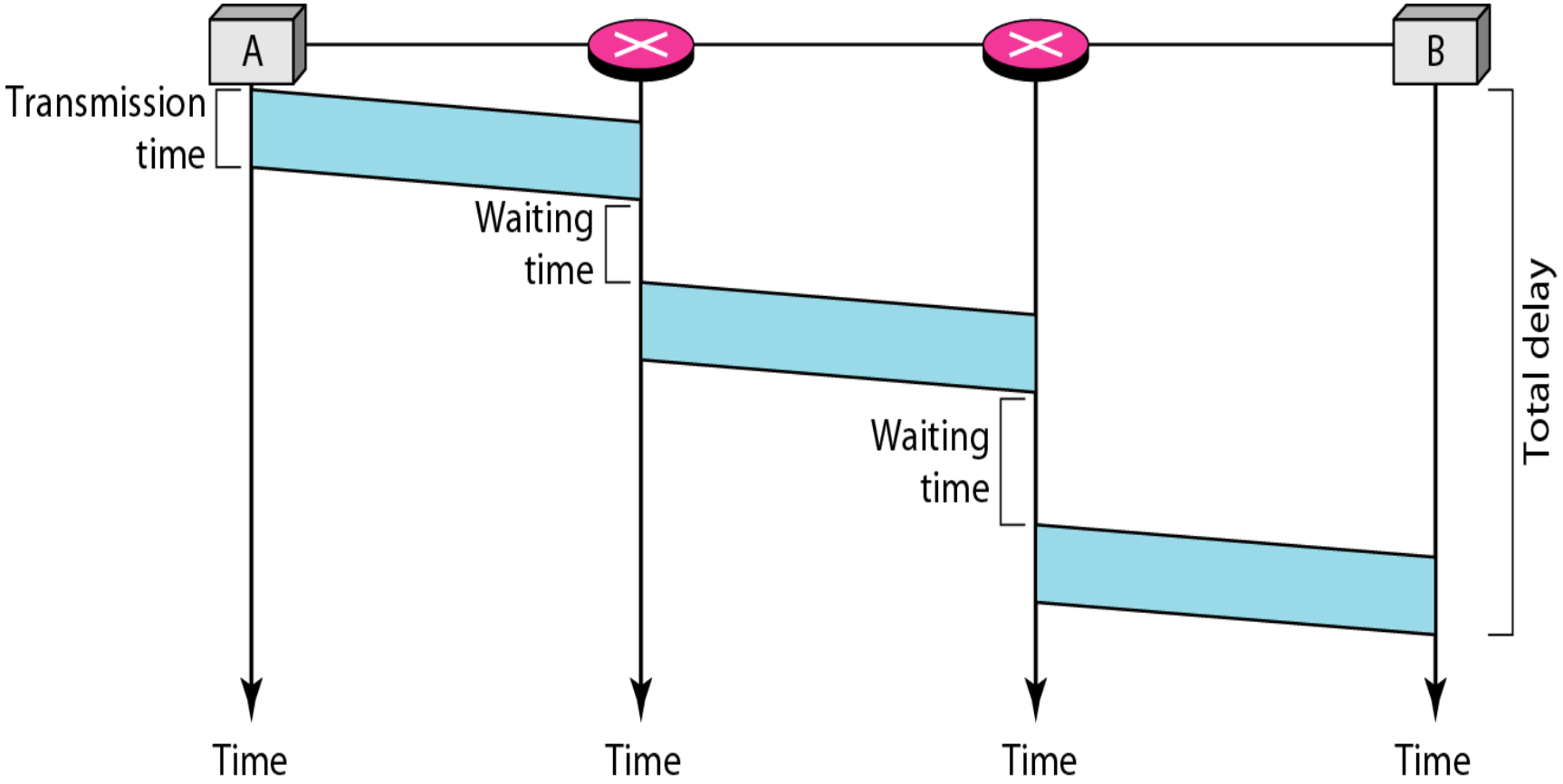


Fig. 5: Delay in a datagram network



- The packet travels through two switches. There are three transmission times (3*T*), three propagation delays (slopes 3τ of the lines), and two waiting times (*w*1 + *w*2). We ignore the processing time in each switch. The total delay is

