Chapter 8: Switching

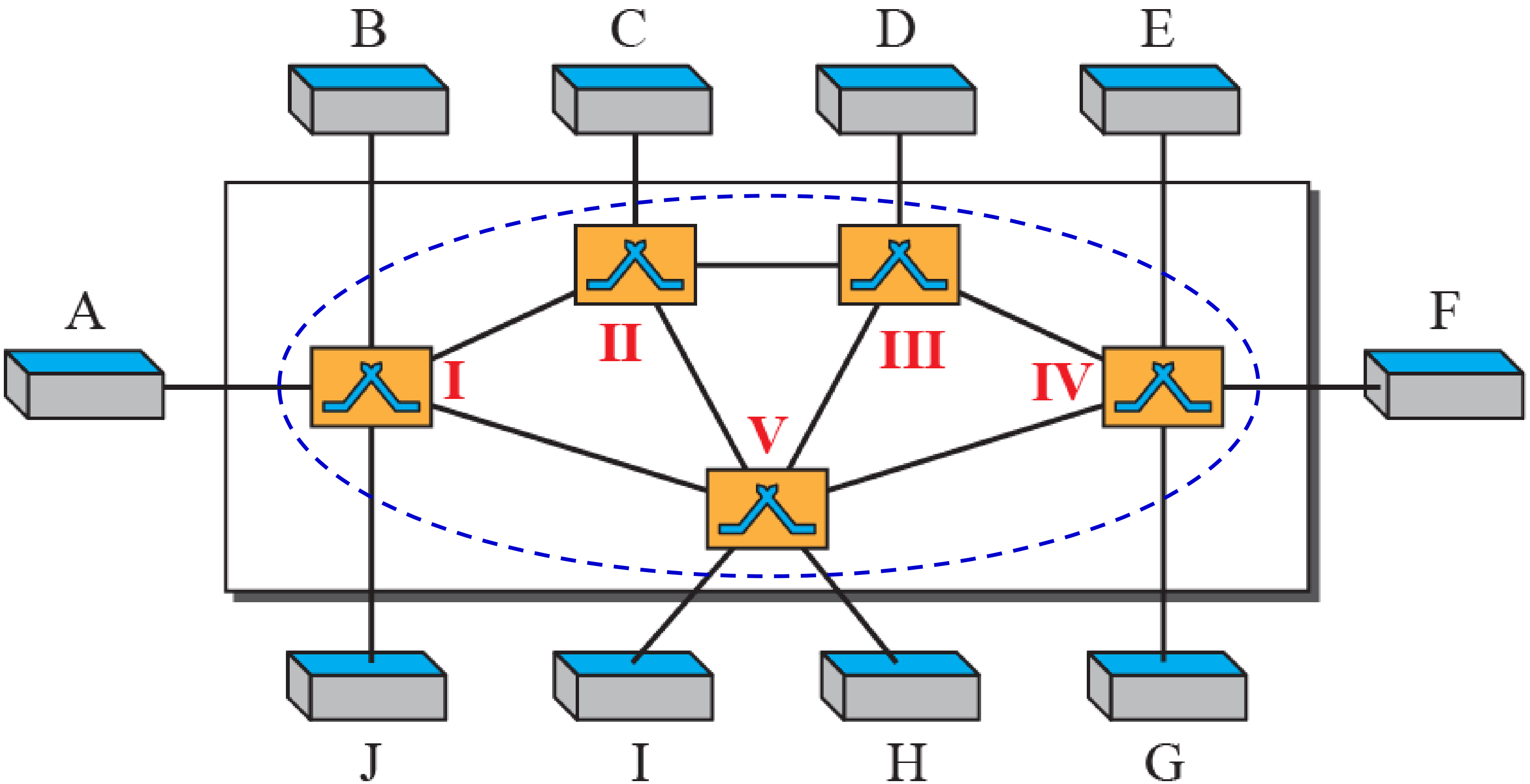
Outline

8-1 INTRODUCTION

A network is a set of connected devices. Whenever we have multiple devices, we have the problem of how to connect them to make one-to-one communication possible. The 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.

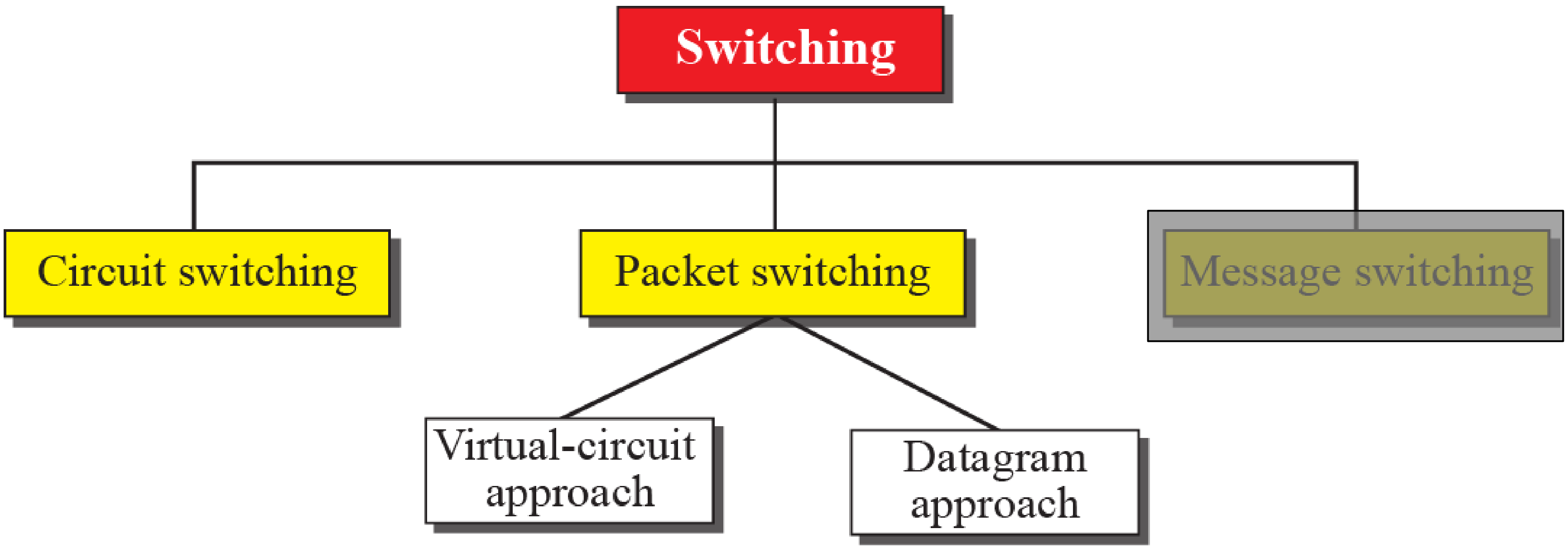
Figure 8.1: Switched network



Switches I, II, III, IV, V are devices capable of creating temporary connections between two or more devices linked to the switch.

