# Data Communication and Computer Network

Wide Area Network and Switching

WAN

❑ A wide area network (WAN) provides long-distance transmission of over large geographic areas that may comprise a country, a continent, or even the whole world.

➢ A WAN can be as complex as the backbones that connect the Internet (switched WAN)

➢ Or as simple as a dial-up line that connects a home computer to the Internet (point-to-point WAN).
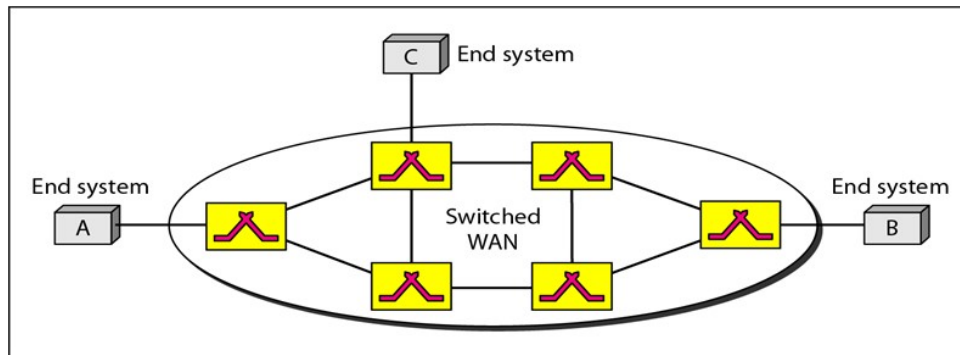

a. Switched WAN
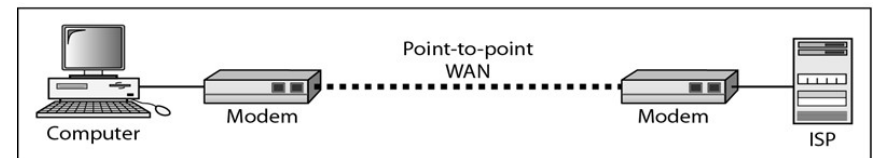
b. Point-to-point WAN

Switched WAN

❑ Network spread over large geographic area
  ➢ All nodes in WAN may not be directly connected to each other
  ➢ Some redundant connections (multiple paths) desirable for reliability
❑ Communication network: collections of nodes and connections
❑ Nodes of two types
  ➢ End devices
  ➢ Switching nodes

LAN

Router

Frame Relay network (WAN)

To the rest of the Internet

Router

❑ Data sent by source node is switched from node to node until it reaches destination node
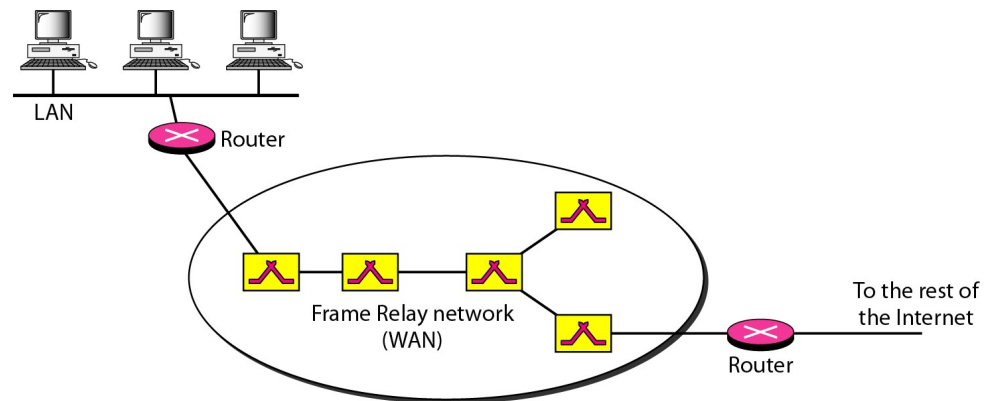
Switching Methods
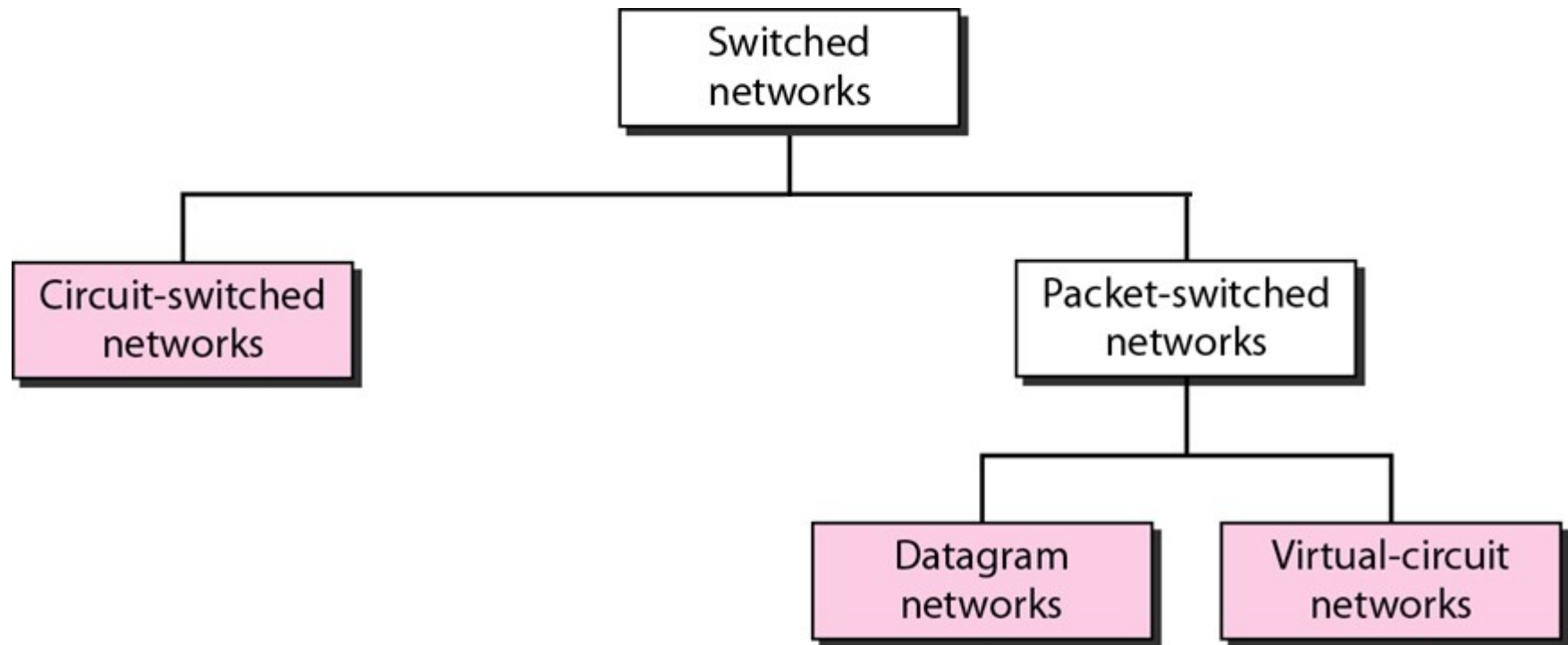
Circuit Switching

