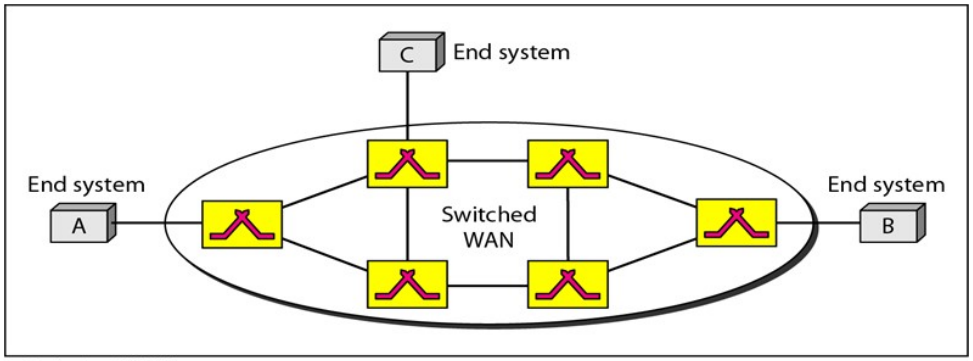
Data Communication and Computer Network

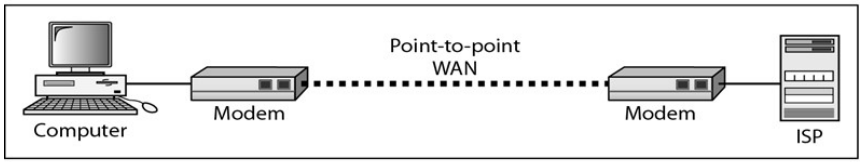
Wide Area Network and Switching

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).