$$3T + 3\tau + w1 + w2$$

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

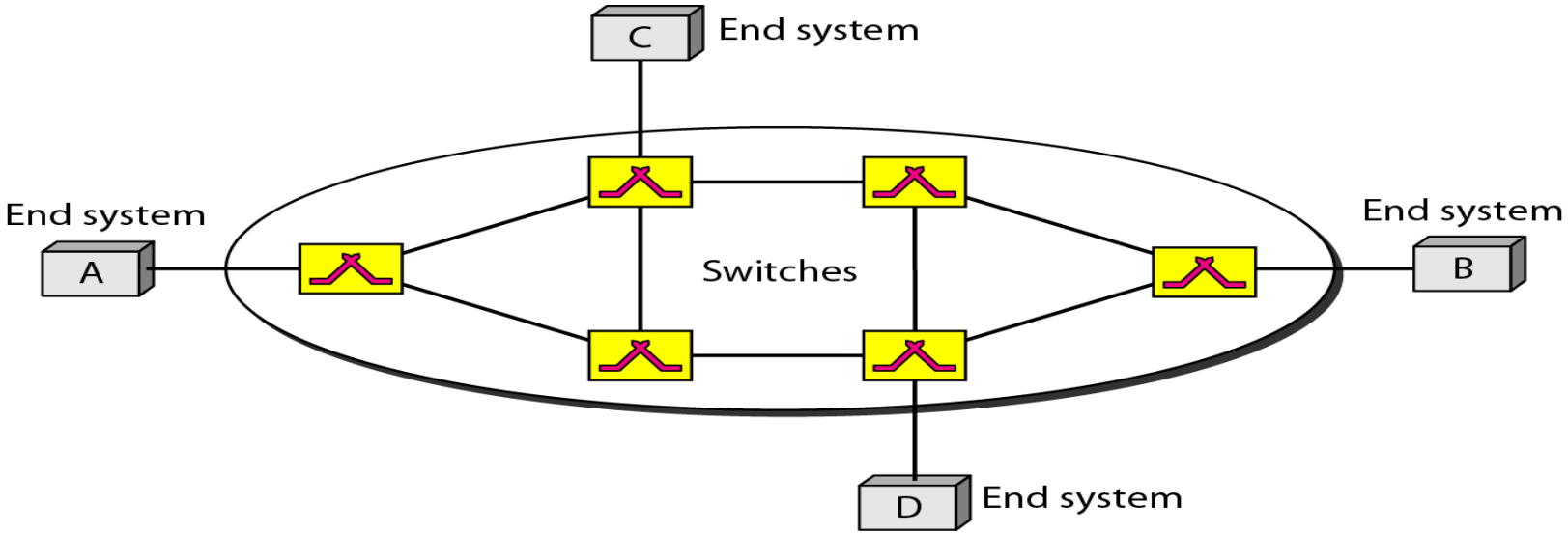
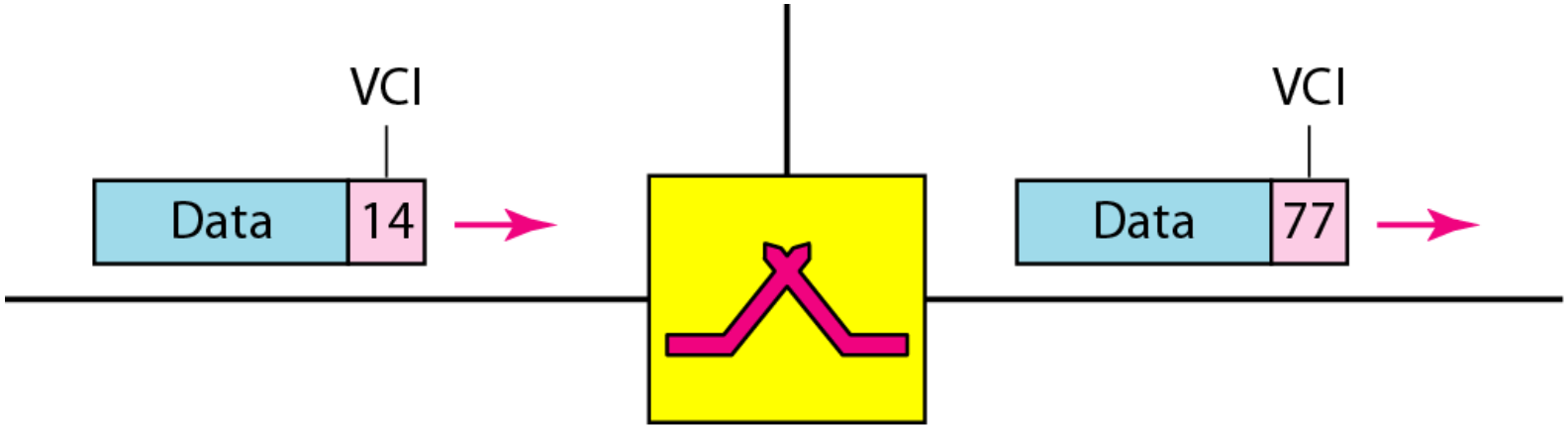


Fig. 6: Virtual-circuit identifier in a VCN

- Virtual circuit identifier(VCI) used for data transfer and act as global address.
- 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.



The overall operation takes three phases**, Setup, data transfer, teardown**

- **Setup Phase** -In the setup phase, a switch creates an entry for a virtual circuit. Two steps are required: the **setup request** and the **acknowledgment.**
  - ***Setup Request -*** A setup request frame is sent from the source to the destination. See Figure 8.13 I book.
  - ***Acknowledgment -*** A special frame, called the acknowledgment frame, completes the entries in the switching tables.

Setup Request Phase

- A setup request frame is sent from source A to destination B.
- Source A sends a setup frame to switch 1.
- Switch 1 receives the setup request frame and it knows that a frame is going from A to B via port 3.