8.1.1 Three Methods of Switching

Traditionally, there are three methods of switching: circuit switching, packet switching and message switching. Packet switching can further be divided into two subcategories: <u>datagram approach</u> and <u>virtual-circuit approach</u>.



8.1.2 Switching and TCP/IP Layers

<u>Circuit switching</u> and <u>packet switching</u> are <u>commonly used</u> today. <u>Message switching</u> has been <u>phased out</u> in general communications but still has networking applications.

Switching can happen at <u>several layers</u> of the TCP/IP protocol suite:

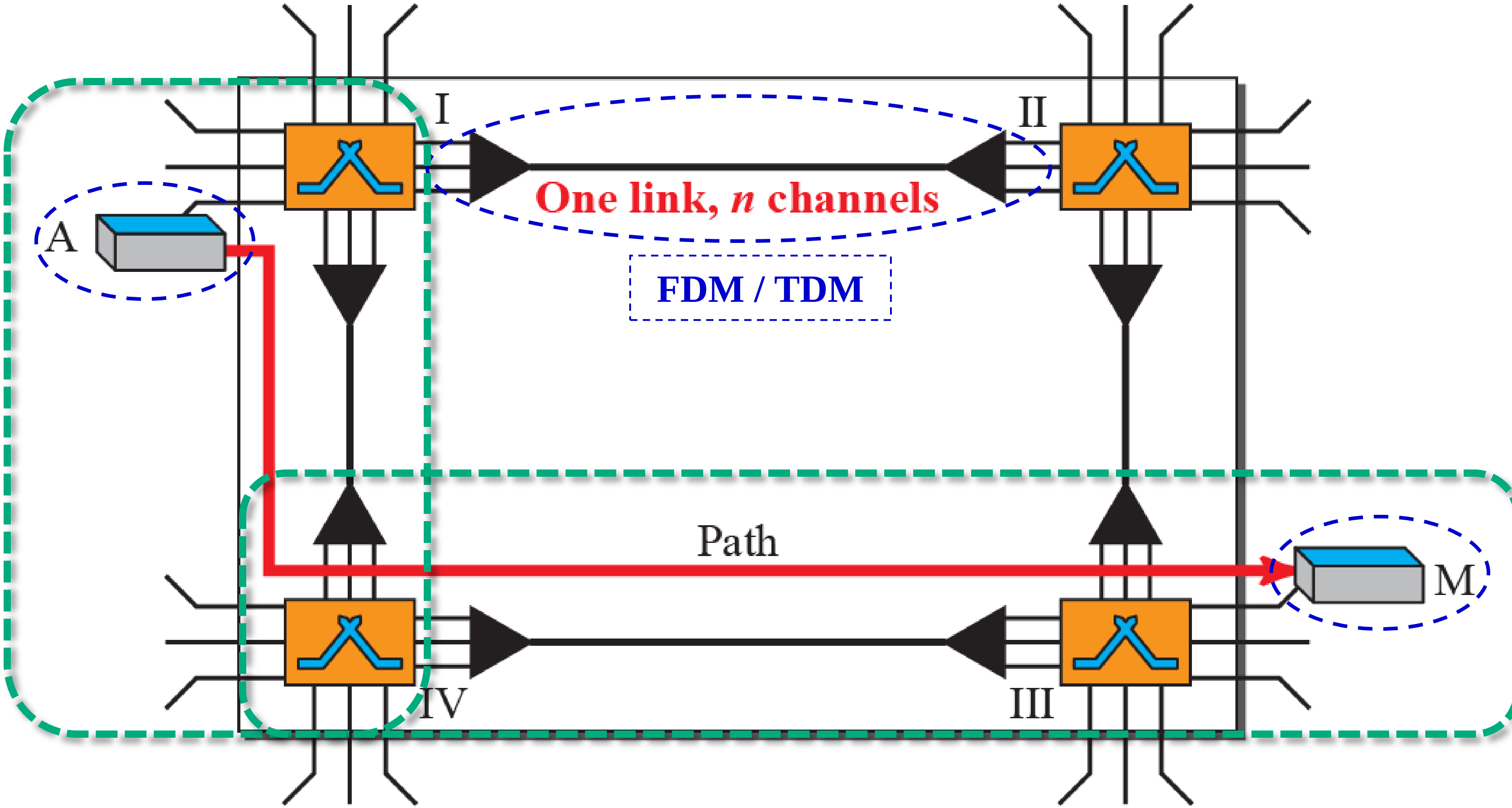
- ***Physical layer: <u>circuit switching</u>***
- ***Data link layer: <u>packet (frame/cell) switching</u>***
- ***Network layer: <u>packet switching</u>***
- ***Application layer: <u>message switching</u>***

8-2 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.

A connection between two stations is a dedicated path made of one or more links. Each connection uses a dedicated channel on each link. Each link is normally divided into n channels by using FDM or TDM.

Figure 8.3: A trivial circuit-switched network



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

8.2.1 Three Phases

The actual communication in a circuit-switched network requires three phases: (1) connection setup, (2) data transfer and (3) connection teardown:

(1) Connection Setup: Before the entities can communicate, a <u>dedicated circuit</u> needs to be <u>established</u>. Note that end-to-end addressing (e.g., telephone numbers) is required for creating a connection between the two end systems.

(2) Data Transfer: After the establishment of the dedicated circuit, the two entities can <u>transfer data</u>.

(3) Connection Teardown: When one of the entities needs to <u>disconnect</u>, a signal is sent to each switch to <u>release</u> the <u>resources</u>.