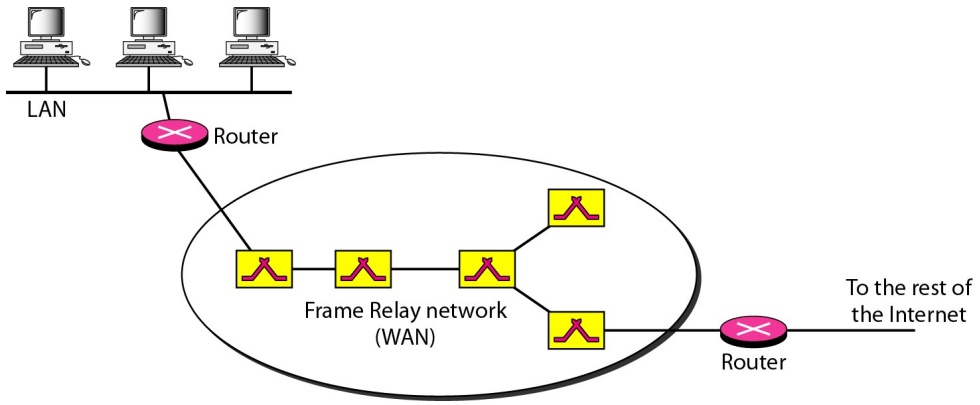
a. Switched WAN



b. Point-to-point WAN

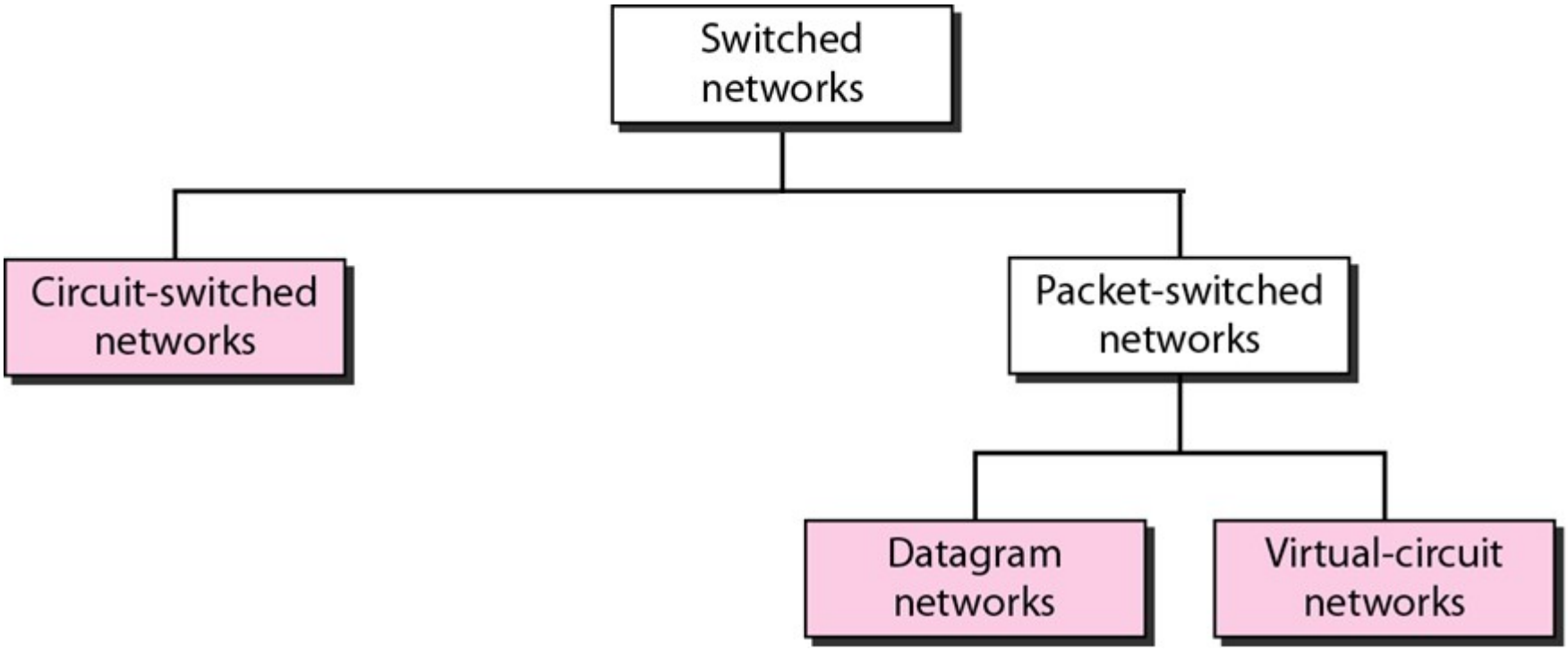
Switched WAN

- 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

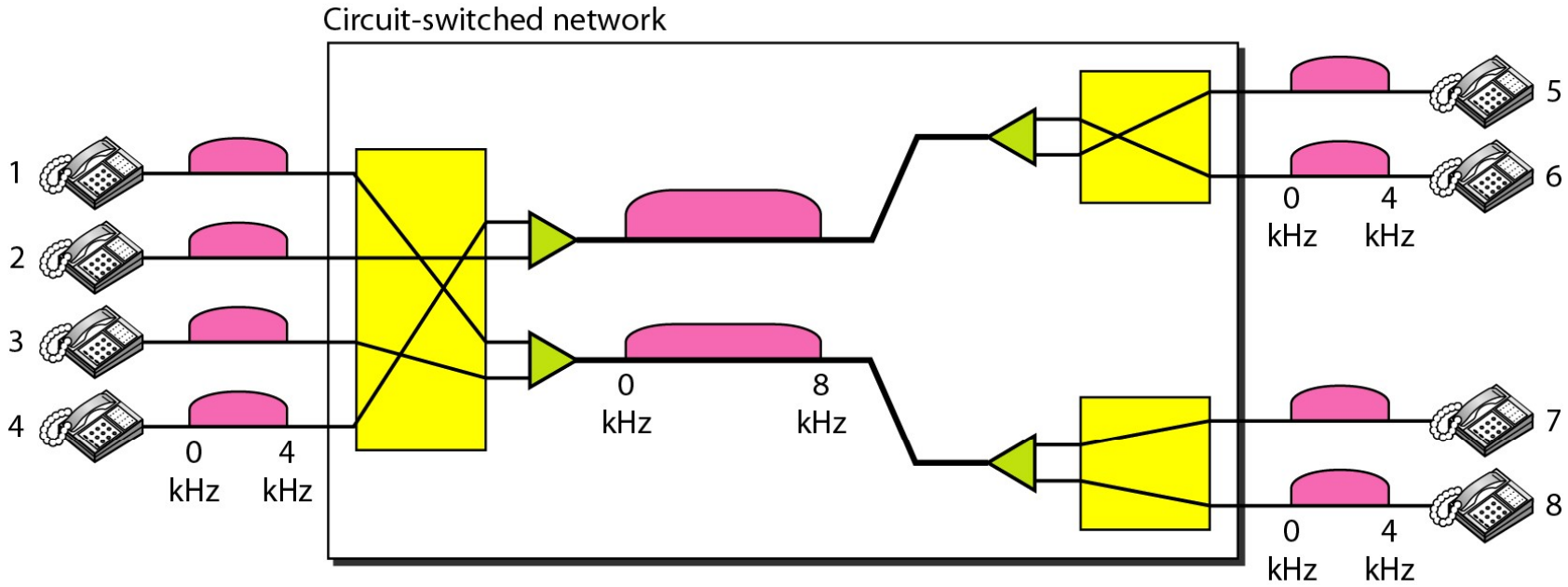
- Before sending data, a dedicated communication path (circuit) set up between source node & destination node, using intermediate nodes
- Three phases
  - Establish: signaling to set up the path
  - Transfer: transfer data through the path
  - Disconnect: signaling to tear down connection
- Links in 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