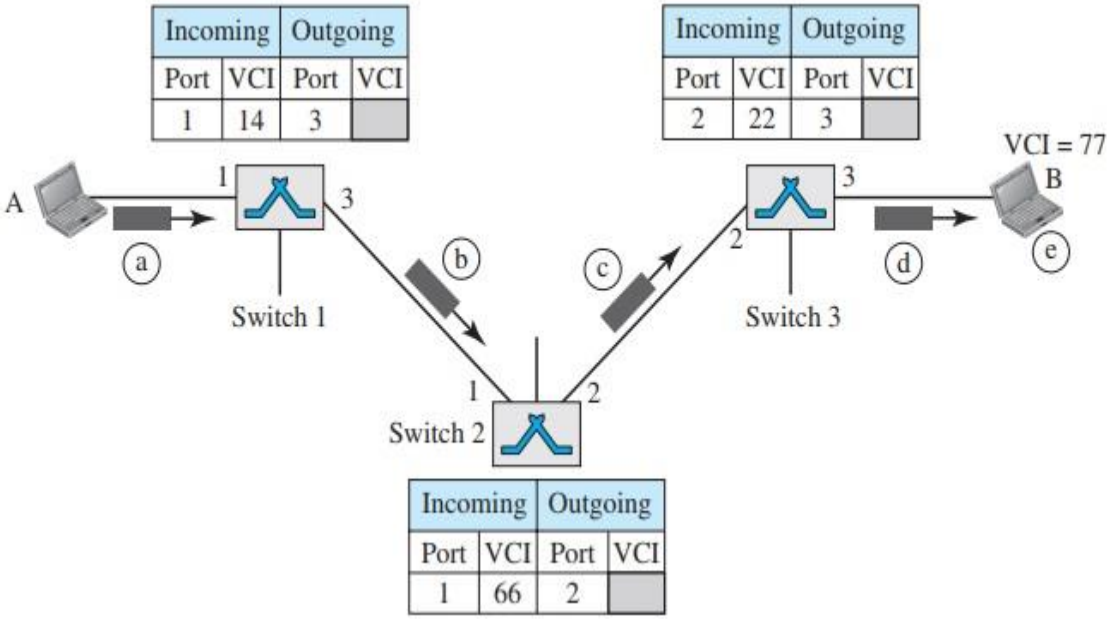


Fig. : Setup Request in a virtual-circuit network

- The incoming port number, VCI, and outgoing port number is known but outgoing VCI is unknown and it will fill up in the acknowledgement step.
- The switch 1,2, and 3 receives the setup request frame and finally destination B received the setup frame. If B ready to receive the frame it assigns a VCI to the incoming frames that comes from A, and it is 77.
- This VCI lets the destination know that the frames comes from A.

Acknowledgement Phase

- A special frame called the acknowledgement frame completes the entries in the switching tables.
- The destination B sends an acknowledgement to switch 3.
- The acknowledgement carries the global source and destination address to complete the table entry.

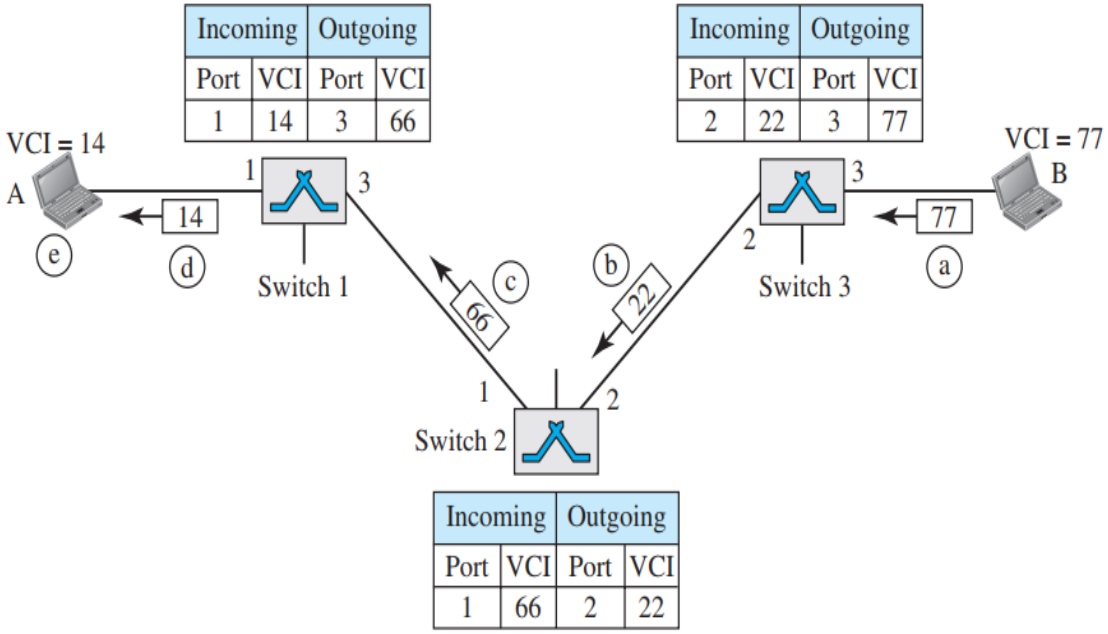


Fig. : Setup Acknowledgement phase in a virtual-circuit network

- The frame also carries VCI 77, chosen by the destination as the incoming VCI for frames from A.
- The switch 3,2, and 1 receives the acknowledgement frame and finally source A received the acknowledgement frame.
- The source A then uses this outgoing VCI to transmit data frames to the destination B.