8.2.2 Efficiency

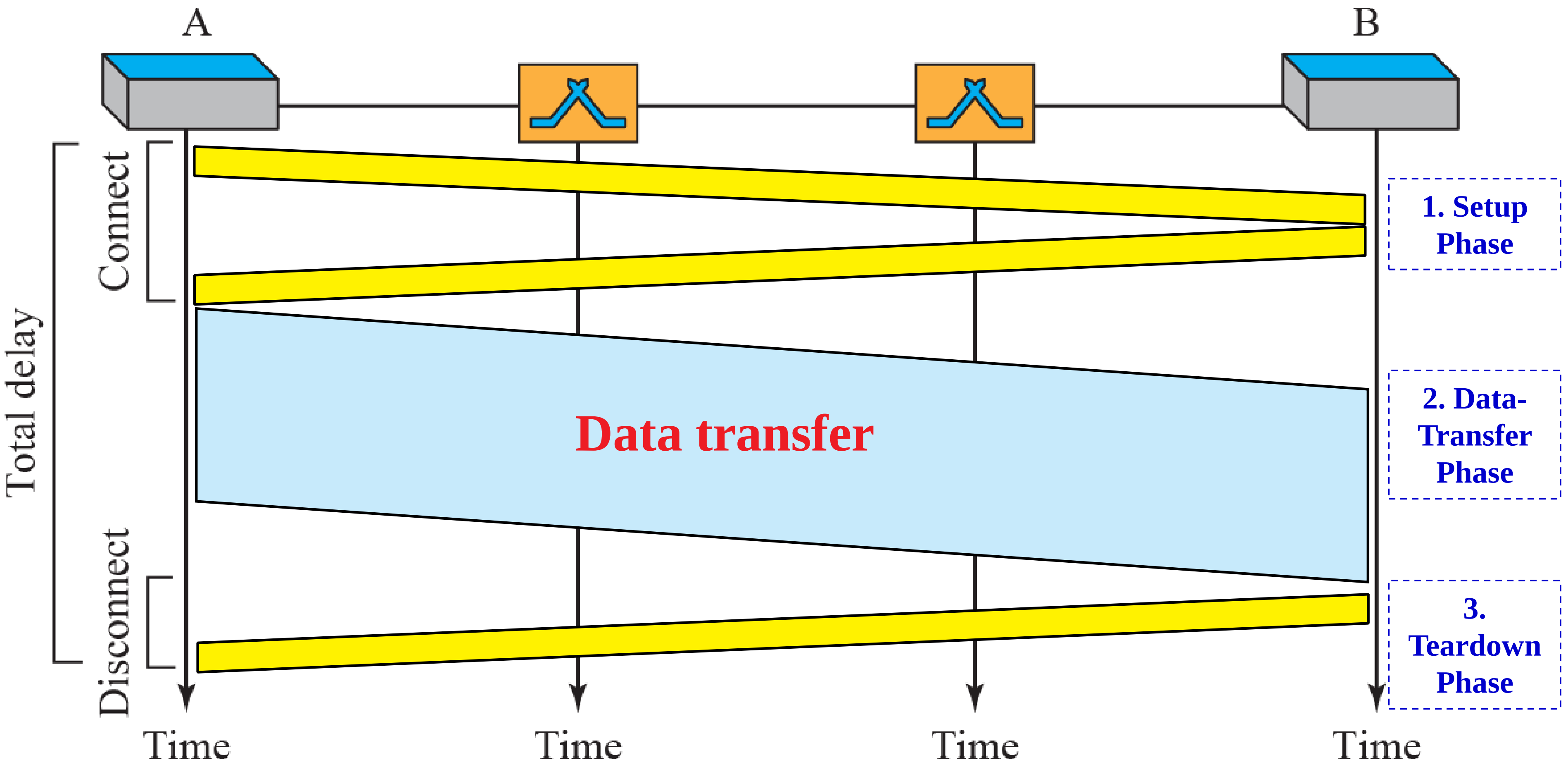
***Efficiency:* It *can be argued* that circuit-switched networks are *not as efficient* as packet- or message-switched networks since *resources* are *allocated* for the *entire duration* of the connection; and *unavailable* to other connections. *Let's* consider the following *2 scenarios for comparison*:**

(a) In a telephone network, people normally terminate the communication when they have finished their conversation.

(b) In a computer network, a computer can remain connected to another computer even if there is no activity for a long time → other connections are deprived.

Figure 8.6: Delay in a circuit-switched network

While a circuit-switched network normally has low efficiency, the delay is minimal. During data transfer, the data are not delayed at each switch as the resources are allocated for the duration of the connection.



Total delay = Setup time + Data transfer Time + Teardown time

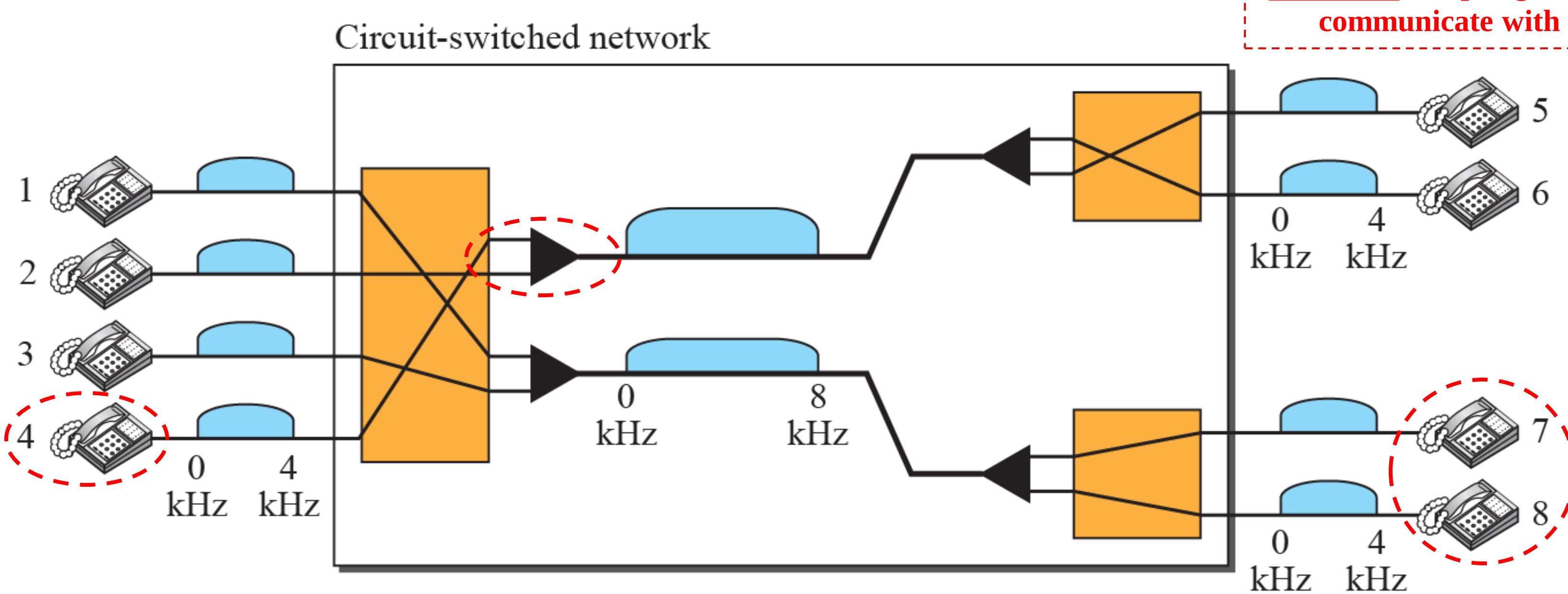
Example

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.