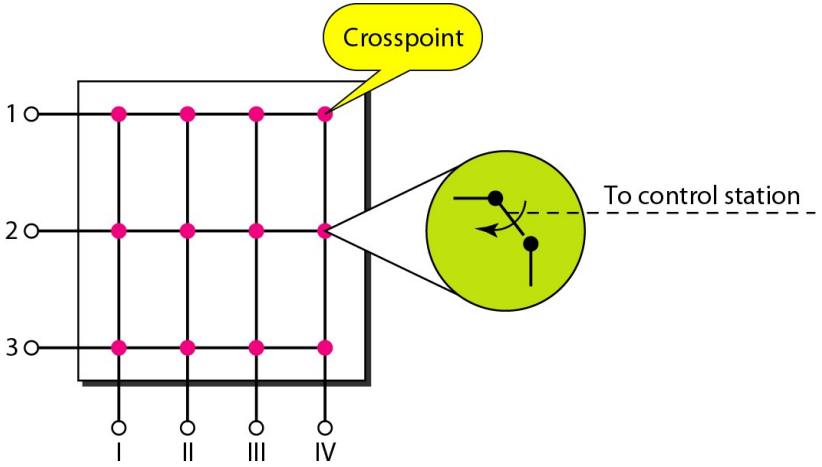
An example of Circuit-switched network



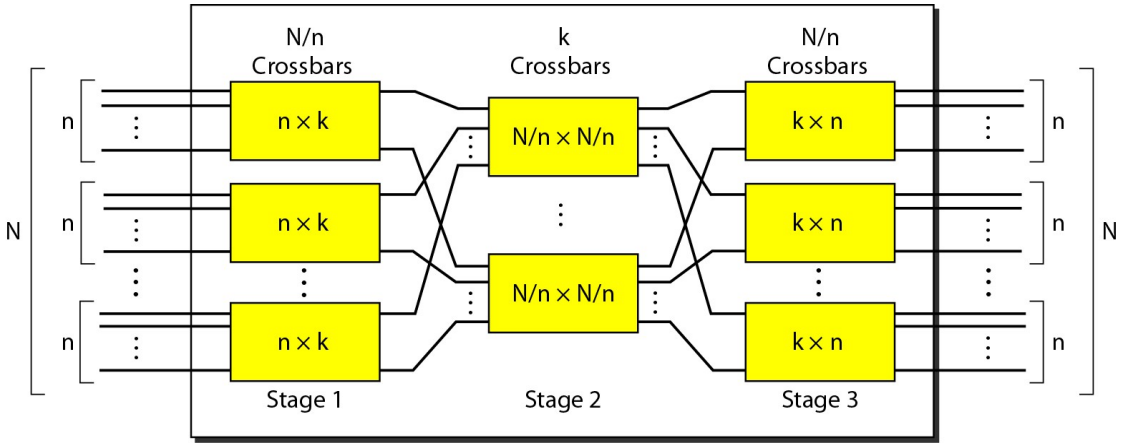
Here assumed that each link uses FDM to connect maximum two voice channels. Bandwidth of each link is then 8KHz.

