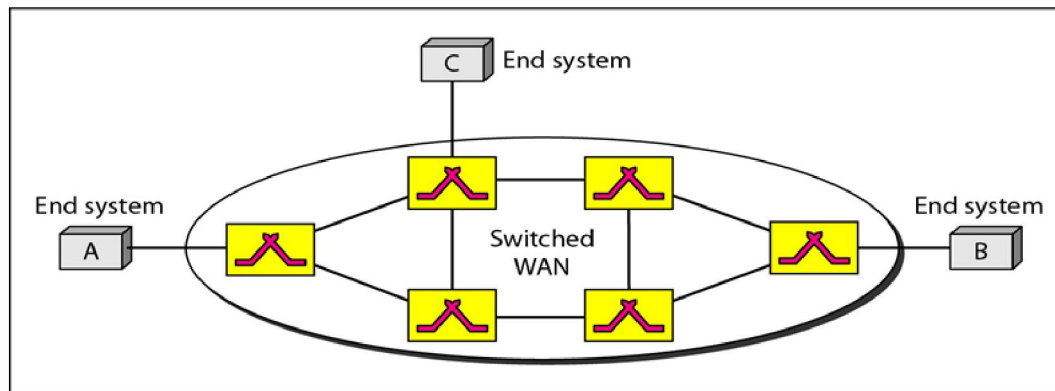


Data Communication and Computer Network

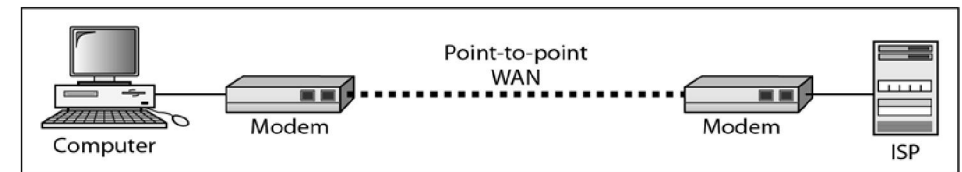
Wide Area Network and Switching

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).