Solution

Telephone 1 is connected to telephone 7; 2 to 5; 3 to 8; and 4 to 6. The switch controls the connections as shown below:

Note this is not a <u>fully-connected</u> setup, e.g., 4 cannot communicate with 7/8.

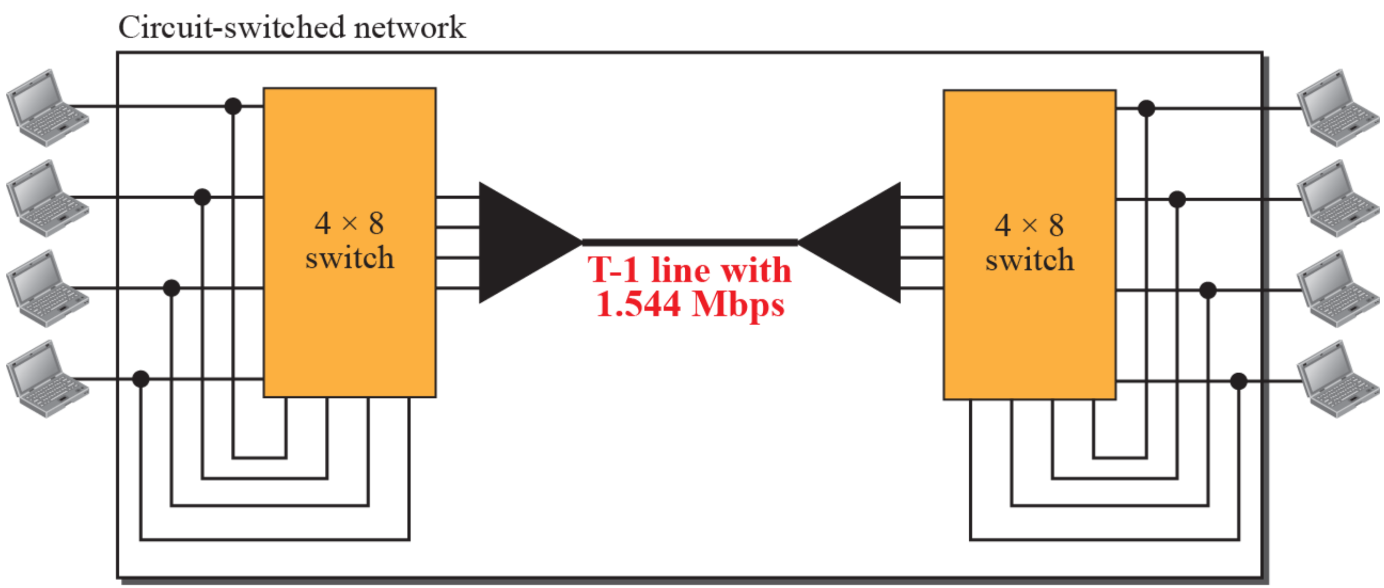


Example

Consider a circuit-switched network that connects computers in two remote offices of a private company. The offices are connected using a T1 line leased from a communication service provider. There are two 4 × 8 (4 inputs, 8 outputs) switches in this network.

Solution

For each 4 x 8 switch, four output ports are folded back into the input ports to allow communication between computers in the same office. The other four output ports allow communication between the two offices as shown below:



8-3 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 <u>packet-switched</u> network, the <u>message</u> needs to be divided into <u>packets</u> of fixed or variable size (size of the packet is determined by the network and the governing protocol).

In packet switching, there is no resource reservation for a packet: <u>no reserved bandwidth</u> on the links, <u>no scheduled processing time</u> for each packet. <u>Resources</u> are <u>allocated on-demand</u> on a <u>first-come, first served</u> (FCFS) basis.

8.3.1 Datagram Networks

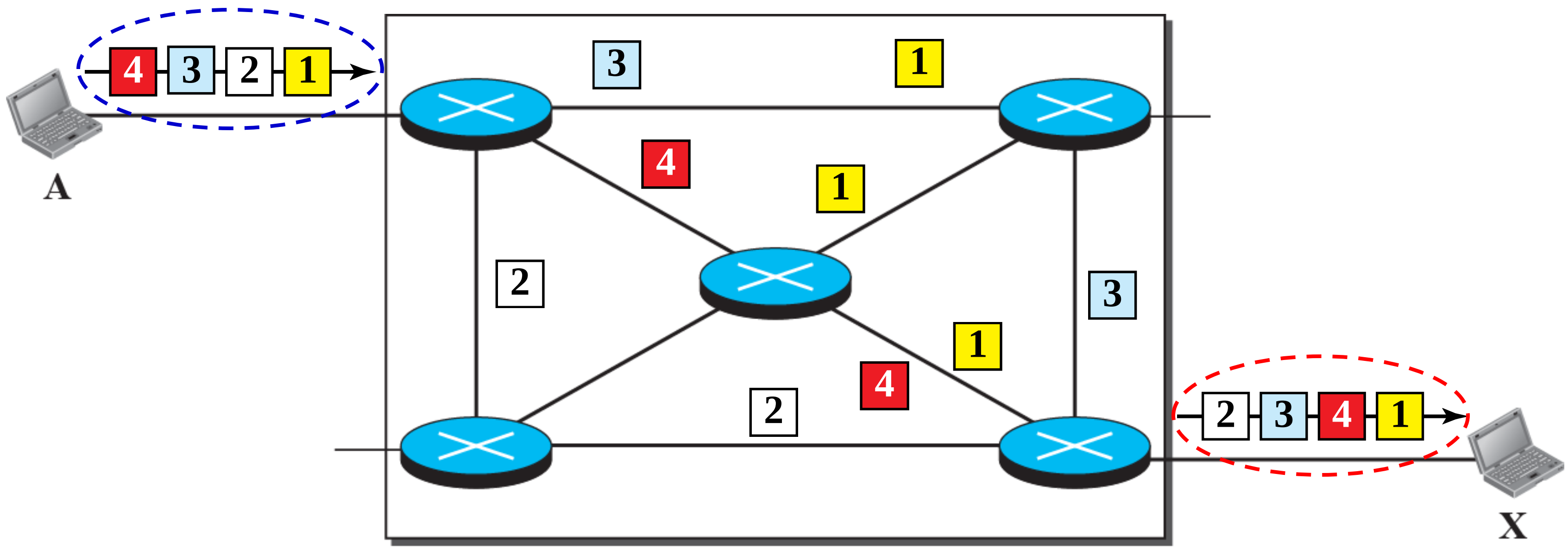
We have two types of packet-switched networks: datagram networks and virtual-circuit networks.