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

Switches in circuit-switched network

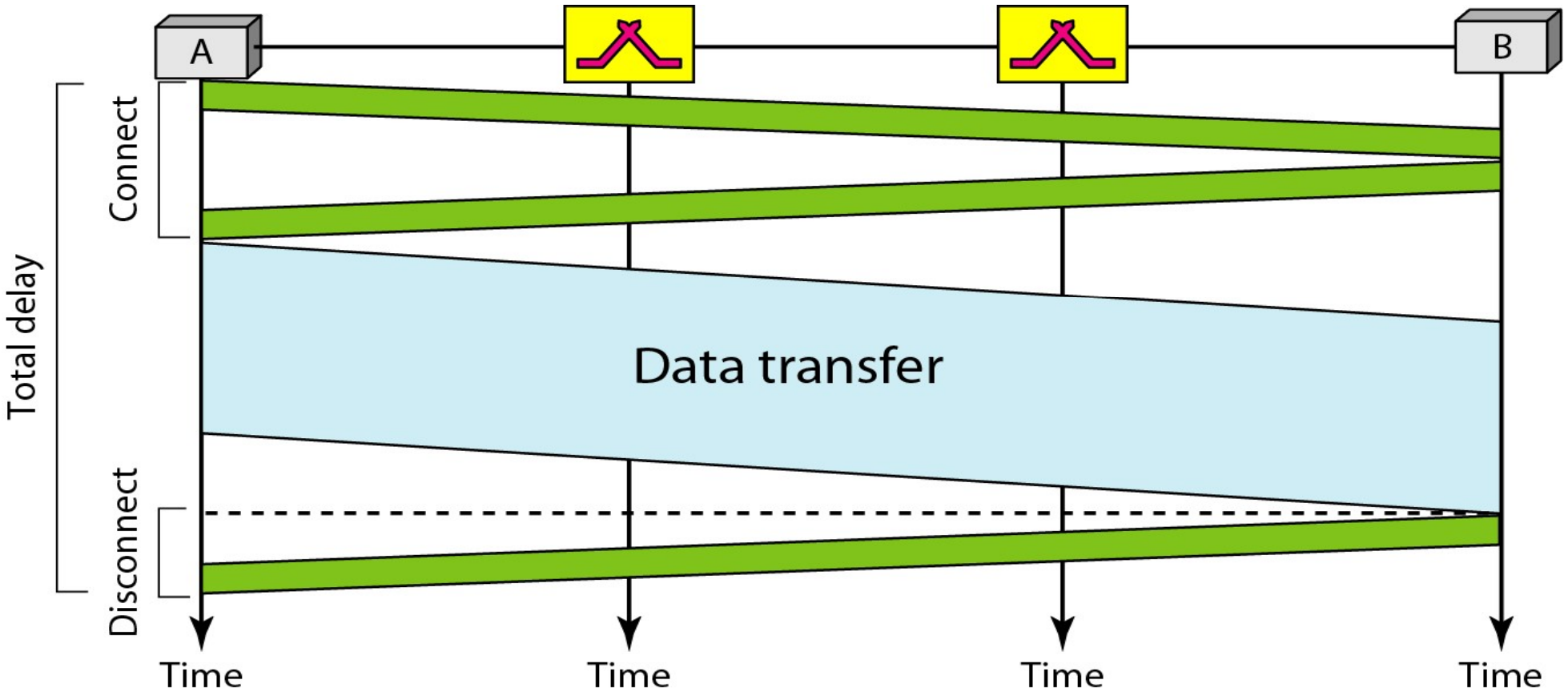


Crossbar switch with three inputs and four outputs



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

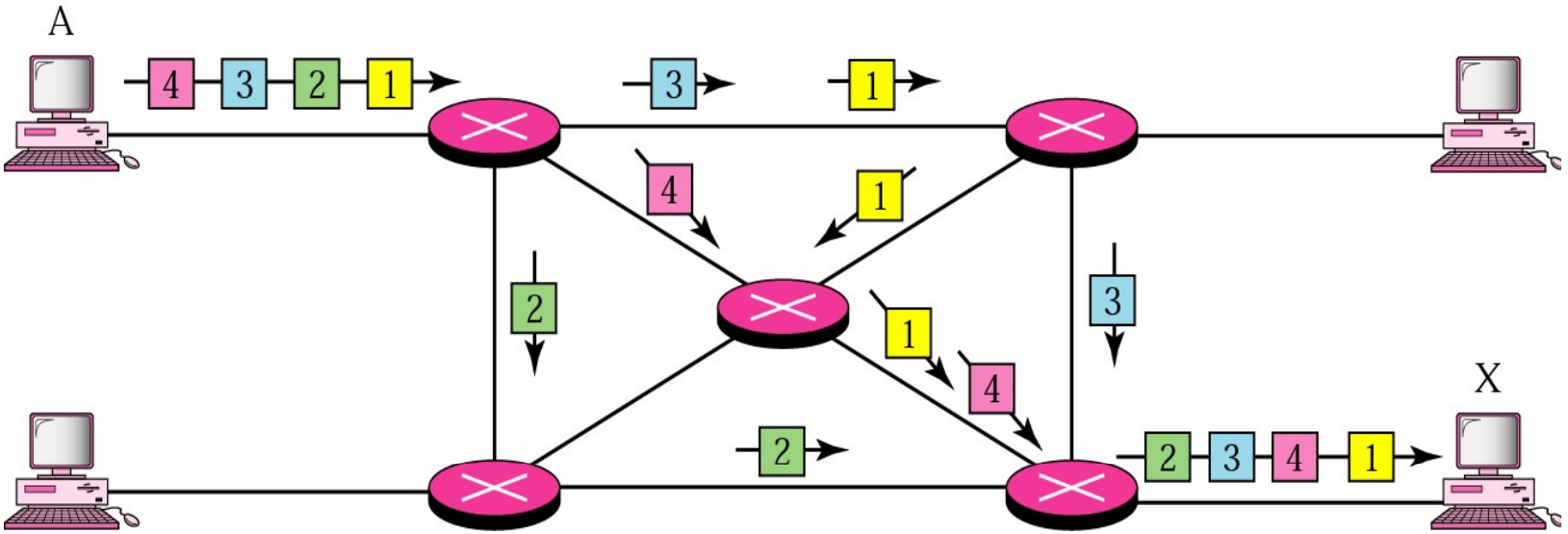
Advantages of packet switching

- 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

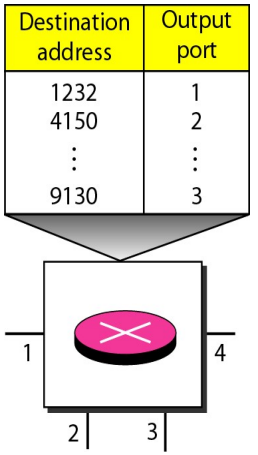
Datagram approach

- 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

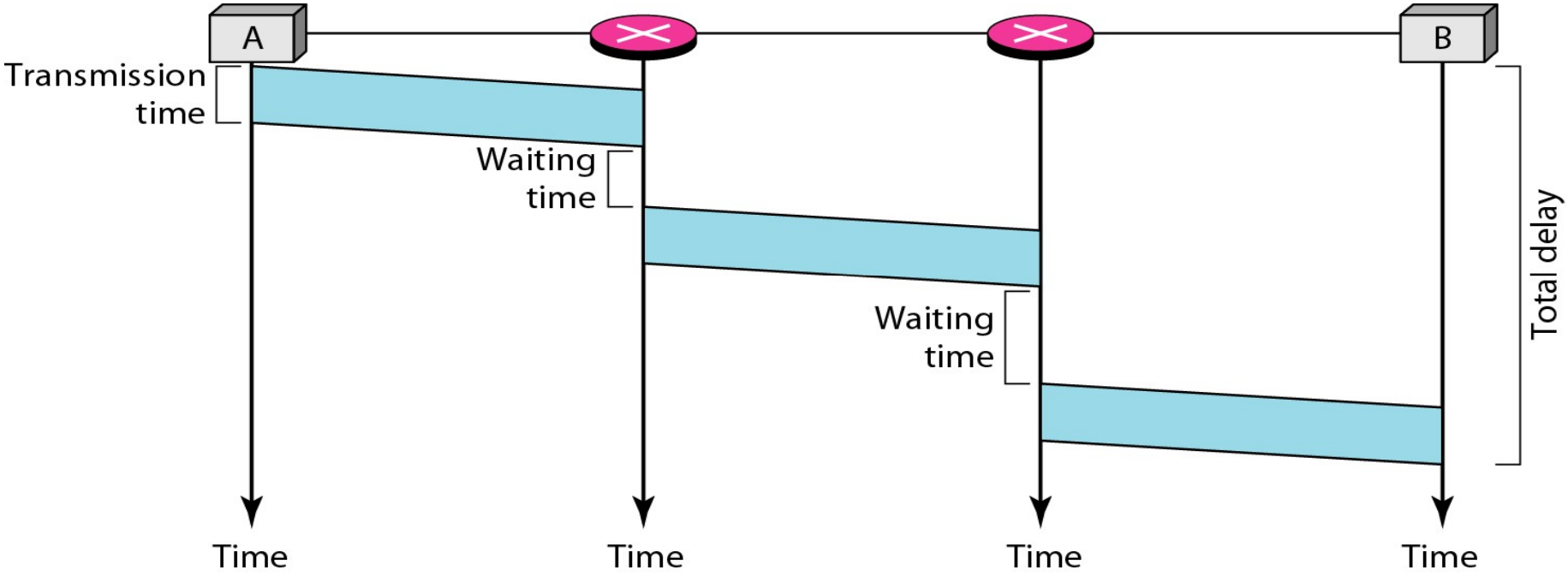


- **A switch in a datagram network uses a routing table that is based on the destination address.**