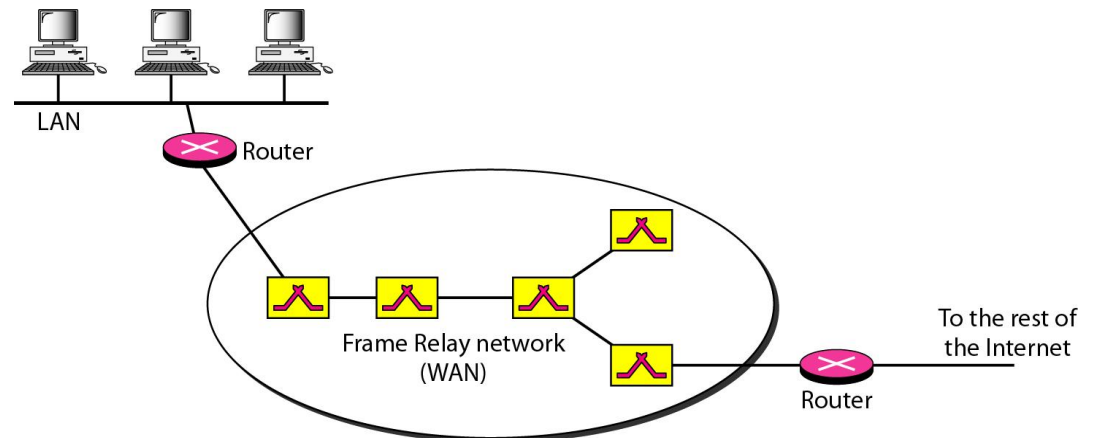
a. Switched WAN



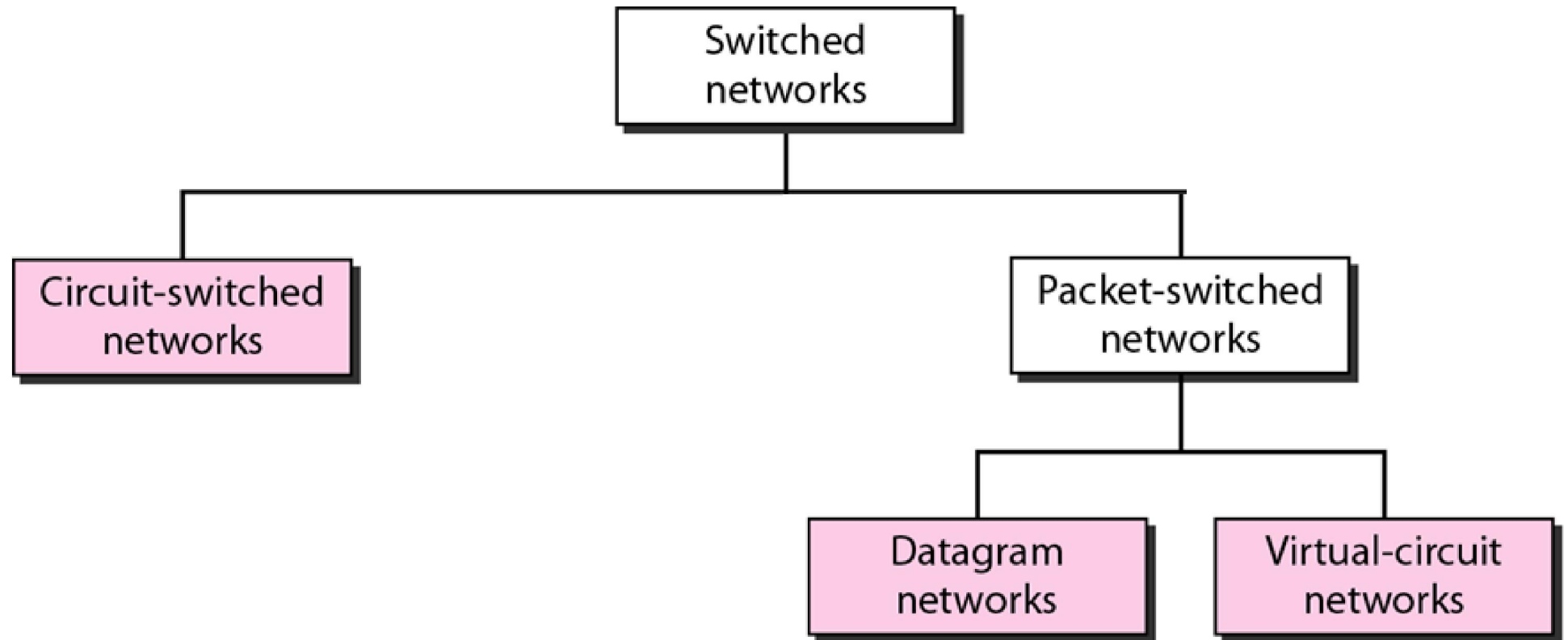
b. Point-to-point WAN

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
- ❑ 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.)