❑ Before sending data, a dedicated communication path (circuit) set up between source node & destination node, using intermediate nodes

❑ Three phases

   ➢ Establish: signaling to set up the path

   ➢ Transfer: transfer data through the path

   ➢ Disconnect: signaling to tear down connection

❑ Links in the path dedicated to a single connection

❑ All data sent from source follows the same path to the destination
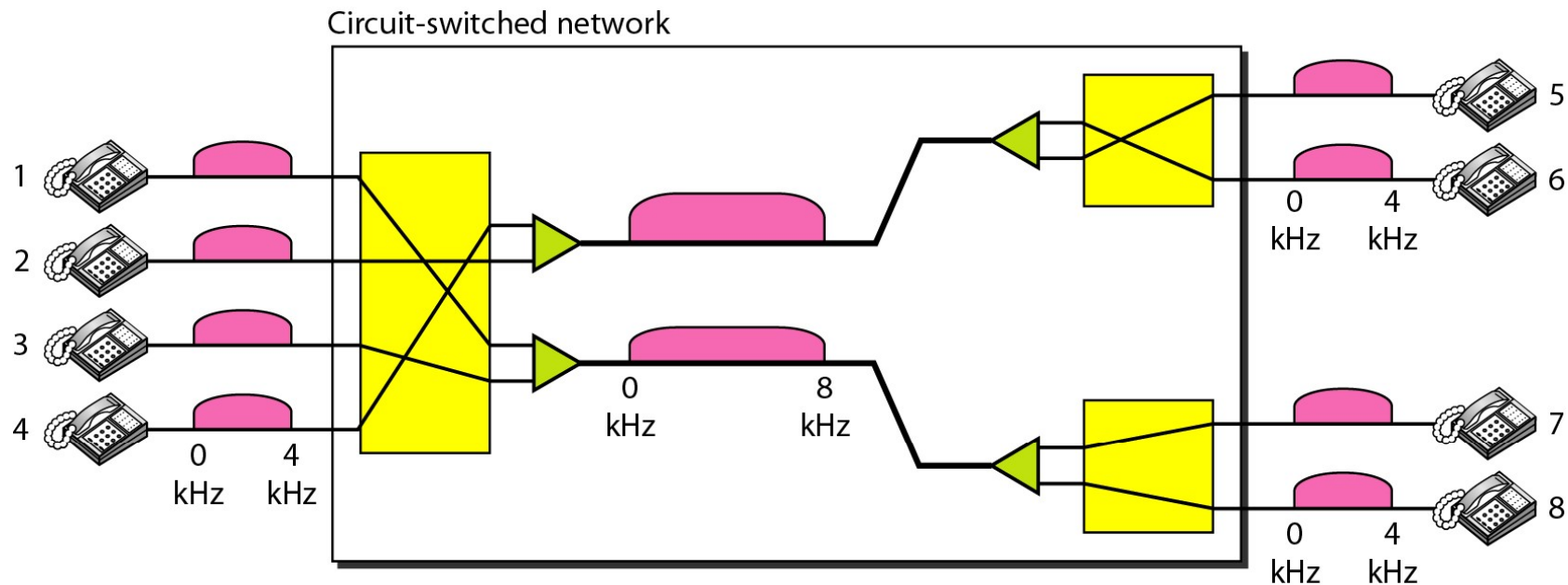
Circuit Switching (contd.)

❑ Advantages

   ➢ Once connected, data transfer is fast

   ➢ Usually in-order reception of data at receiver

❑ Disadvantages

   ➢ Inefficient: Channel capacity dedicated for duration of connection, if no data transmitted, capacity wasted

   ➢ Setting up connection takes time (high overhead if only small amount of data to send)

   ➢ Failure of any intermediate node breaks connection

   ➢ Less flexibility: if one node slows down, entire circuit slows down
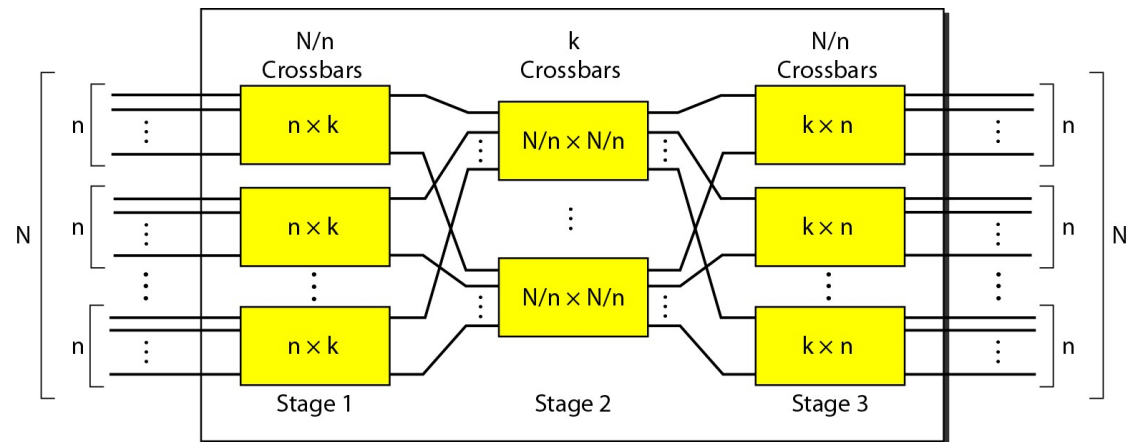
An example of Circuit-switched network

Here assumed that each link uses FDM to connect maximum two voice channels. Bandwidth of each link is then 8KHz.