  - **The destination address in the header of a packet in a datagram network remains the same during the entire journey of the packet (*recall IP address*)**



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

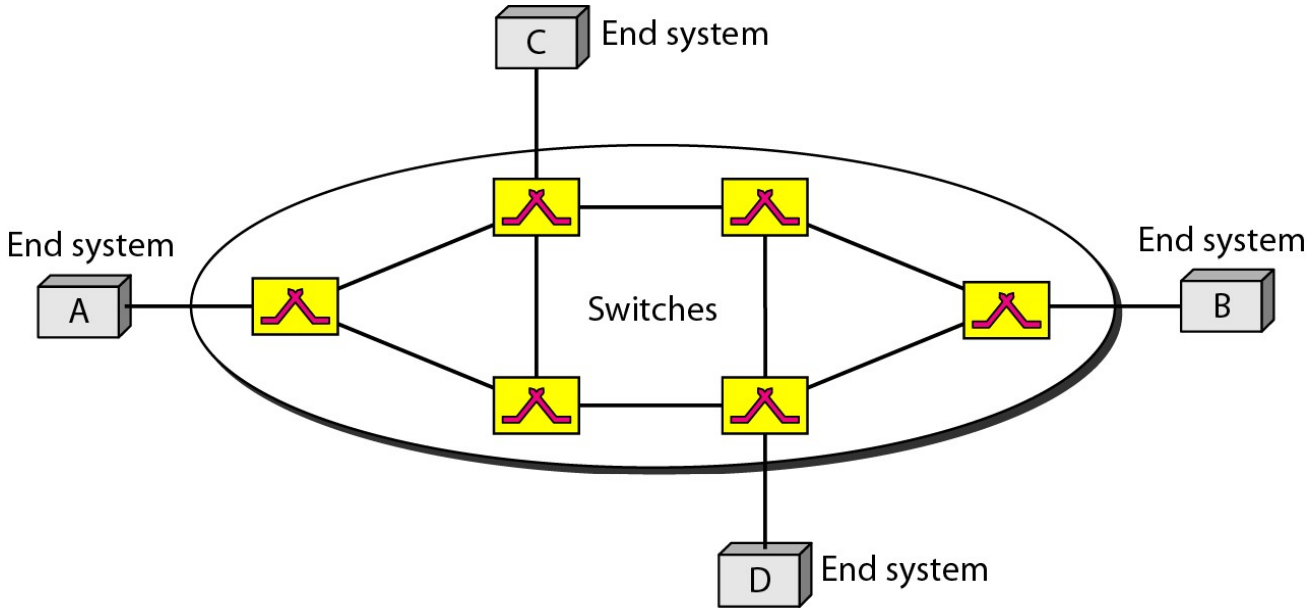
Delay in a datagram network



Virtual-circuit Approach

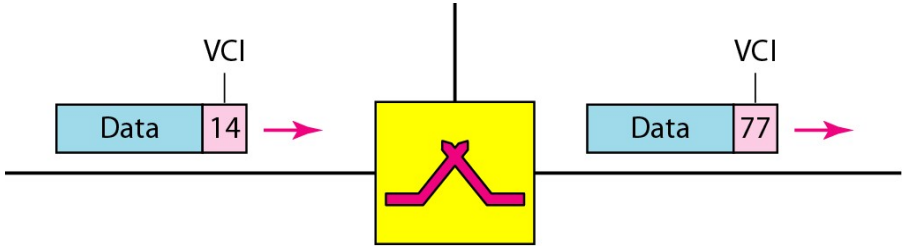
- A virtual-circuit network is a cross between a circuit-switched network and a datagram network. It has some characteristics of both.
- As in a circuit-switched network, there are setup and teardown phases in addition to the data transfer phase.
- Resources can be allocated during the setup phase, as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