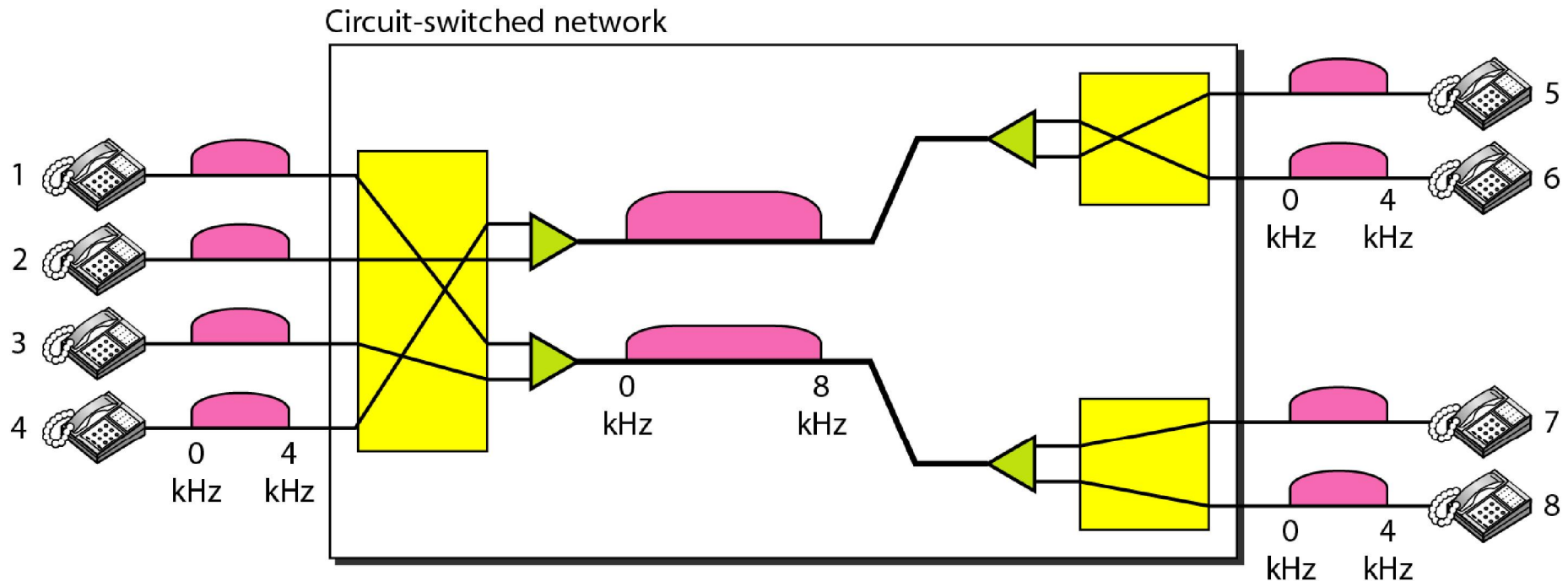
❑ Advantages

- 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
-

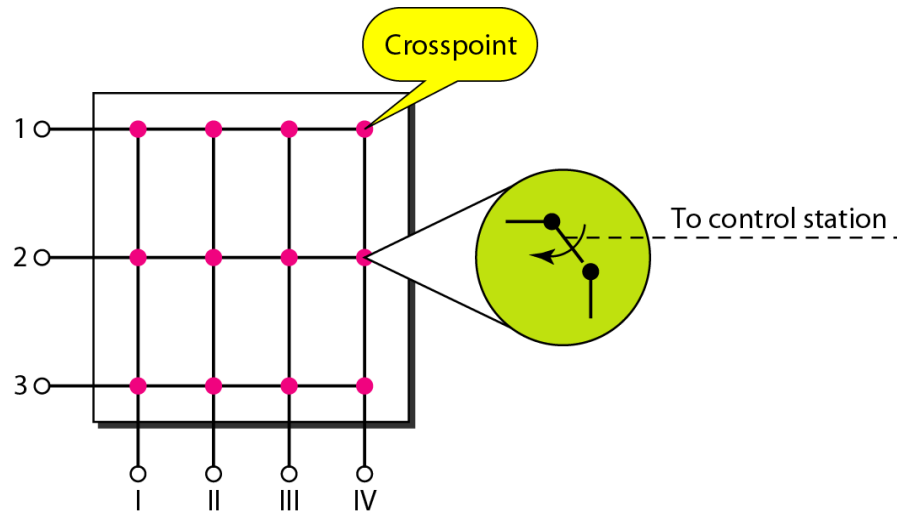
An example of Circuit-switched network



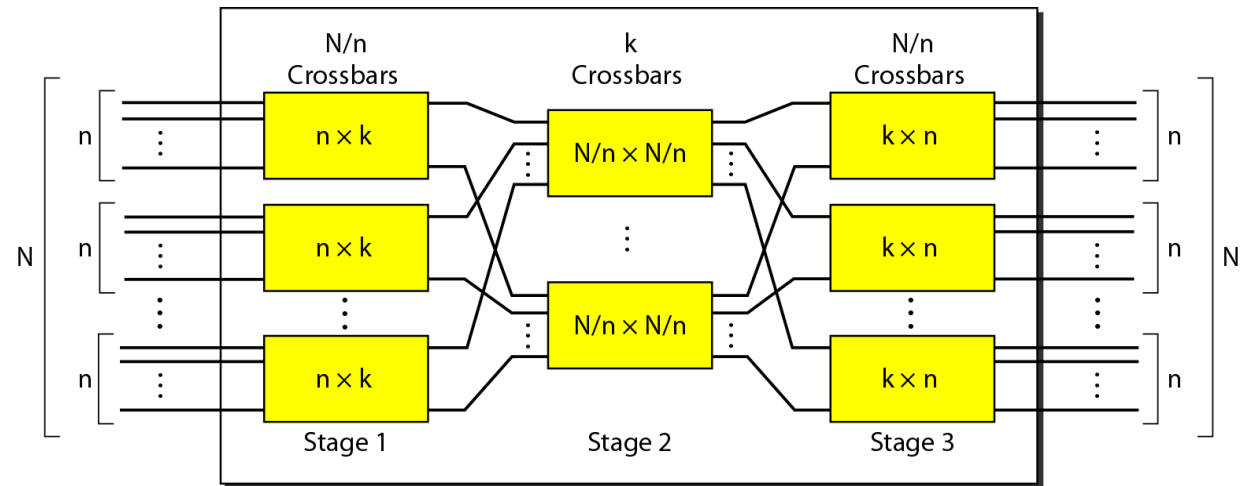
Here assumed that each link uses FDM to connect maximum two voice channels. Bandwidth of each link is then 8KHz.