Data Transfer Phase

- To Transfer a frame from S-> D, all switches need to have a table of virtual circuit.
- In table of figure, a frame arriving at port 1 with VCI 14 will forwarded to port 3 with VCI 22 and
- A frame arriving at port 1 with VCI 77 will forwarded to port 2 with VCI 41.
- Moreover, the next slide figure represents the frame transmission from source A to destination B where VCI changes during the trip.

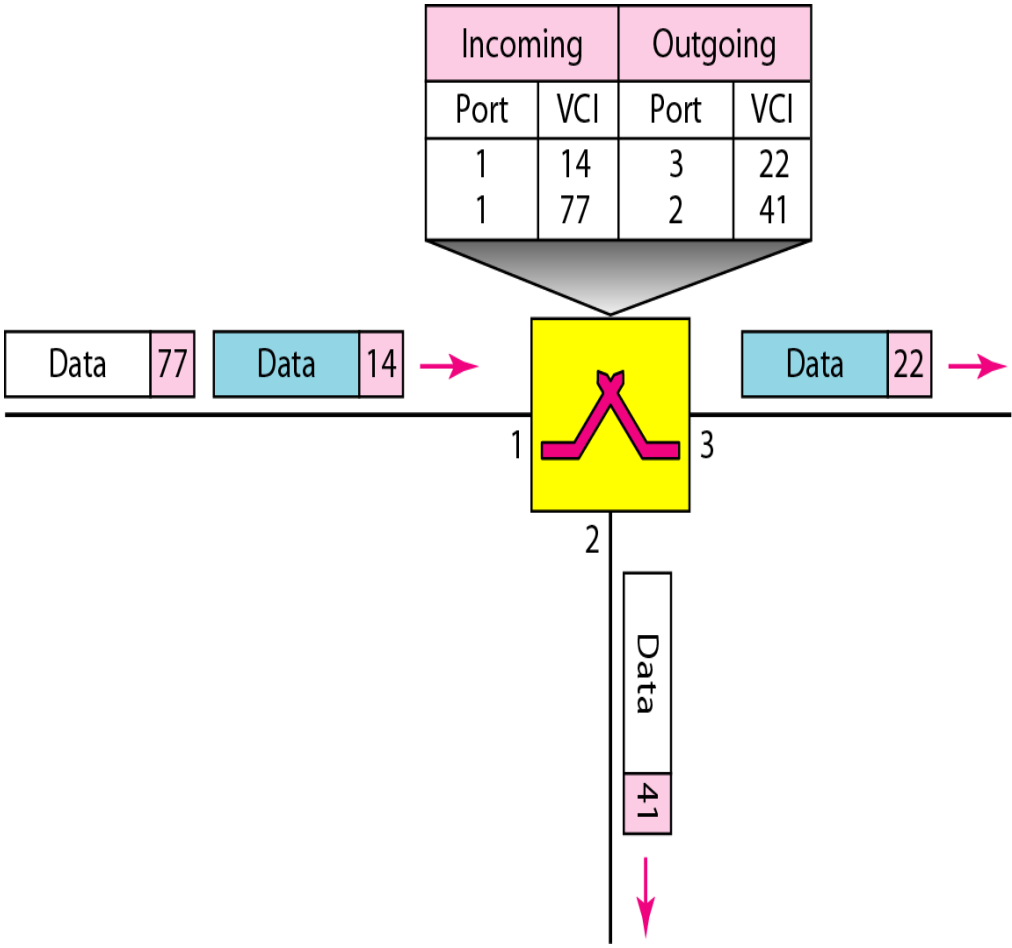


Fig. : Switch and tables in a virtual-circuit network

Data Transfer Phase(Con..