❑Switching at the physical layer in the traditional telephone network uses the circuit-switching approach.
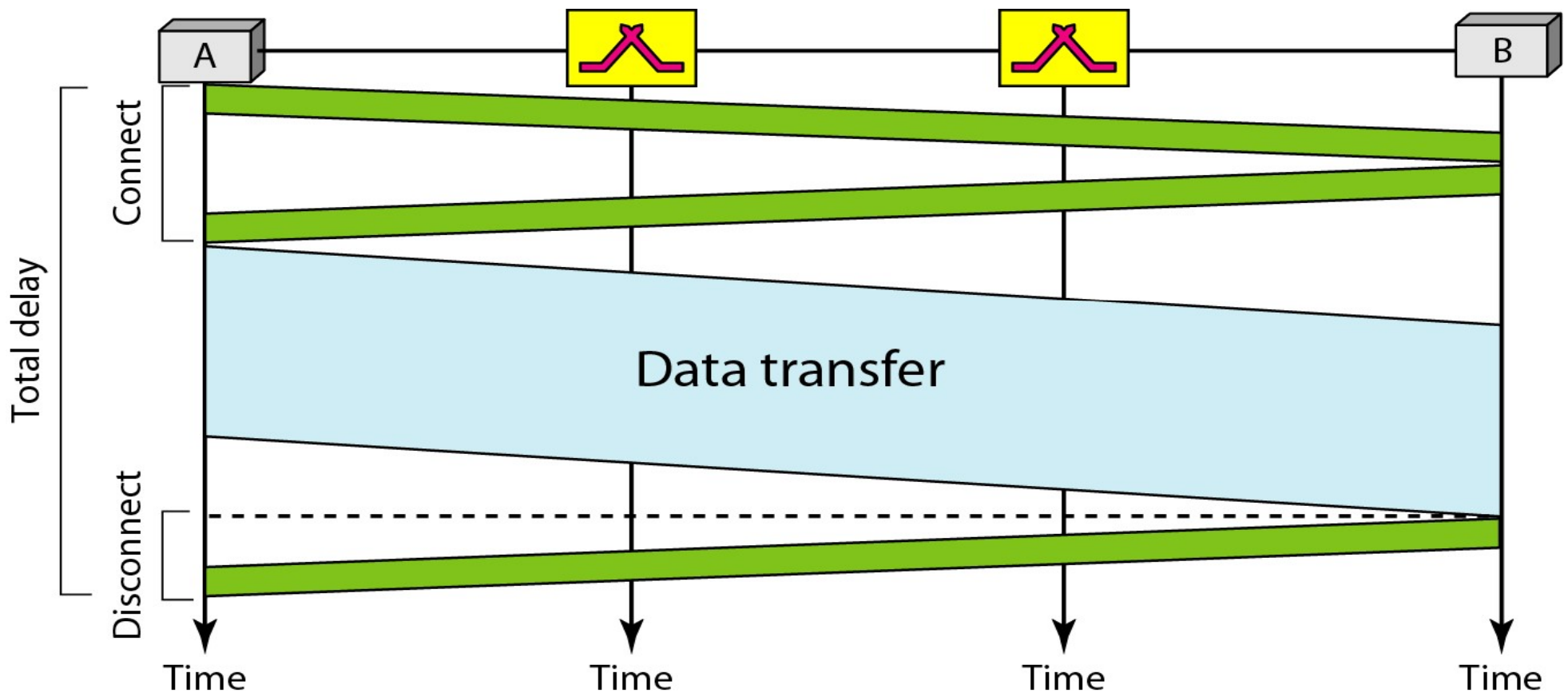
Switches in circuit-switched network
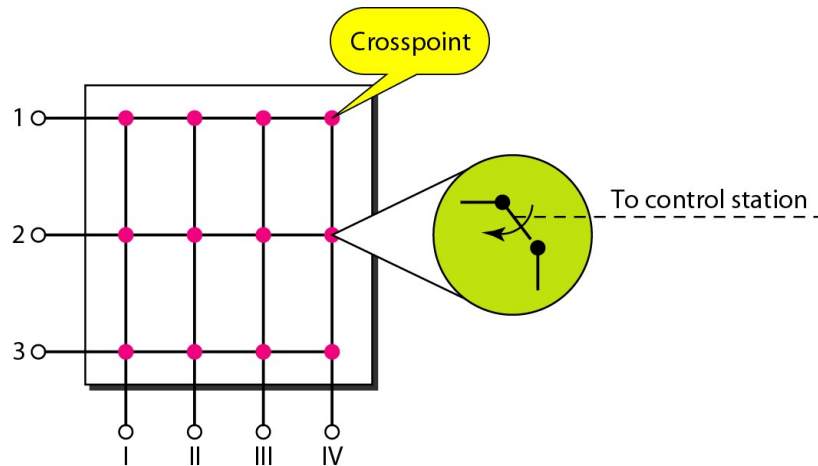
Crossbar switch with three inputs and four outputs

Multistage switch

Delay in a circuit-switched network

Packet Switching

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

❑ Data transmitted in short units called packets
  ➢ Maximum packet size is pre-defined
  ➢ Longer messages split into sequence of packets
  ➢ Each packet contains a portion of user data plus some control information (address, error check info, sequence info, …)

❑ Intermediate nodes receive packets, store briefly (buffer) and pass on to next node – Store and Forward