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

Switches in circuit-switched network

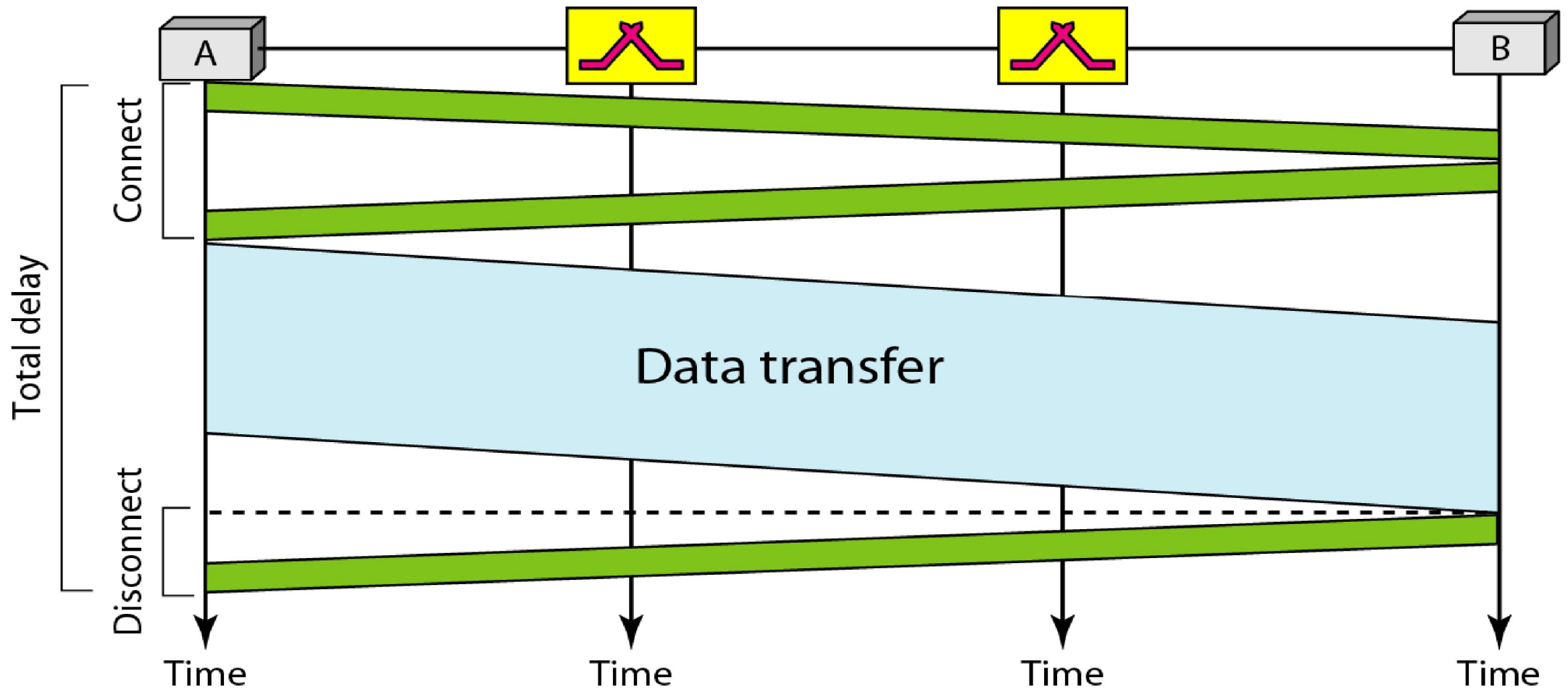


Crossbar switch with three inputs and four outputs



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

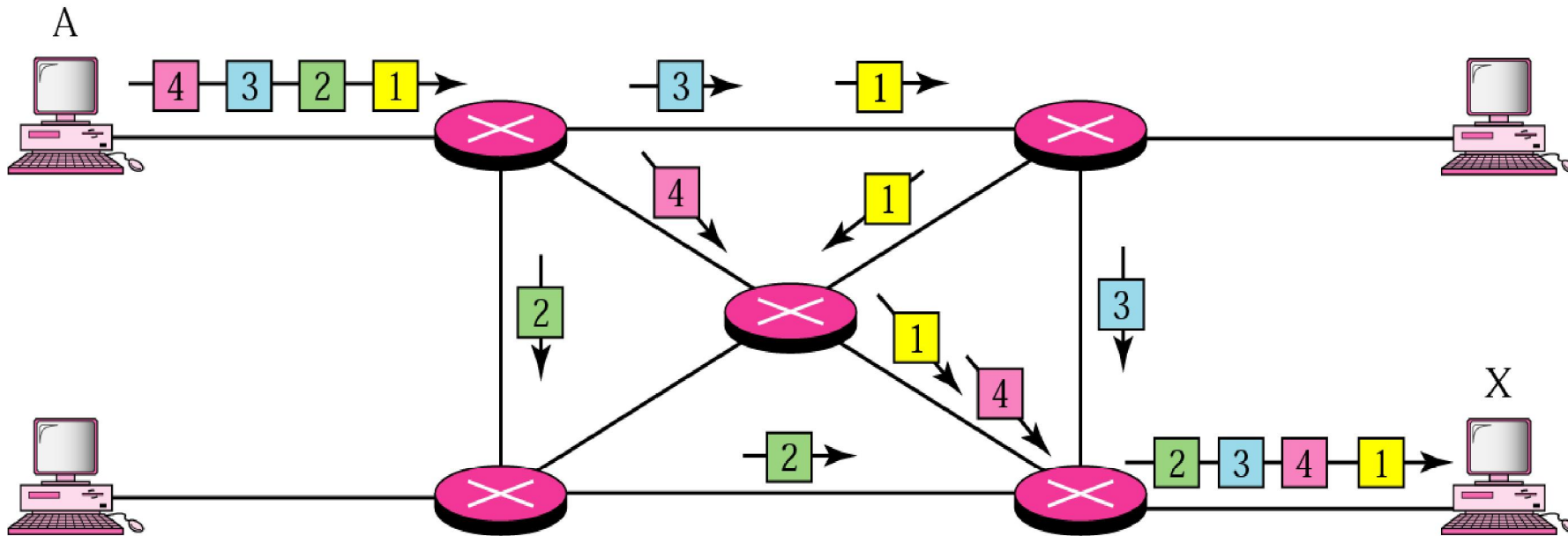
- Delivery may slow down

❑ 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

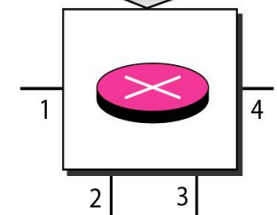


❑ A switch in a datagram network uses a routing table that is based on the destination address.

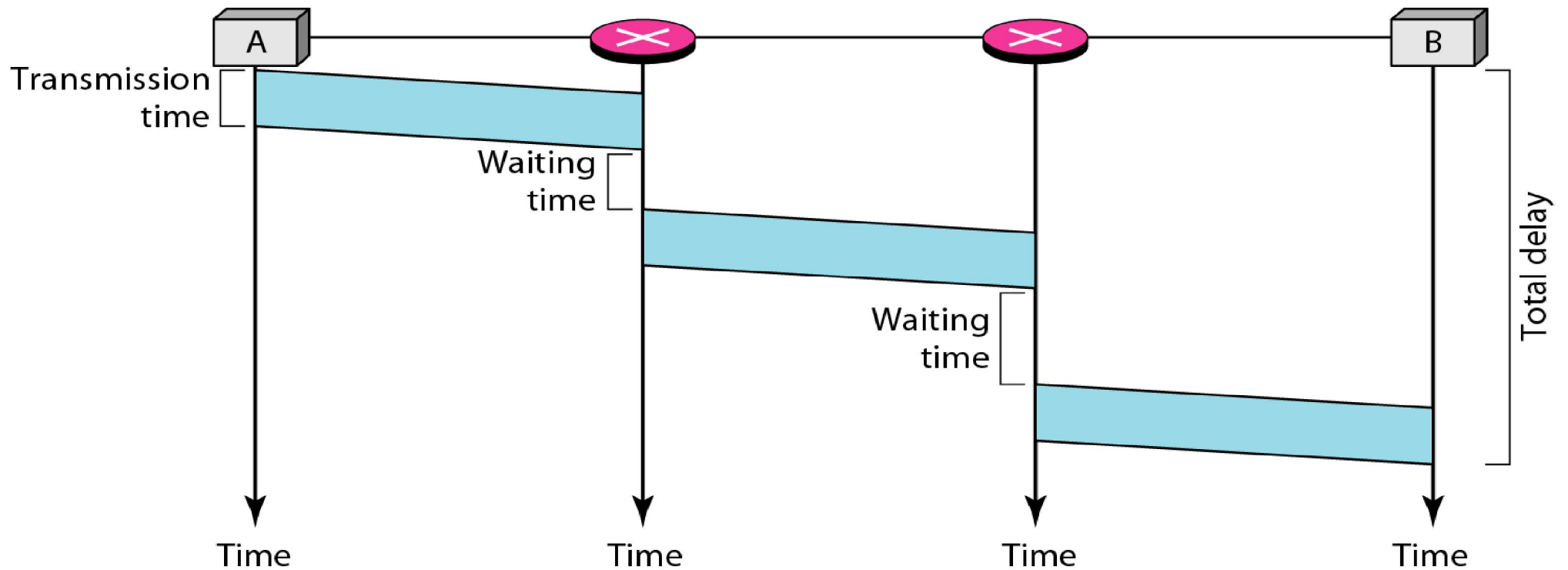
➤ The destination address in the header of a packet in a datagram network remains the same during the entire journey of the packet (*recall IP address*)