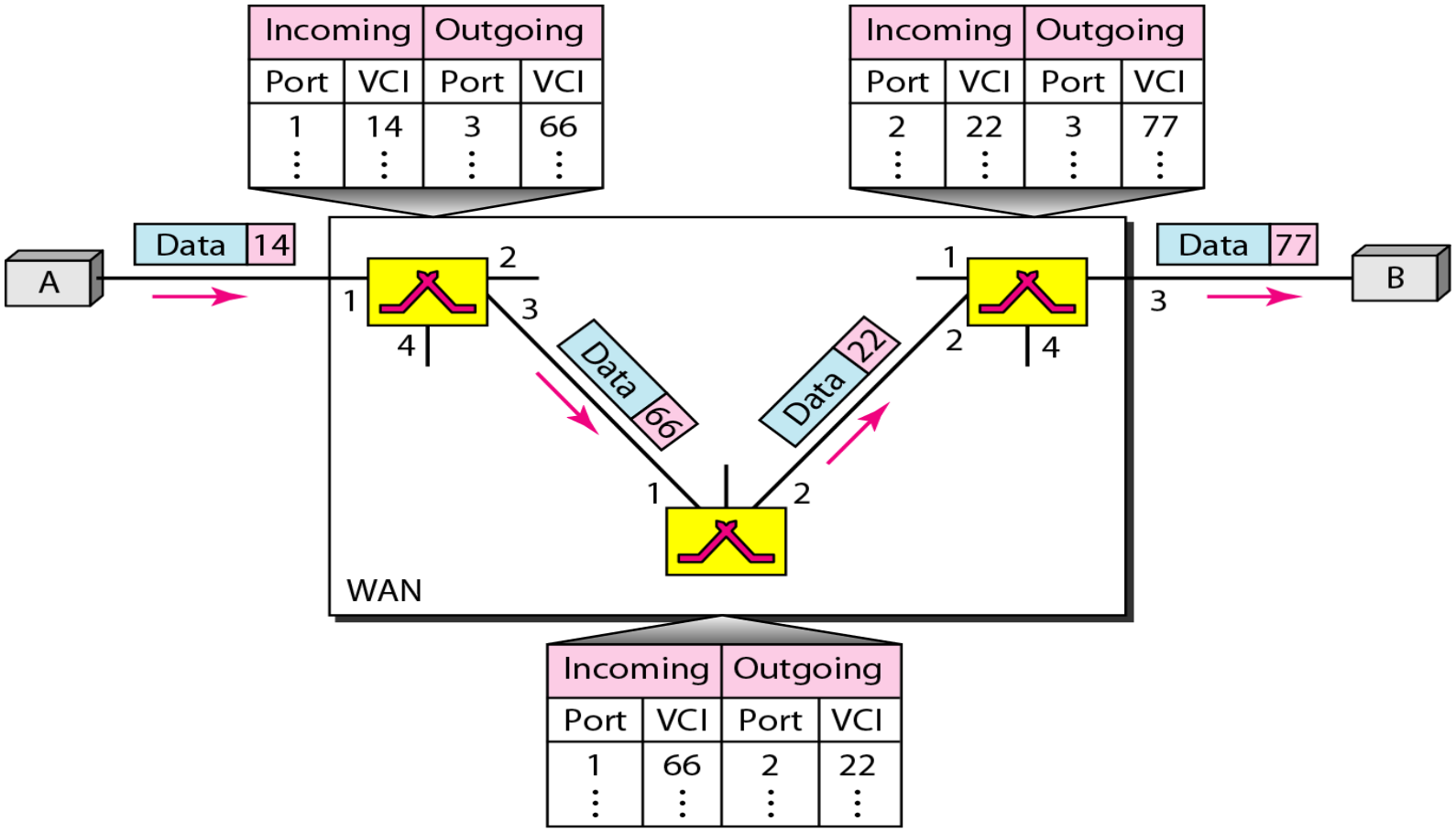


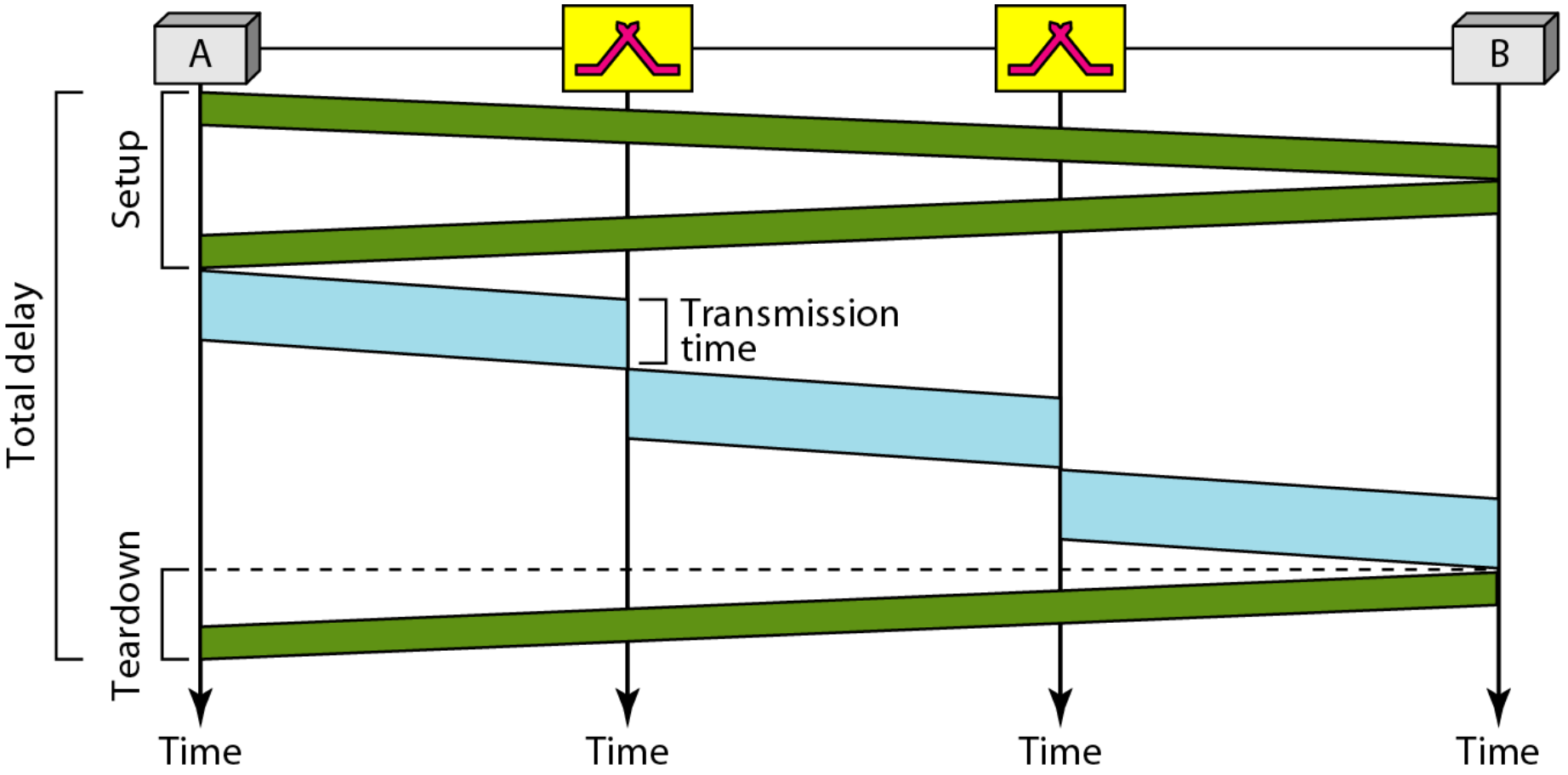
Fig. : Source-to-destination data transfer in a VCN