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 (note that the term "switching" is not exclusively referencing only layer 2 "switches").

Figure 8.7: A Datagram network with four switches (routers)

Example of datagram switching to deliver four packets from A to X. All four packets belong to the same message, but <u>may travel different paths</u> from A to X.



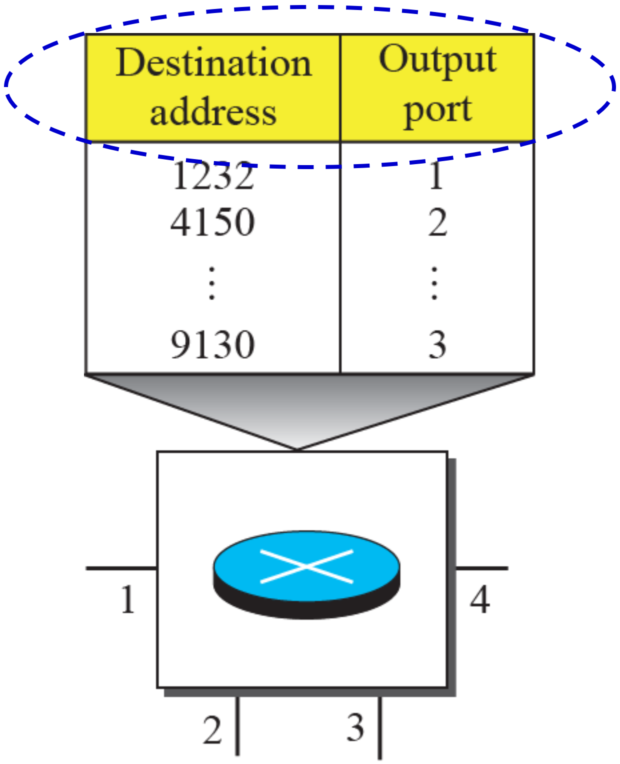
Datagram network

Datagram networks are sometimes referred to as <u>connectionless networks</u>. The term *connectionless* means that the <u>switch</u> does not keep <u>information</u> about the <u>connection state</u>: each <u>packet</u> is treated the <u>same</u> by a switch regardless of its source or destination.

Figure 8.8: Routing table in a datagram network

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

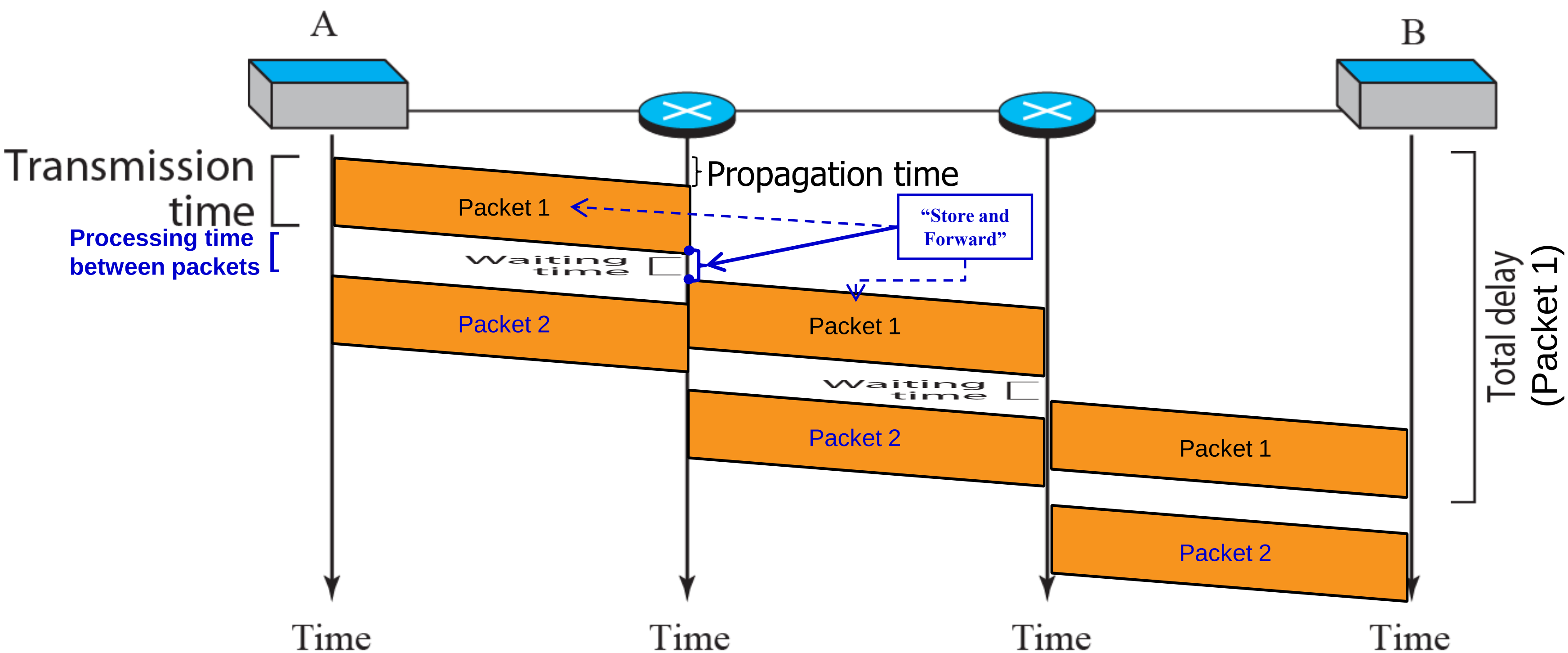
A switch in a datagram network uses a <u>routing table</u> (based on the destination address) where the <u>destination addresses</u> and corresponding <u>forwarding output ports</u> are recorded.



The routing tables are <u>dynamic</u> and <u>updated periodically</u>.