❑ Packet switching handled in two ways
  ➢ Datagram approach
  ➢ Virtual circuit approach

Advantages of packet switching

❑ Line efficiency
  ➢ Single node to node link can be shared by many packets over time
  ➢ Packets queued and transmitted as fast as possible
❑ Data rate conversion
  ➢ Nodes buffer data if required to equalize rates
❑ Packets are accepted even when network is busy
  ➢ Delivery may slow down
❑ Priorities can be used

Datagram approach

❑ Each packet treated independently of any other packet (each packet has destination address)

❑ Packets sent by a source node can take different routes to the same destination

❑ Packets may arrive out of order at destination node, may be lost

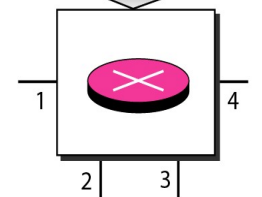 ➢ Up to destination node to re-order packets and recover from missing packets

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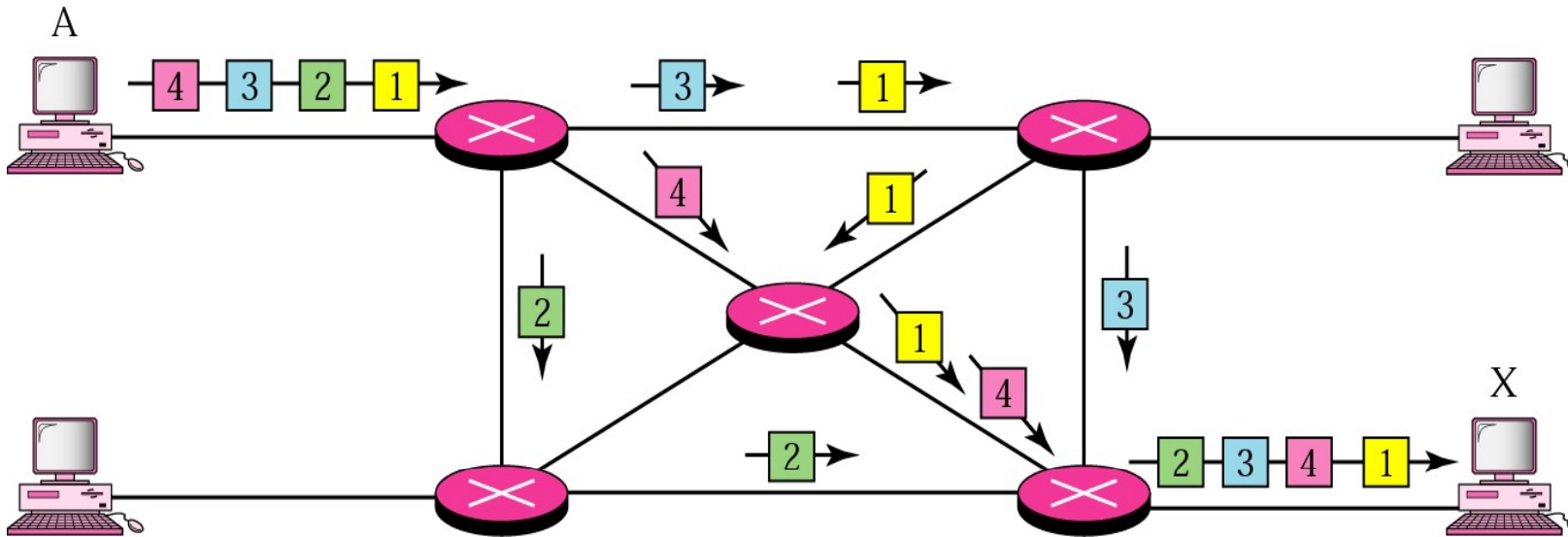
□ **A switch in a datagram network uses a routing table that is based on the destination address.**

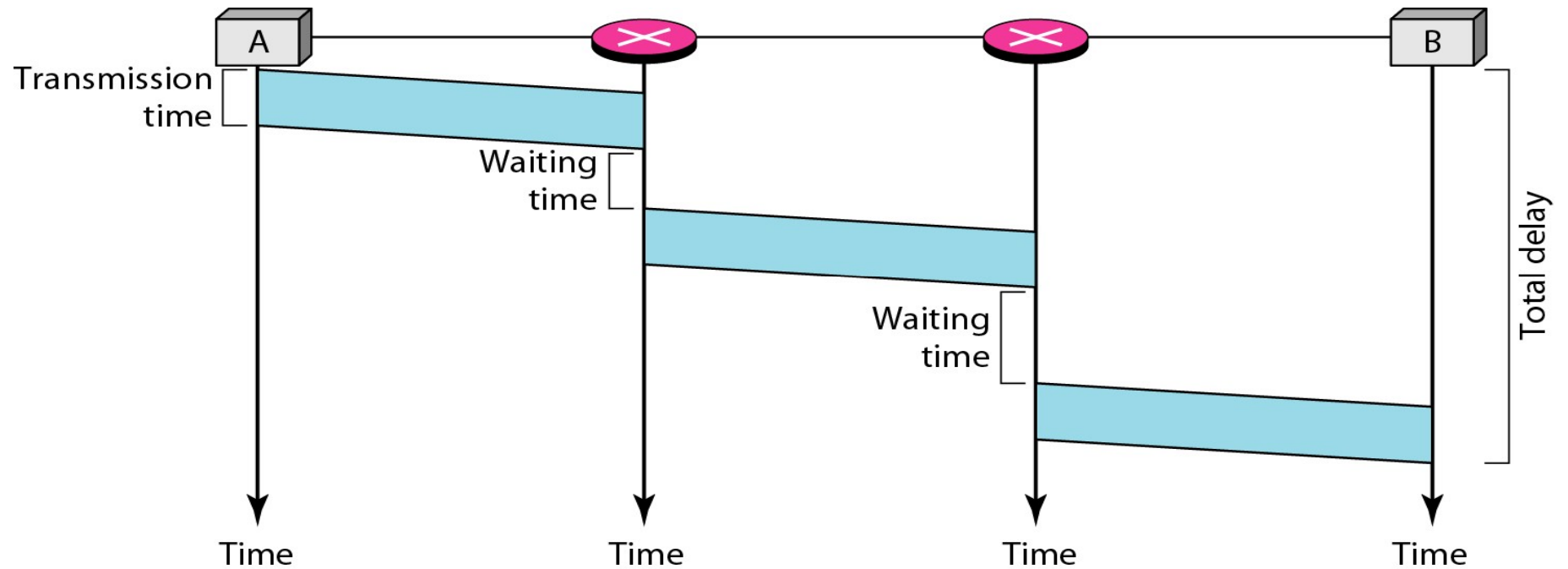 ➢ **The destination address in the header of a packet in a datagram network remains the same during the entire journey of the packet (*recall IP address*)**