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

- In 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.

Fig. 9: Delay in a virtual-circuit network



The packet is traveling through two switches (routers). There are three transmission times (3T), three propagation times (3τ), data transfer depicted by the sloping lines, a setup delay (which includes transmission and propagation in two directions), and a teardown delay (which includes transmission and propagation in one direction). We ignore the processing time in each switch. The total delay time is

$$3T + 3\tau + \text{setup delay} + \text{teardown delay}$$

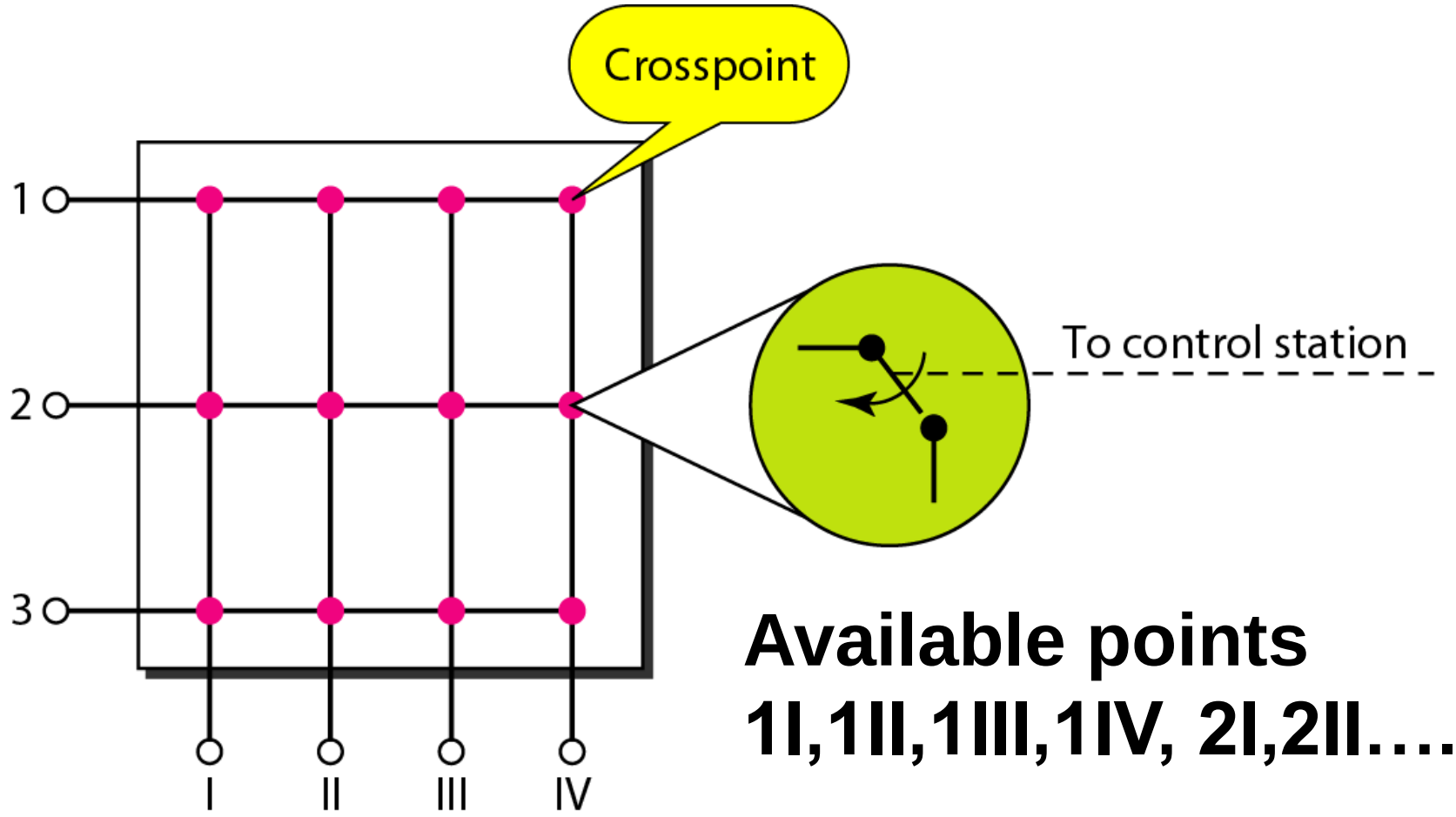
Repeaters, Bridges, Routers, & Gateways

- Repeaters: at physical level
- Bridges: at datalink level (based on MAC addresses) (L2)
  - discover attached stations by listening
- Routers: at network level (L3)
  - participate in routing protocols
- Application level gateways: at application level (L7)
  - treat entire network as a single hop
- Gain functionality at the expense of forwarding speed
  - for best performance, push functionality as low as possible

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.
- 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

Fig. 10: Crossbar switch(with three inputs and four outputs)



Available points
1I,1II,1III,1IV, 2I,2II…..

Crossbar switch