Figure 8.9: *Delays in a datagram network*

Efficiency ***of a datagram network is*** ***better*** ***than that of a circuit-switched network as*** ***resources are allocated*** ***only when*** ***there are packets to be transferred*****.** ***However, there may be*** ***longer delays*** ***in a datagram network as*** ***each packet*** ***may experience a*** ***wait time at each switch*** ***before being forwarded. In addition, the*** ***delay may not be the same*** ***for all packets.***



Total delay $_{\text{(Packet 1)}}$ = 3 x Transmission time + 3 x Propagation time + 2 x Waiting time

(Note that the transmission, propagation and waiting times may not be the same at each switch)

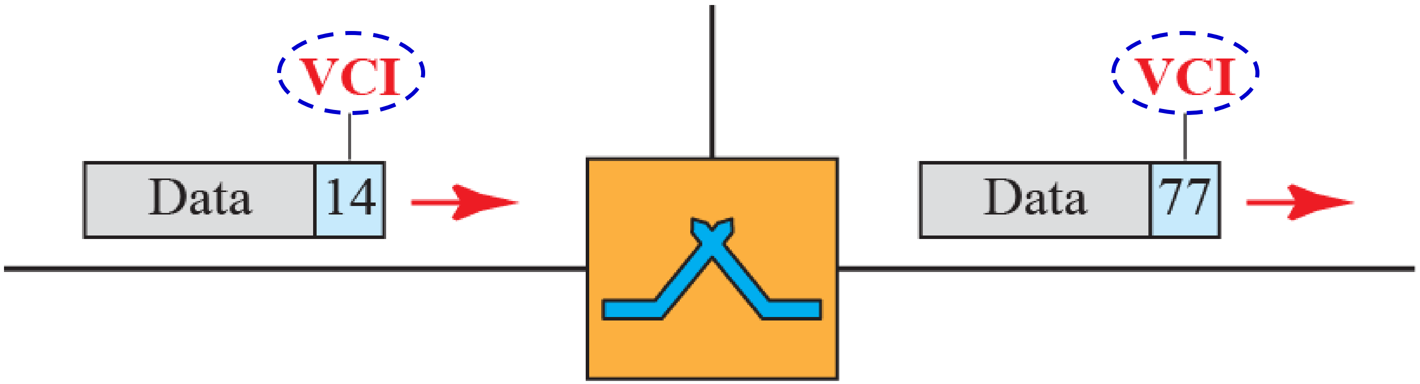
8.3.2 Virtual-Circuit Networks

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

1) *There are setup and teardown phases in addition to the data transfer phase (circuit-switched).*
2) *Resources can be allocated during the setup phase (circuit-switched) or on-demand (datagram).*
3) *Data are packetized (datagram) but address in header only has local jurisdiction, i.e., only knows next switch/channel, not end-to-end jurisdiction.*
4) *All packets follow the same path established during the connection (circuit-switched)*
5) *Normally implemented in the data link layer. (Physical layer: circuit-switched; Network layer: datagram)*

Figure 8.11: *Virtual-circuit identifier*

In a virtual-circuit network, two types of <u>addressing</u> are involved: <u>global</u> and <u>local</u>. The <u>global address</u> is used to create a <u>virtual-circuit identifier</u> (VCI), usually a small number, that only has <u>local switch scope</u>, i.e., when a frame arrives at a switch, it has a VCI; when it leaves, it has a different VCI.



As in a circuit-switched network, a source and destination goes through three phases in a virtual-circuit network: <u>setup phase</u>, <u>data transfer phase</u> and <u>teardown phase</u>.

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

In the <u>setup phase</u>, the source and destination use their global addresses to help the switches make table entries for the connection. Two steps are required: (a) the <u>setup request</u> and (b) the <u>acknowledgment</u>.