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

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

# Delay in a datagram network

Virtual-circuit Approach

❑ A virtual-circuit network is a <u>cross between a circuit-switched network and a datagram network</u>. 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 this address has only local scope (not end to end scope).

❑ As in a circuit-switched network, all packets follow the same path established during the connection.

❑ A virtual-circuit network is normally implemented in the data link layer, while a circuit-switched network is implemented in the physical layer and a datagram network in the network layer (in general).

Virtual-circuit network
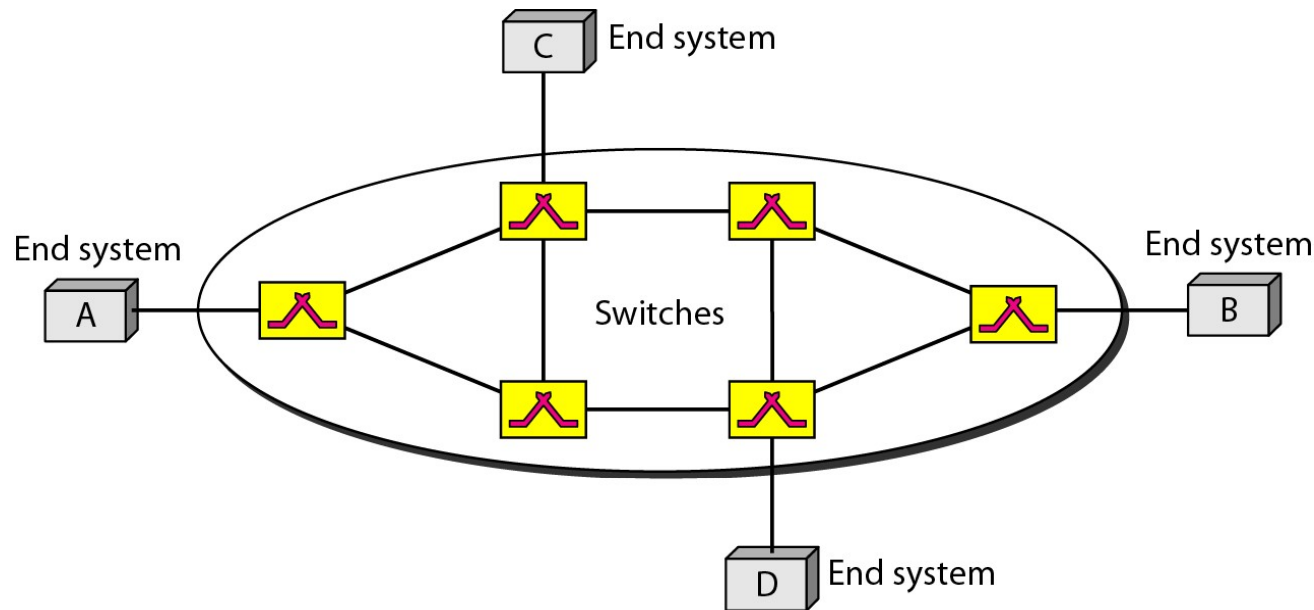
❑Switching at the data link layer in a switched WAN is normally implemented by using virtual-circuit techniques like X.25, Frame Relay, ATM.

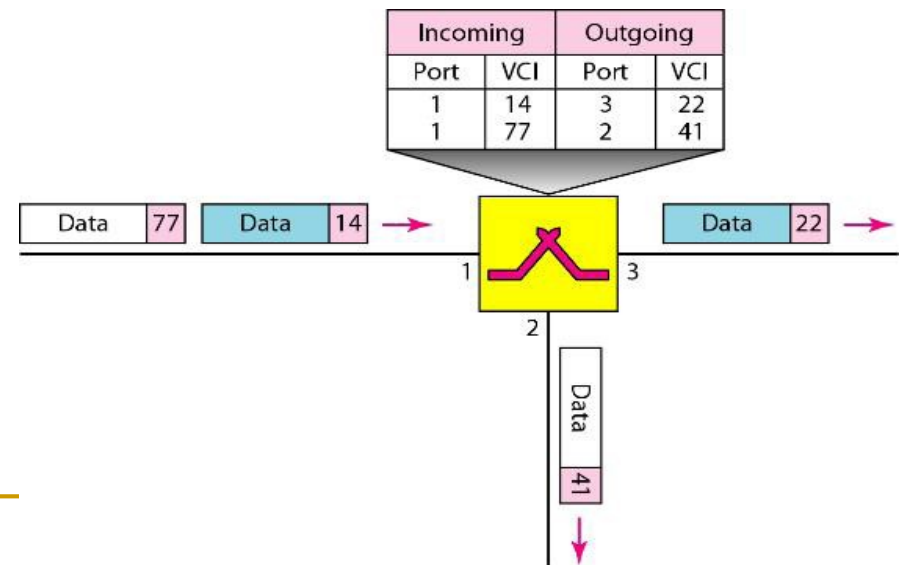❑A source or destination can be a computer, packet switch, bridge, or any other device that connects other networks.