- Simplest possible space-division switch
- Connects n inputs to m outputs in a grid, using electronic microswitches at each crosspoint.
- Every input port has a connection with each output port.
- *Crosspoints* can be turned on or off
- To connect n inputs to m outputs using a crossbar switch requires n × m crosspoints.
- For multiplexed inputs, need a switching *schedule (randomized scheduling algorithm)*
- In practice, fewer than 25 percent of the crosspoints are in use at any given time. The rest are idle.

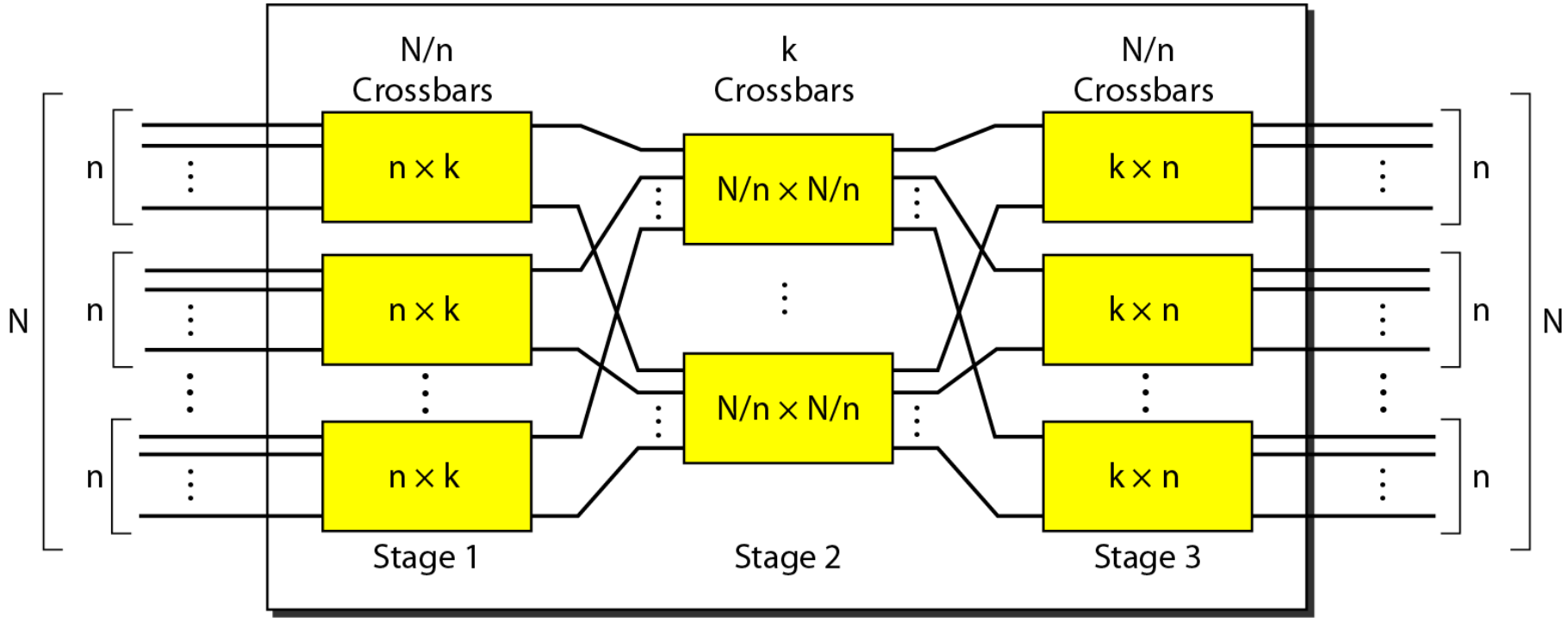
Multistage crossbar

- In a crossbar during each switching time only one crosspoint per row or column is active
- Can save crosspoints if a crosspoint can attach to more than one input line
- This is done in a multistage crossbar
- Need to rearrange connections every switching time

Multistage switch

- Usually consider three stage as multistage switch.
- From NxN crossbar switch, if we allow multiple paths inside the switch, that can decrease the number of crosspoint.
- Divide the N input lines into n groups.
- For each group, use one crossbar of size nxk, where k is the number of crossbar in the middle stage.
- The first stage has N/n crossbar of nxk crosspoint.
- The middle stage is k crossbar of (N/n)x(N/n) crosspoints and
- Similarly from the first stage, the third stage has N/n crossbar of kxn crosspoint.