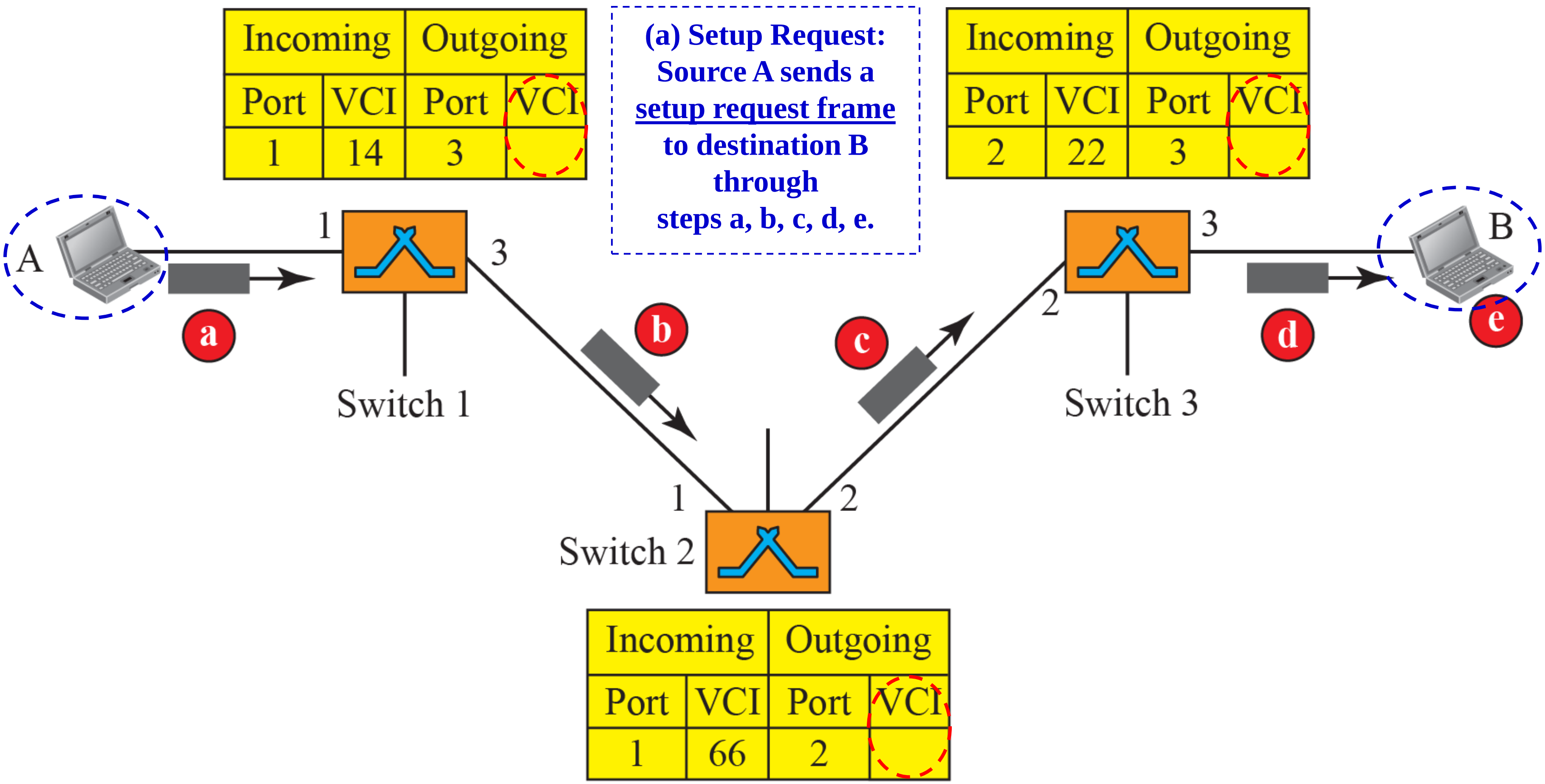
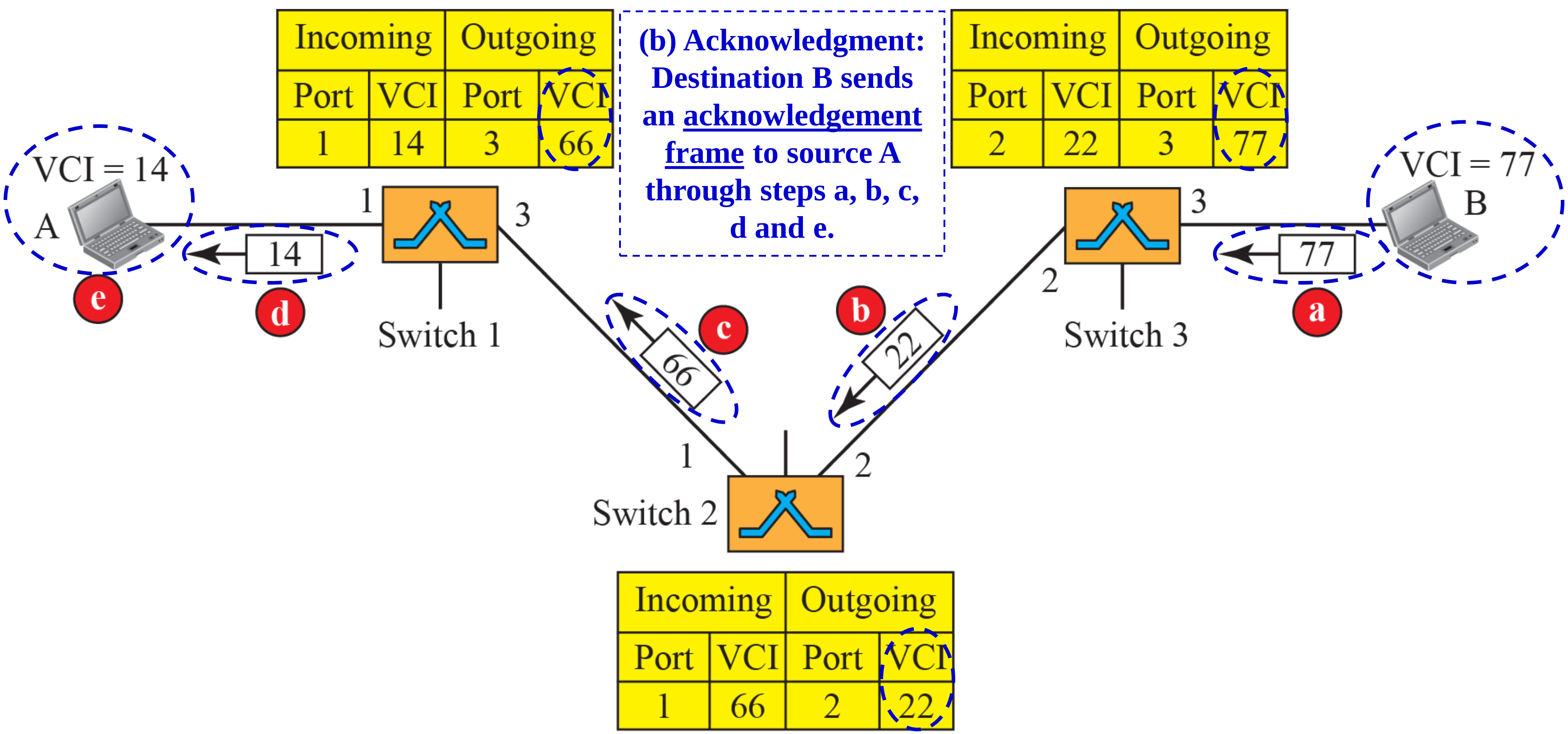


Figure 8.15: Setup acknowledgment in a virtual-circuit network

After the setup request, in the acknowledgment step, a special frame, called the acknowledgment frame, completes the entries in the switching tables. This process creates a virtual circuit between the source and the destination.



Switch 1:

Incoming		Outgoing	
Port	VCI	Port	VCI
1	14	3	66

Switch 3:

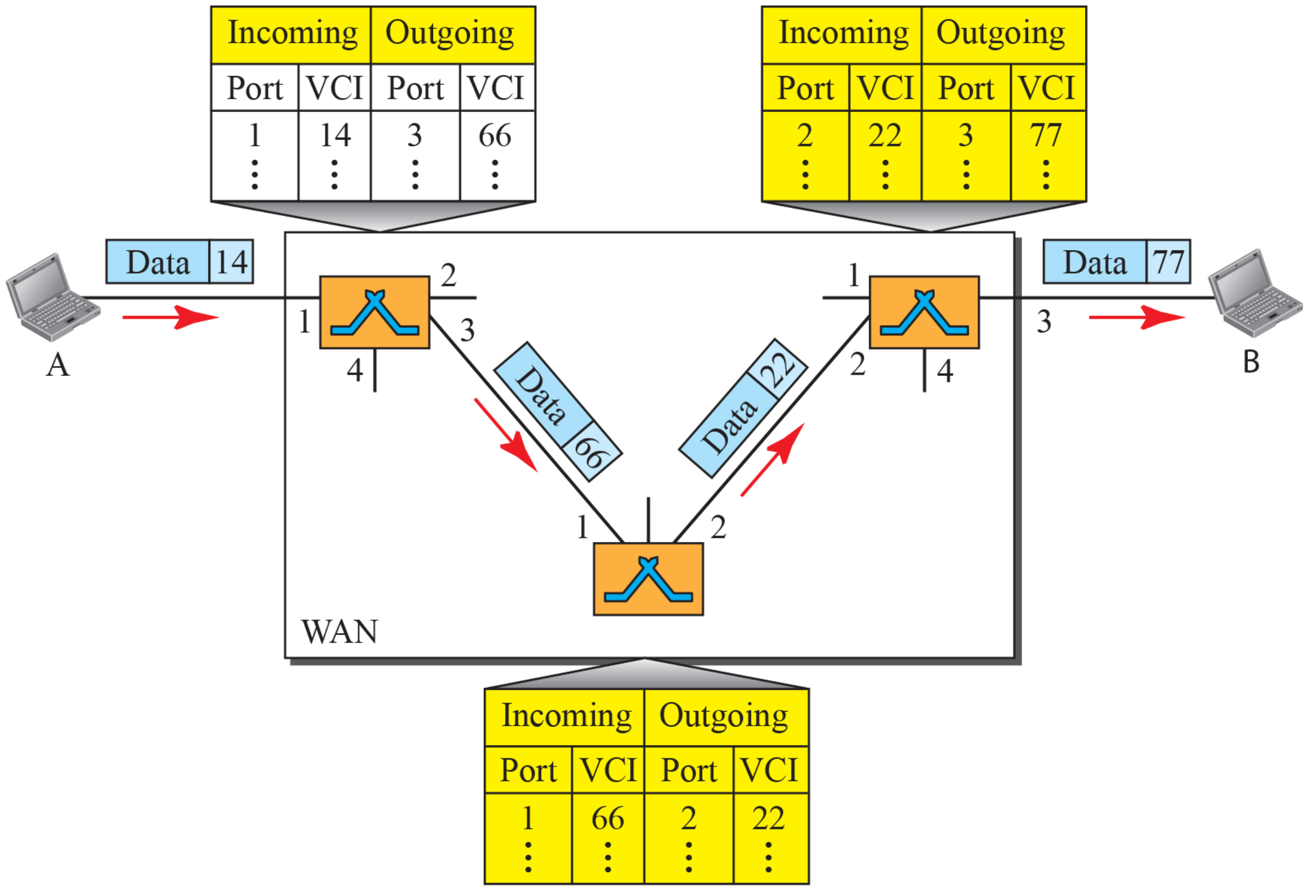
Incoming		Outgoing	
Port	VCI	Port	VCI
2	22	3	77