Virtual Circuit Addressing
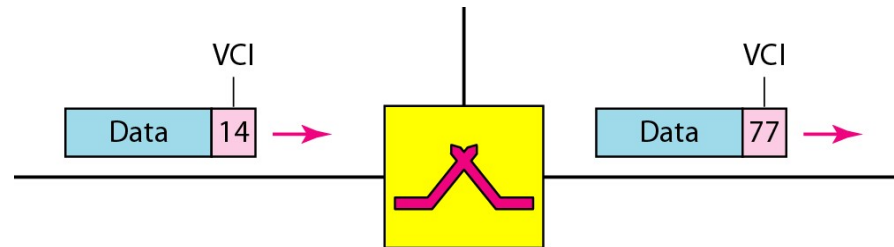
❑ In a virtual-circuit network, two types of addressing are involved: global and local (virtual-circuit identifier).

❑ *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. However, a global address in virtual-circuit networks is used only to create a virtual-circuit identifier (discussed next).

❑ *Virtual-Circuit Identifier (VCI) :* This is actually used for data transfer. Unlike a global address, it 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.

Virtual Circuit Technique

❑ Three phases of operations : Establish circuit, Data transfer, and Teardown circuit.

❑ Pre-planned route or 'circuit' established between source & destination before any data packets sent

❑ Each node maintains information about each virtual circuit passing through itself, in a table

❑ Each packet contains a Virtual Circuit Identifier (VCI) instead of destination address

❑ The links in a path are NOT dedicated – may be shared among different virtual circuits