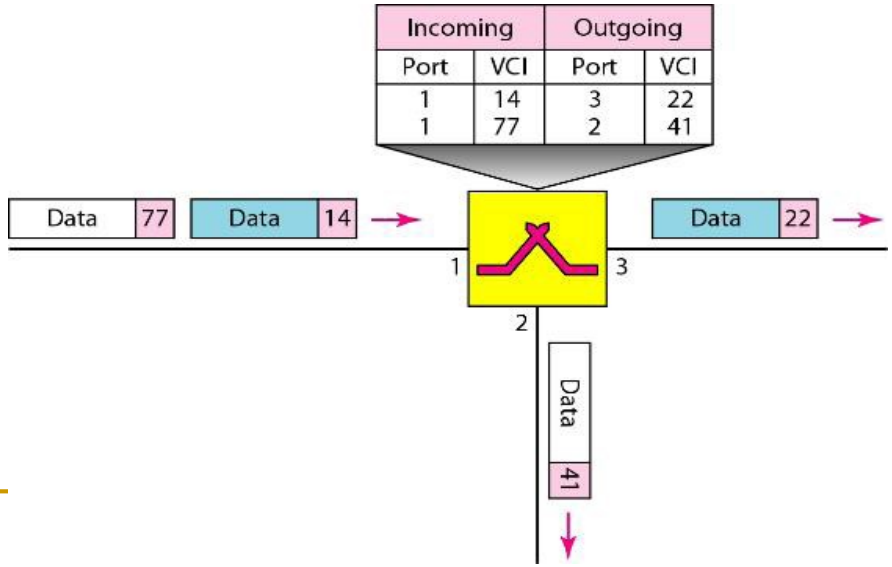
Virtual Circuit Addressing



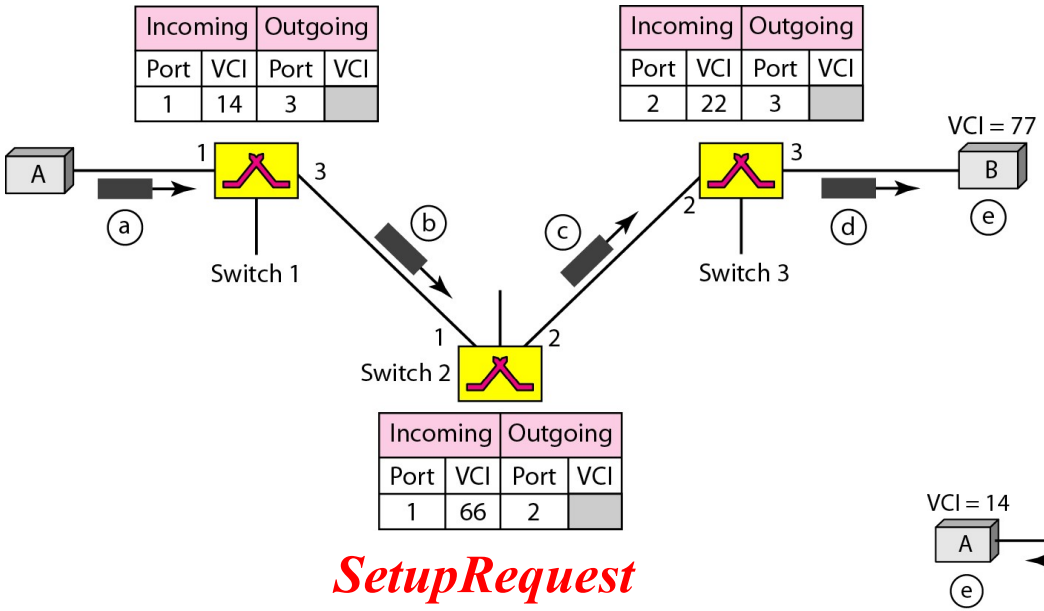
- In a virtual-circuit network, two types of addressing are involved: global and local (virtual-circuit identifier).
- *Global Addressing :* A source or a destination needs to have a global address-an address that can be unique in the scope of the network. However, a global address in virtual-circuit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