❑ 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



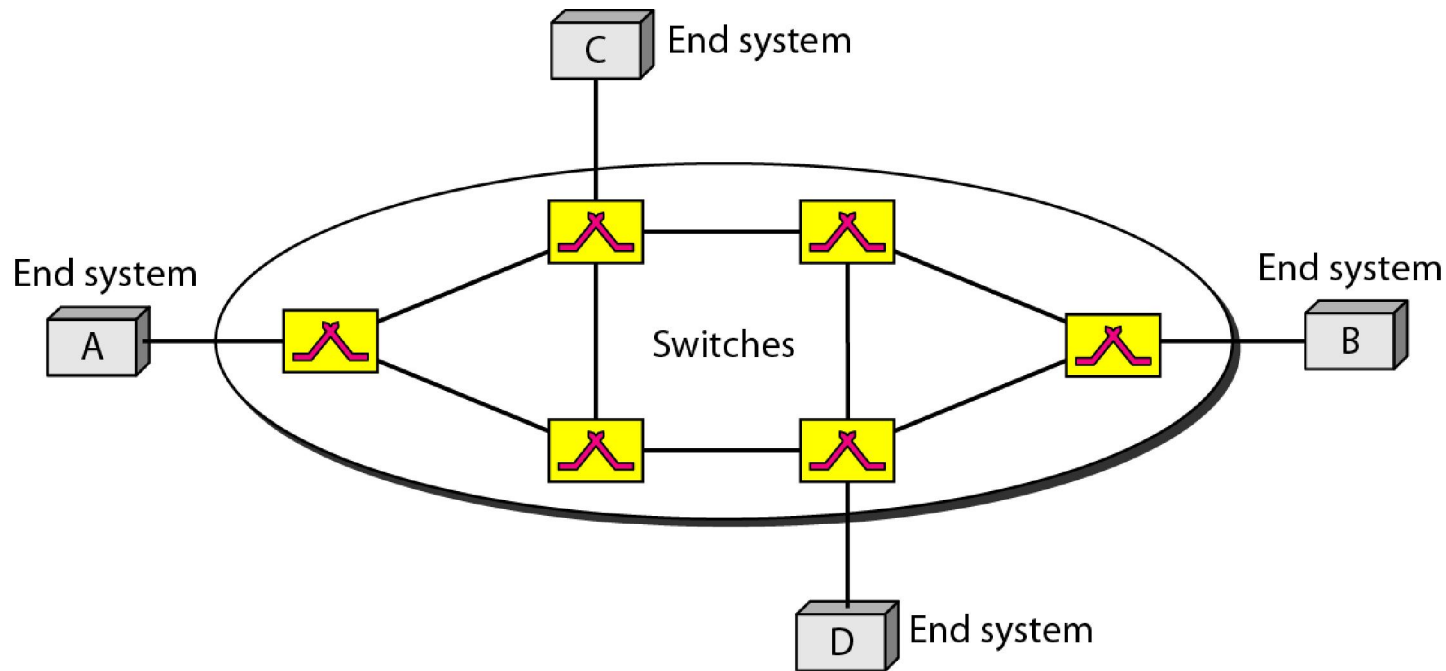
Delay in a datagram network



Virtual-circuit Approach

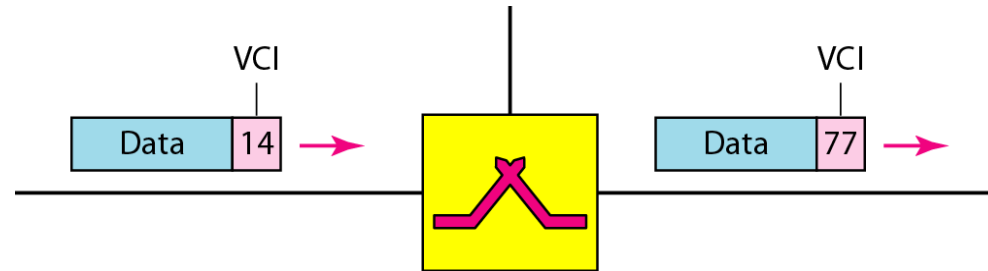
- ❑ A virtual-circuit network is a cross between a circuit-switched network and a datagram network. It has some characteristics of both.
 - ❑ As in a circuit-switched network, there are setup and teardown phases in addition to the data transfer phase.
 - ❑ Resources can be allocated during the setup 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 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.