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

| Data | 77 | Data | 14 | → | | Data | 22 | → |

Data 41

Setup Circuit Phase

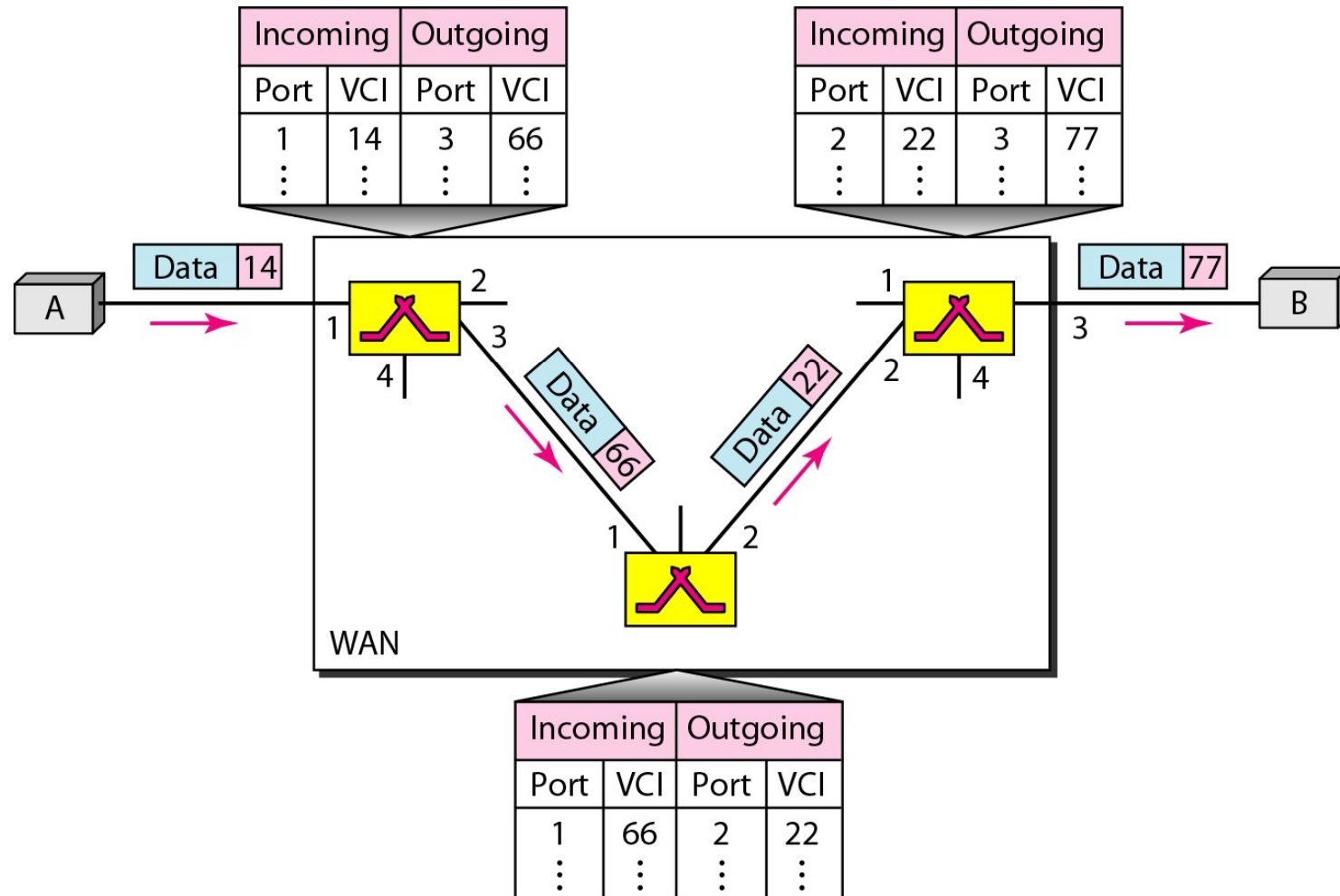**SetupRequest**

Incoming		Outgoing	
Port	VCI	Port	VCI
1	14	3	

Incoming		Outgoing	
Port	VCI	Port	VCI
2	22	3	

VCI = 77

Incoming		Outgoing	
Port	VCI	Port	VCI
1	66	2	

SetupAck

Incoming		Outgoing	
Port	VCI	Port	VCI
1	14	3	66

Incoming		Outgoing	
Port	VCI	Port	VCI
2	22	3	77

VCI = 14

VCI = 77

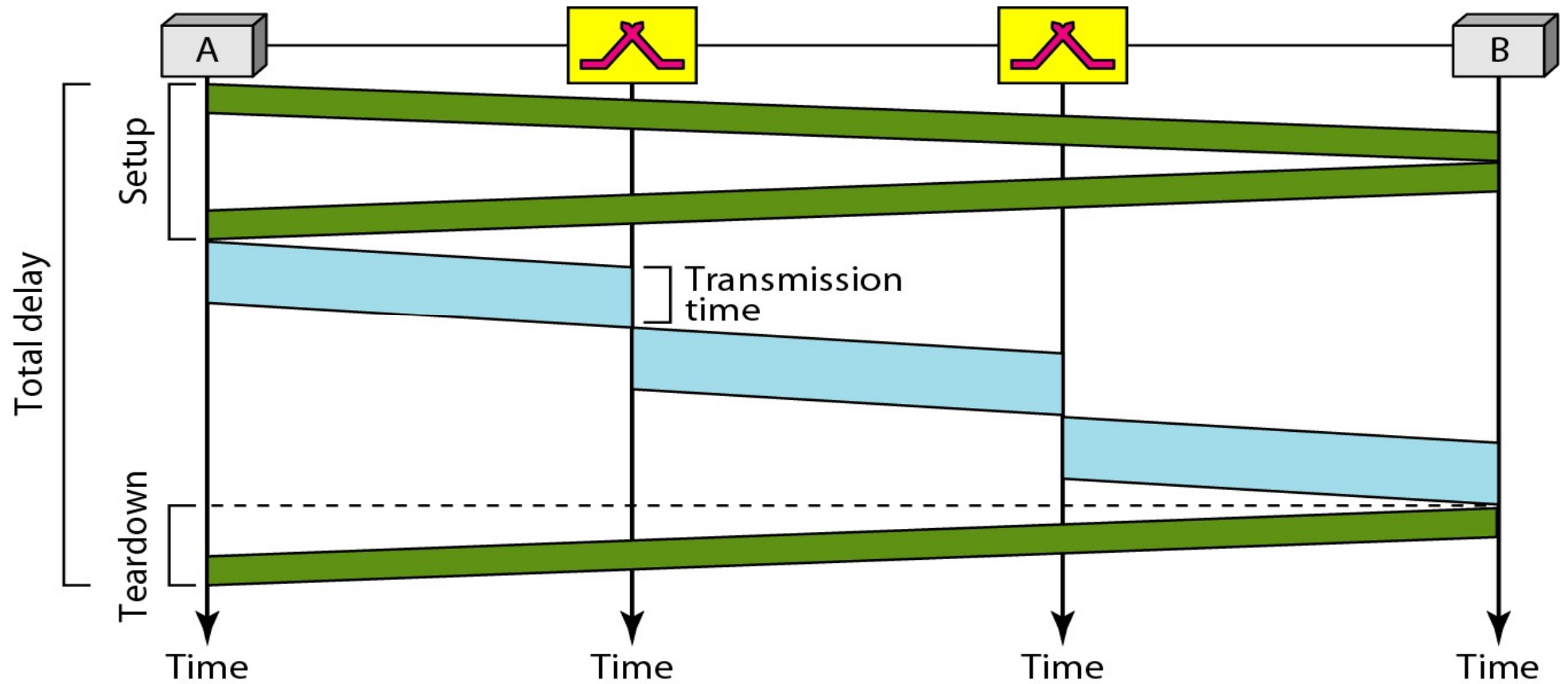| Incoming		Outgoing	
Port	VCI	Port	VCI
1	66	2	22
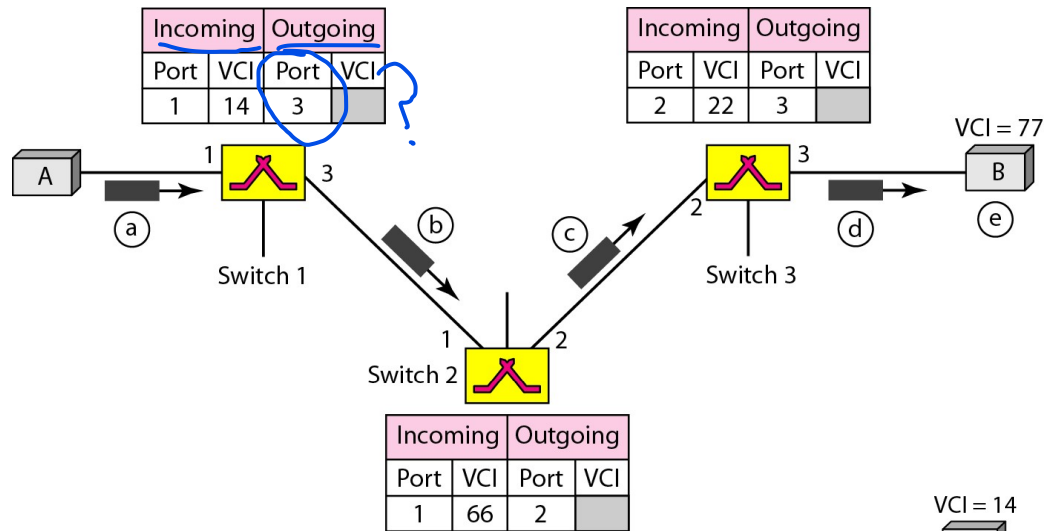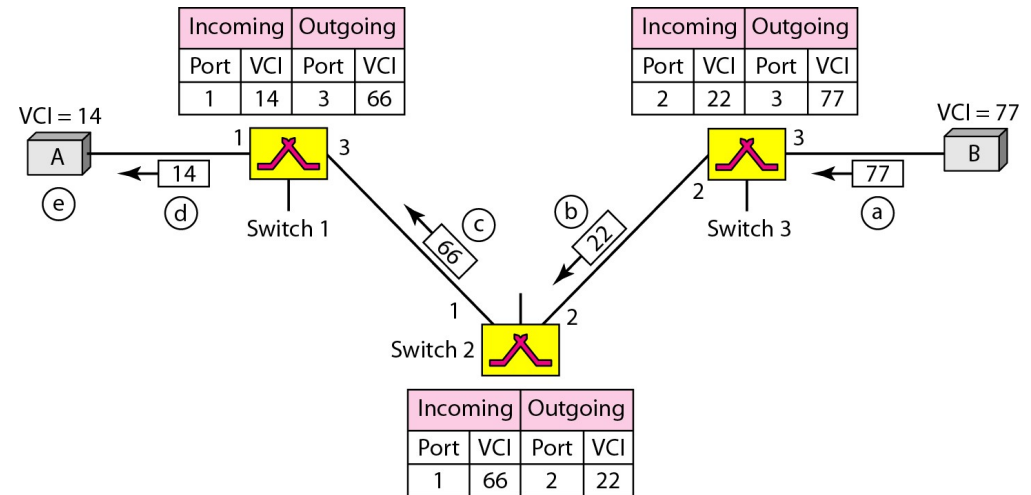
Data Transfer Phase

Teardown Circuit Phase

❑ In this phase, source A, after sending all frames to B, sends a special frame called a *TeardownRequest*.