Multistage switch



So the total crosspoints can be calculated as:

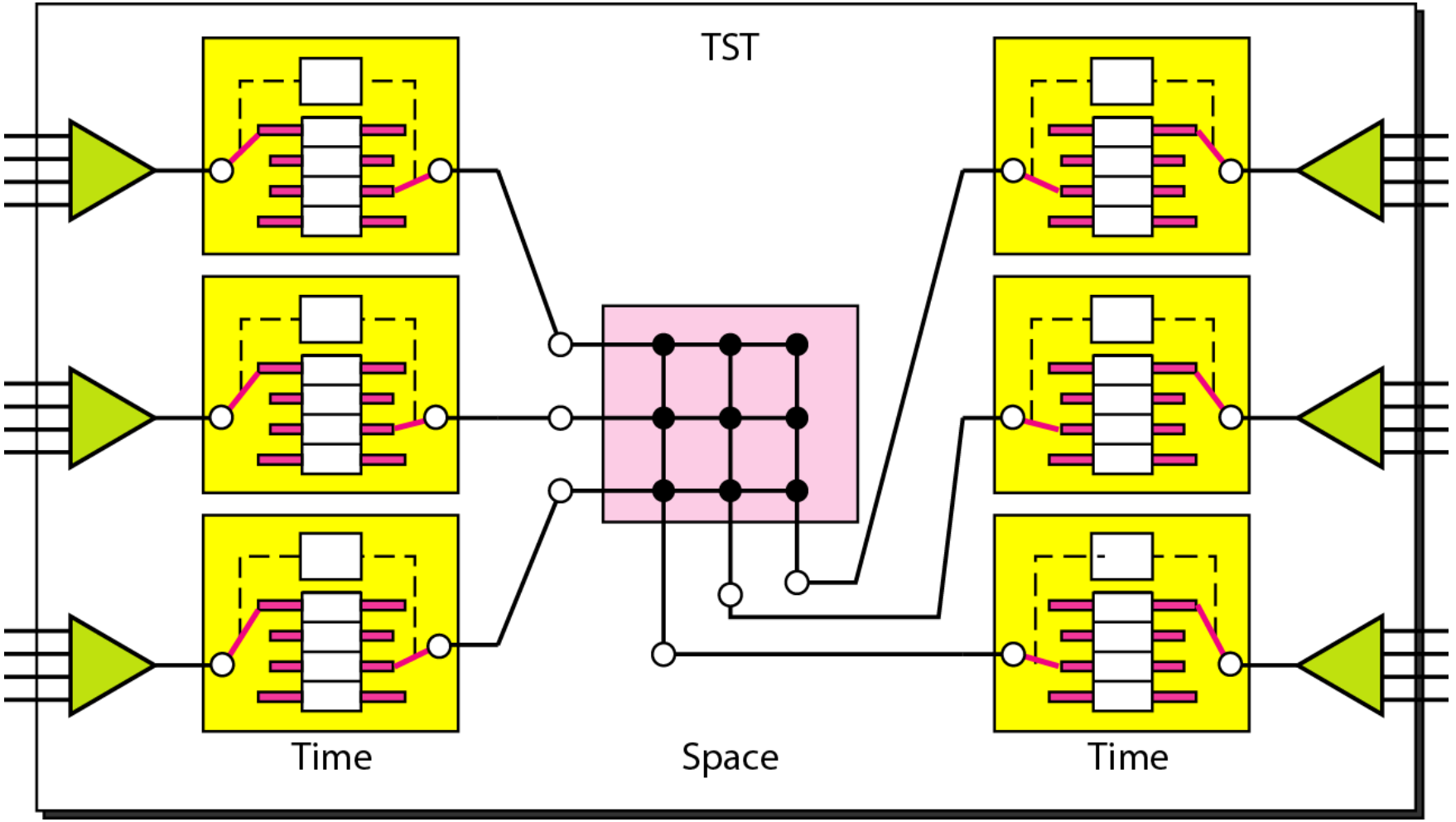
$$\frac{N}{n}(nxk) + k\left(\frac{N}{n}x\frac{N}{n}\right) + \frac{N}{n}(kxn)$$

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).

Time-space-Time switch

- The advantage of time-division switching is that it needs no crosspoints but added delay due to processing each connection.
- Space-division switching is instantaneous but the number of crosspoints required to make the space-division switching acceptable in terms of blocking.
- To combine both, physically(number of crosspoint) and temporally(amount of delay), multistage switch can be designed as time-space-time (TST) switch.

Figure Time-space-time (TST) switch



Time-space-time (TST) switching

- A simple Time-space-time switching that consists of two time stages and one space stages.
- It has 12 inputs and 12 outputs.
- The time-division switch divides the inputs into three group of four input each and directs them to three time slot interchanges.
- This results the one-third of the average delay to handle all 12 inputs.


Thank You