Switch 2:

Incoming		Outgoing	
Port	VCI	Port	VCI
1	66	2	22

Figure 8.13: *Source-to-destination data transfer / Teardown*

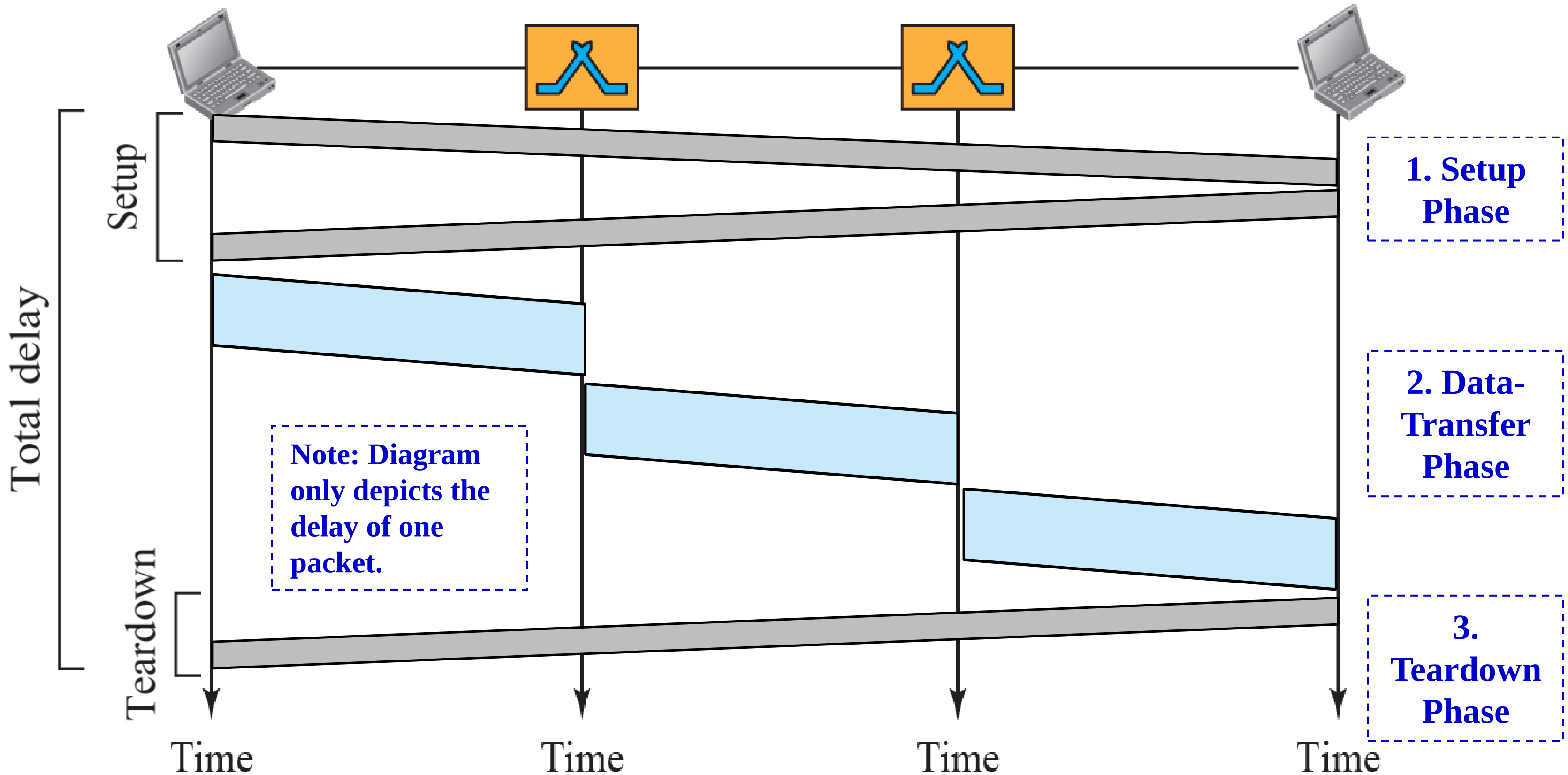
The <u>data transfer phase</u> is active until the source sends all its frames to the destination.



After A sends all its frames to B, it sends a special frame called a <u>teardown request</u> in the <u>teardown phase</u>. B responds with a <u>teardown confirmation</u> and <u>all switches delete</u> the <u>corresponding entries</u> from their tables.

Figure 8.16: Delay in a virtual-circuit network

In virtual-circuit switching, all packets belonging to the same source and destination travel the same path. Resource reservation can be made during the setup phase or on-demand during the data-transfer phase. The delay for each packet is the same for the former and may be different for the latter.



Total delay = Setup time + 3 x Transmission time + 3 x Propagation time + Teardown time

(Assumption: resource reservation is made during the setup phase, otherwise include additional delay for individual packets at each switch)