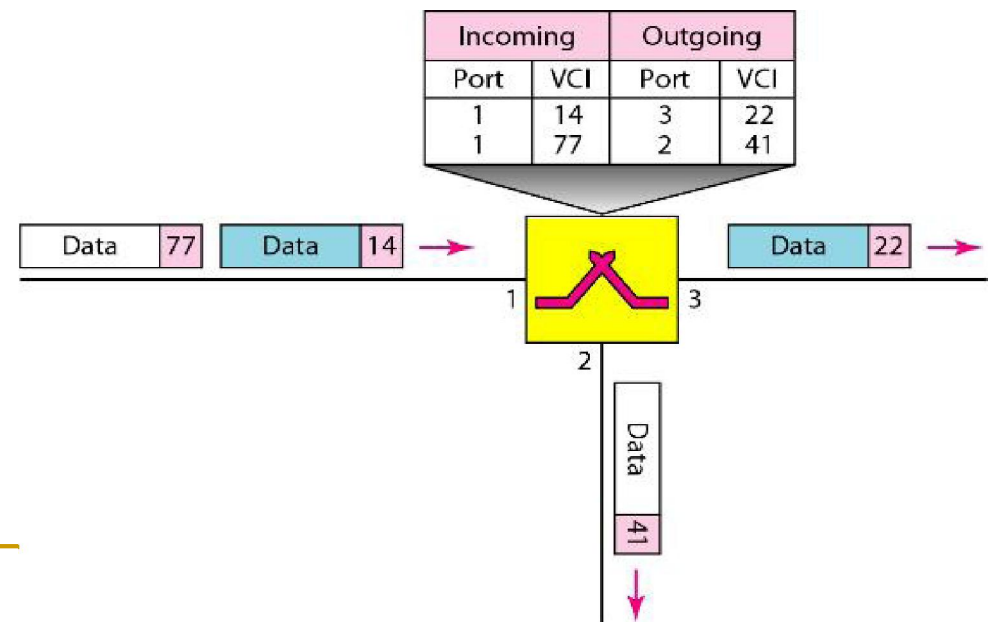
Virtual Circuit Addressing



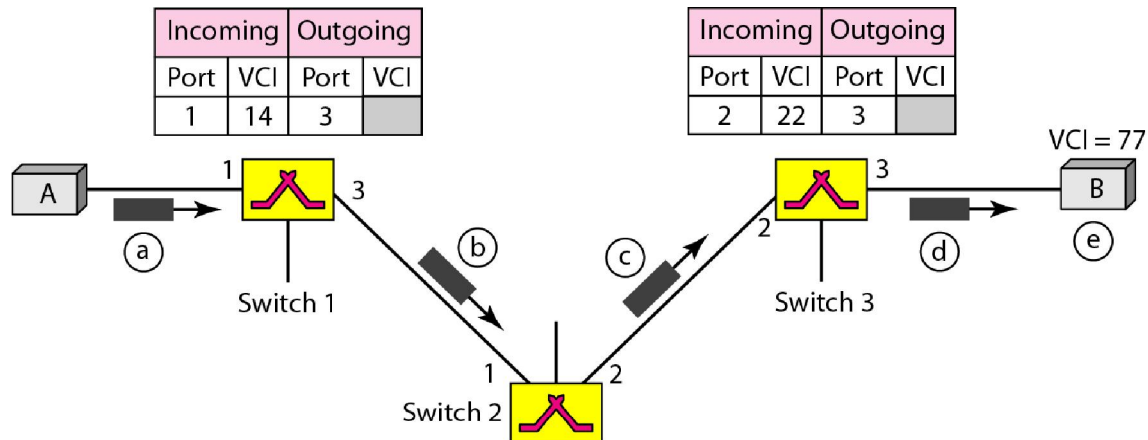
- ❑ In a virtual-circuit network, two types of addressing are involved: global and local (virtual-circuit identifier).
- ❑ *Global Addressing* : A source or a destination needs to have a global address—an address that can be unique in the scope of the network. However, a global address in virtual-circuit 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

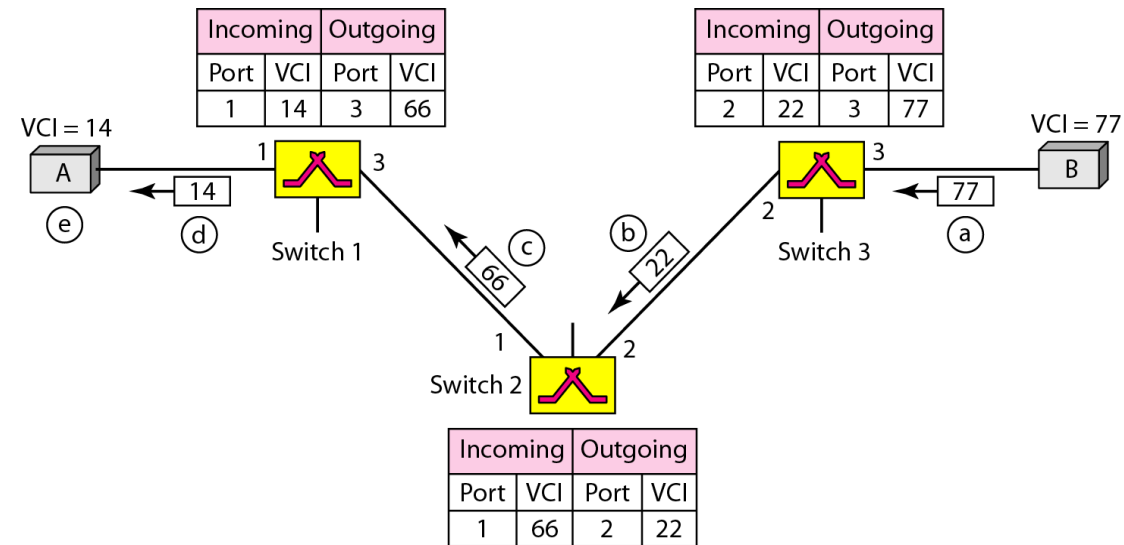
- ❑ Three phases of operations : Establish circuit, Data transfer, and Teardown circuit.
- ❑ Pre-planned route or '**circuit**' established between source & destination before any data packets sent
- ❑ Each node maintains information about each virtual circuit passing through itself, in a table
- ❑ Each 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