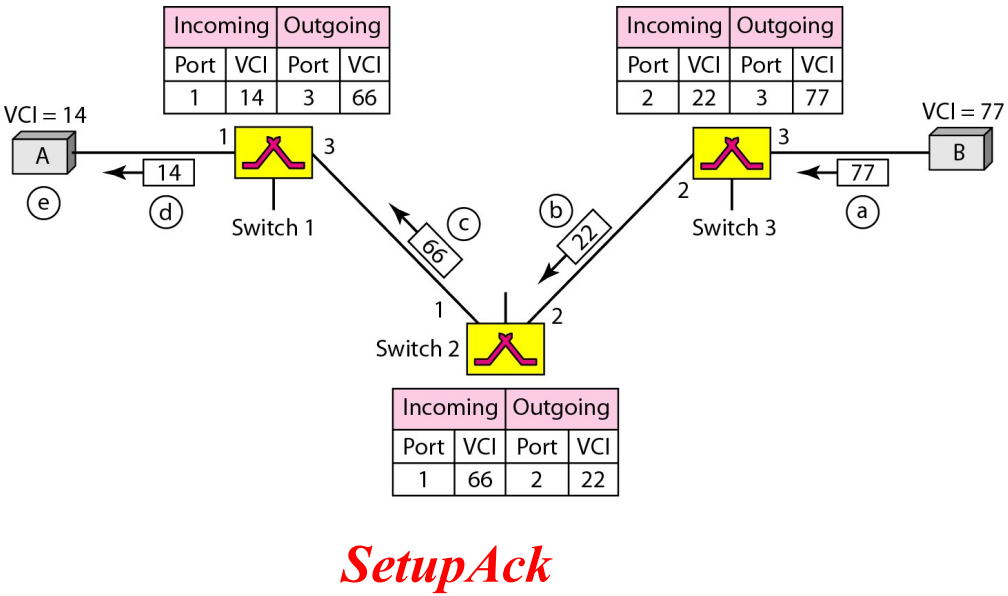
Virtual Circuit Technique

- 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

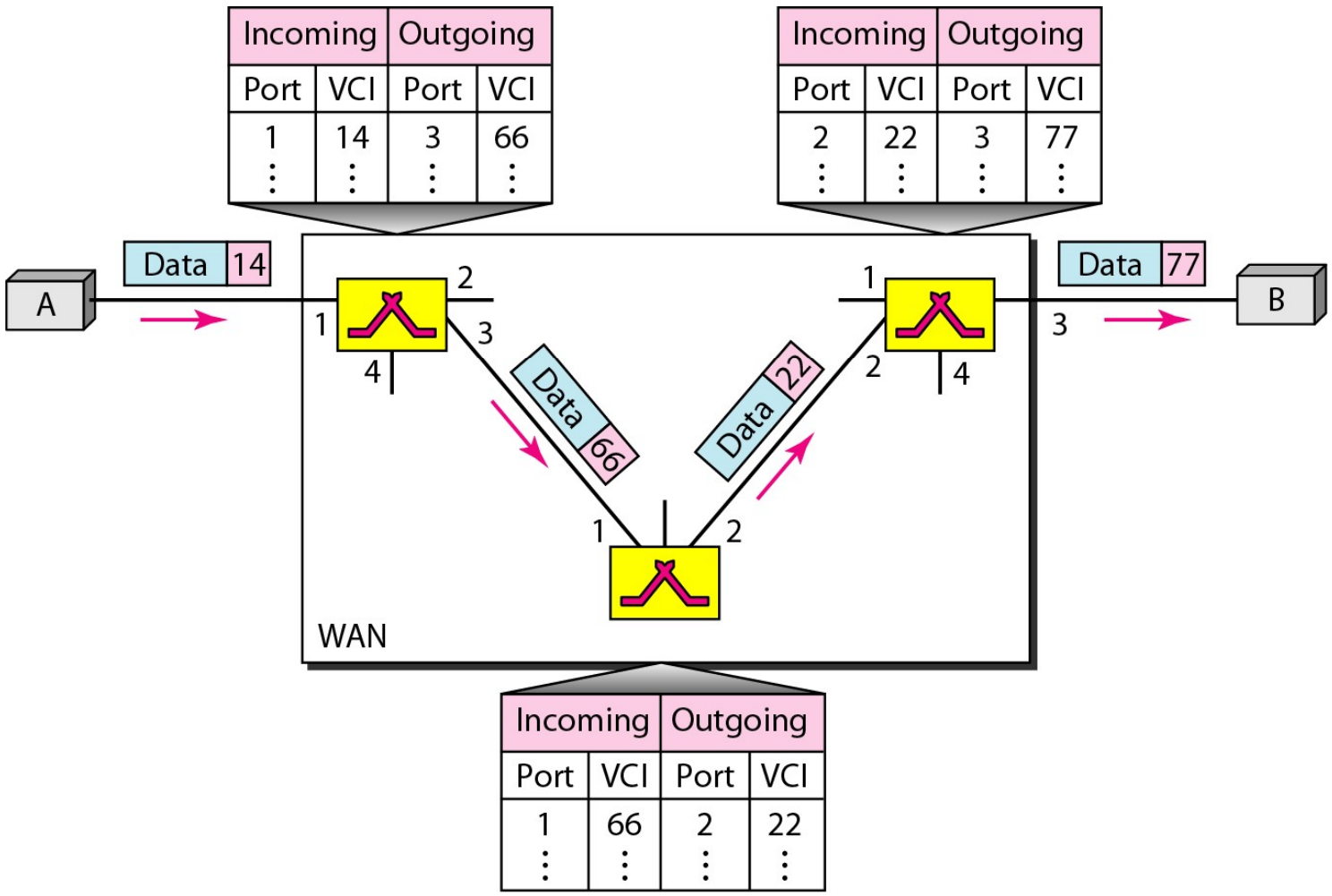