❑ Destination B responds with a *TeardownConfirmation* frame.

❑ All switches delete the corresponding entry from their tables.

Delay in a virtual-circuit network

Example of Virtual Circuit Networks

❑ **X.25** is an ITU-T standard protocol suite for packet-switched data communication in a wide-area network designed in the 1970s. It performed switching at the network layer. It has a low 64-kbps data rate.

❑ **Frame Relay** is a virtual-circuit wide-area network that was designed in response to demands for a new type of WAN in the late 1980s and early 1990s. It operates at a higher speed (1.544 Mbps and recently 44.376 Mbps).

❑ **Asynchronous Transfer Mode (ATM)** is the cell relay protocol designed by the ATM Forum and adopted by the ITU-T. The combination of ATM and SONET will allow high-speed interconnection of all the world's networks.

Virtual Circuit vs Datagram

❑ Virtual circuit

  ➢ Network can provide sequencing and error control

  ➢ Packets are forwarded more quickly

  ➢ Less reliable: loss of a node disconnects all circuits through that node

❑ Datagram

  ➢ No call setup phase, better if few packets to be sent

  ➢ More flexible

   ✓ Routing can be used to avoid congested parts of the network

   ✓ Communication can go on even if any node fails

  ➢ Packets may arrive out-of-order at destination

Switches in packet-switched network
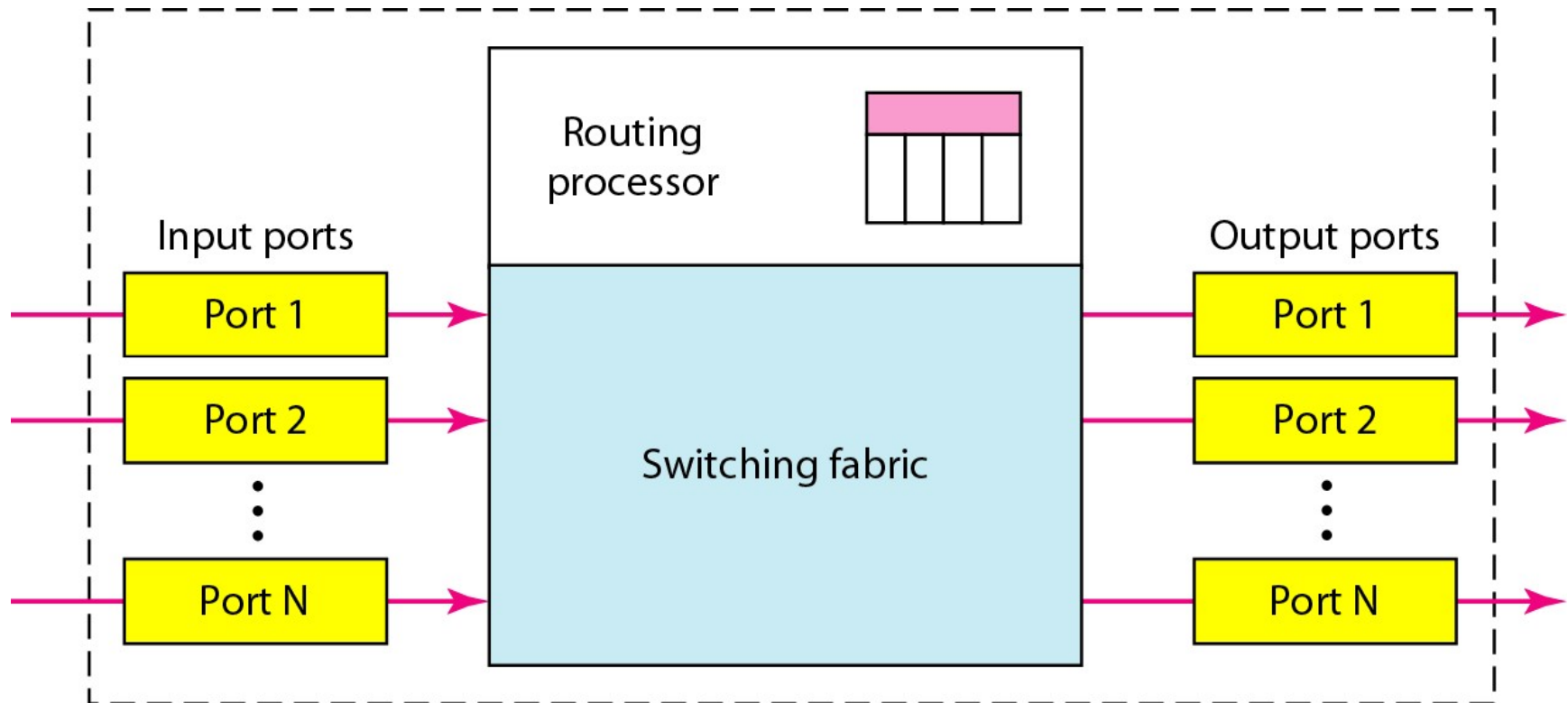
References

❑ *Data Communications & Networking, 5th Edition, Behrouz A. Forouzan*
❑ *Computer Networks, Andrew S. Tanenbaum and David J. Wetherall*
❑ *Wikipedia*