Setup Circuit Phase

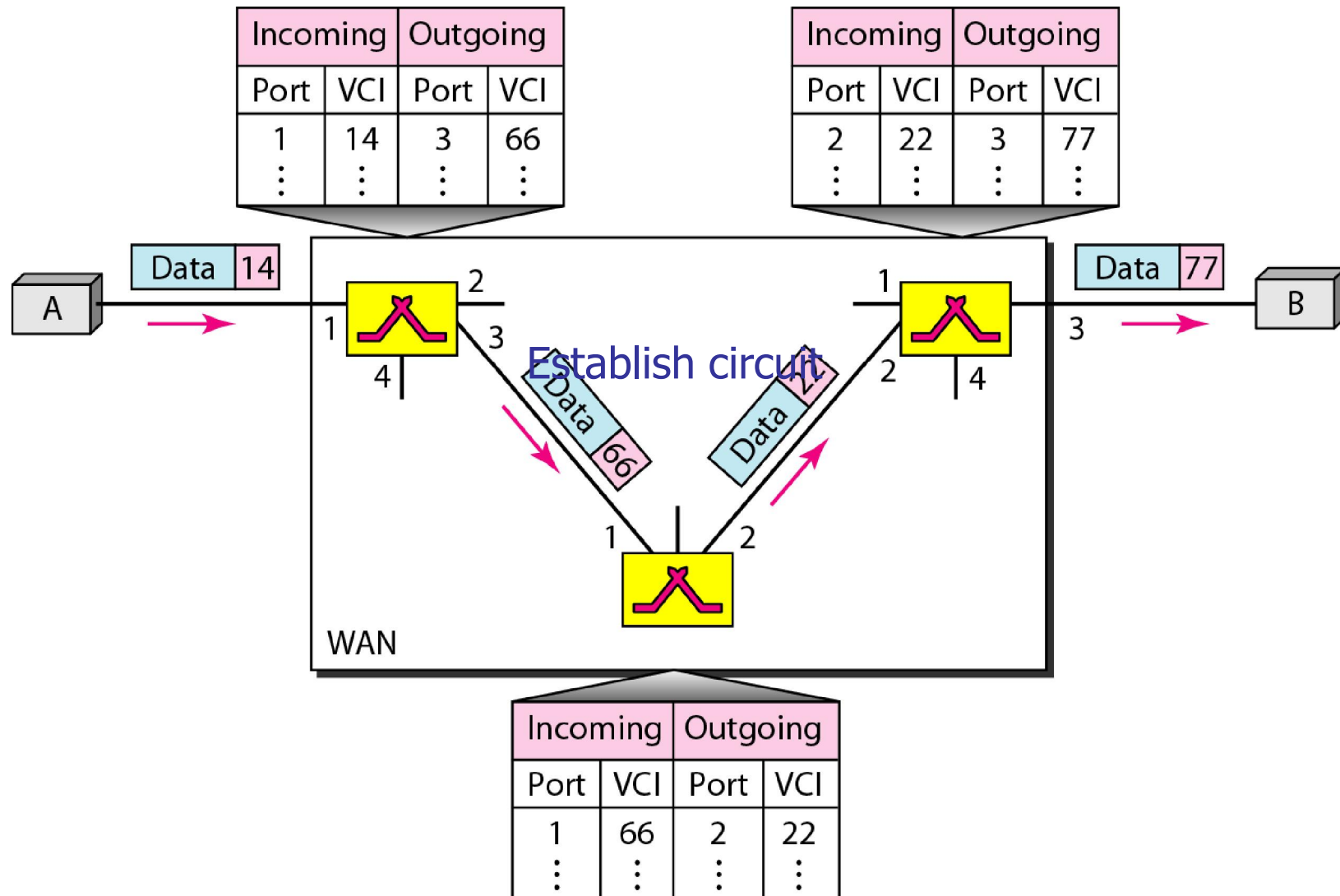


SetupRequest



SetupAck

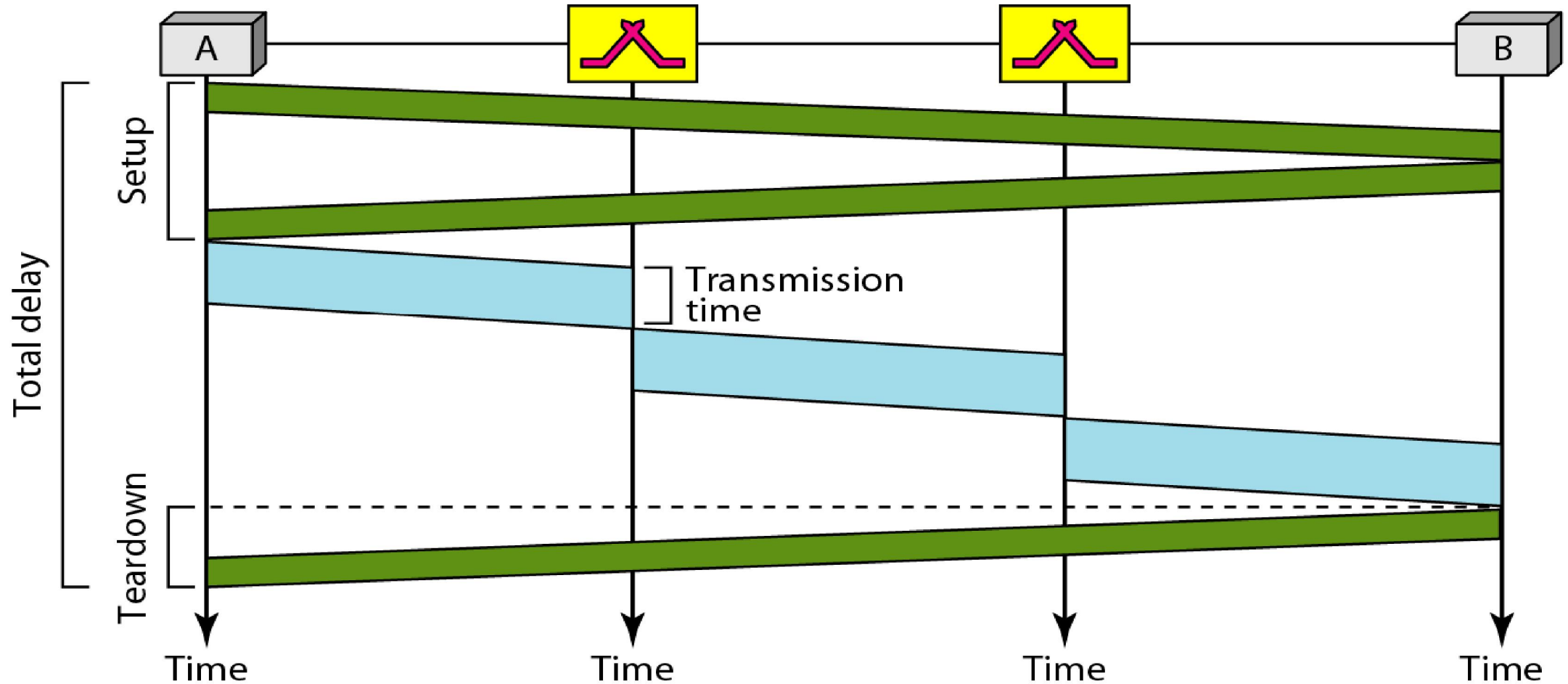
Data Transfer Phase



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.
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Virtual Circuit vs Datagram

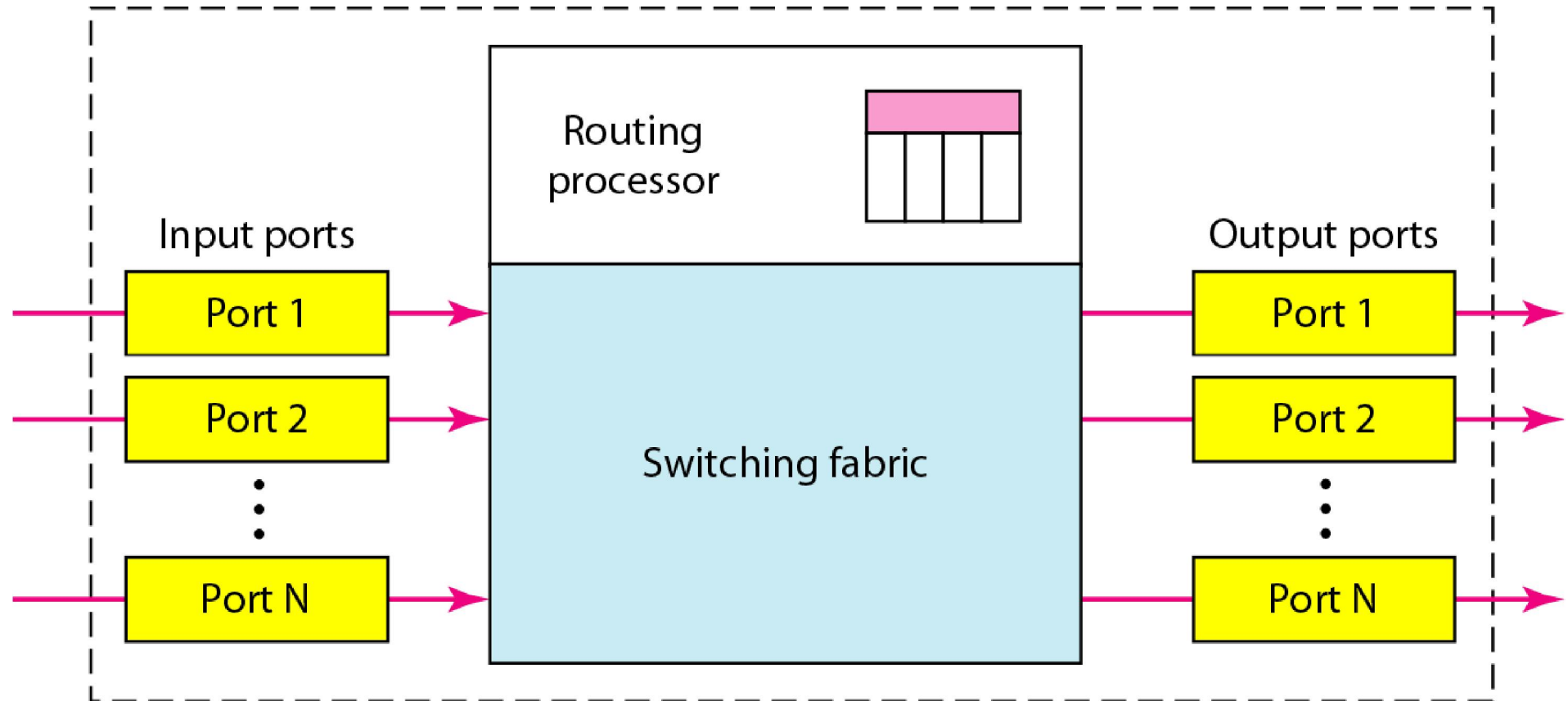
❑ Virtual circuit

- 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*
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