Setup Circuit Phase





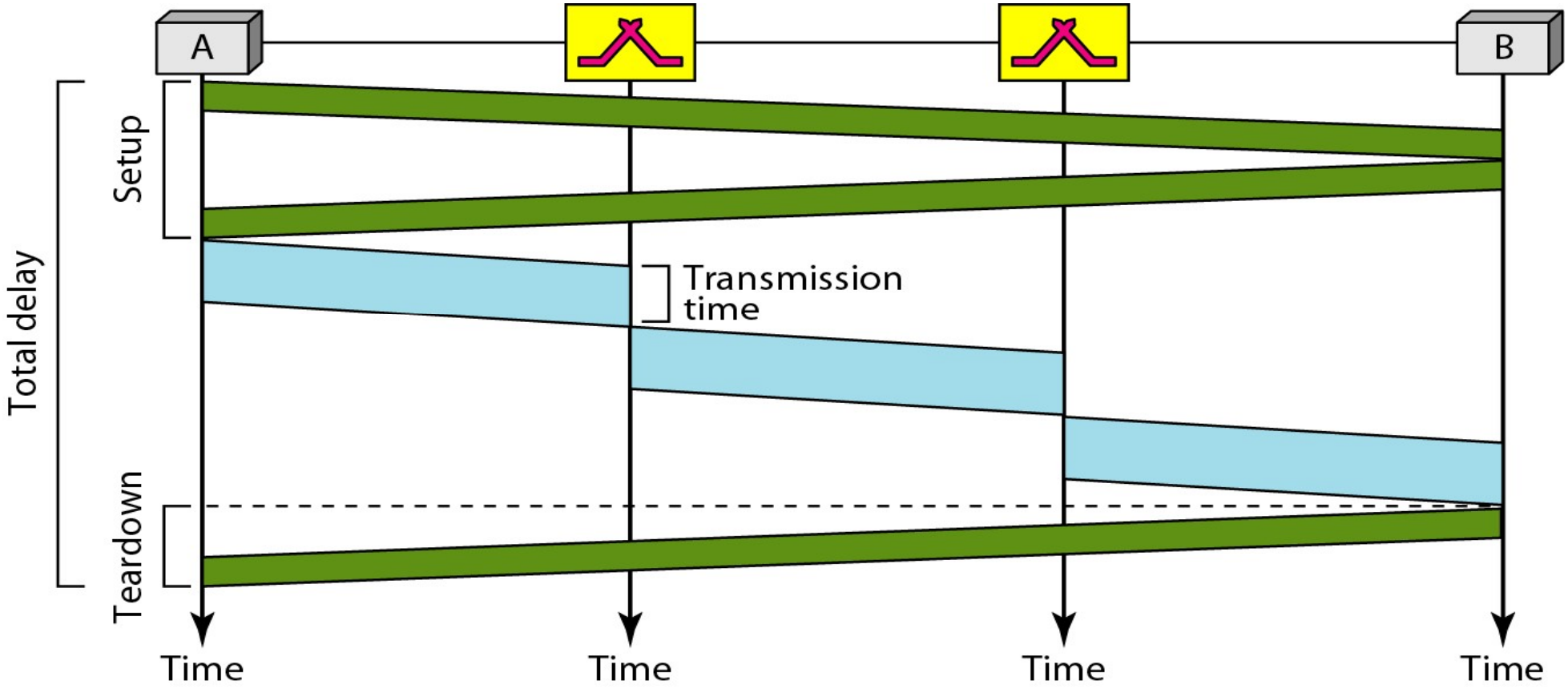
Data Transfer Phase



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.

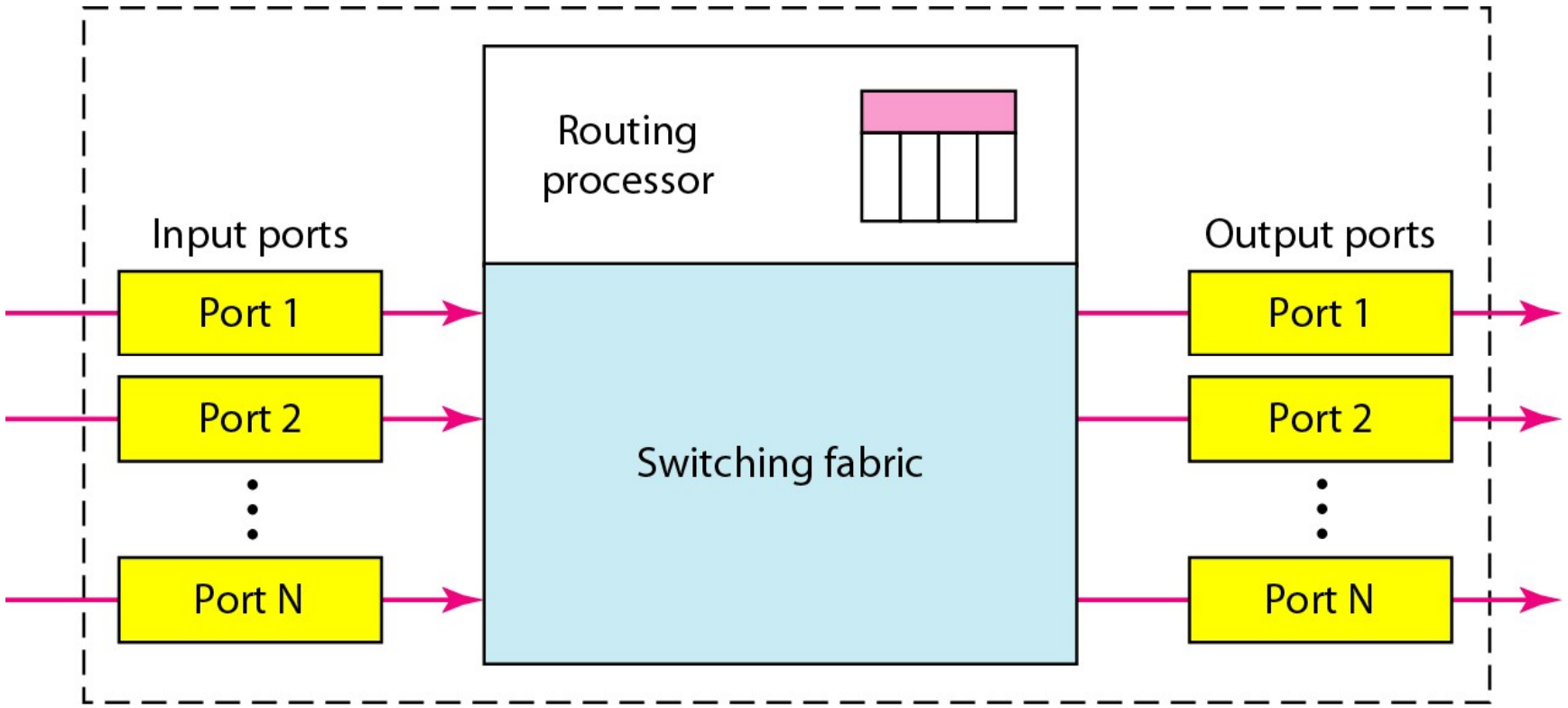
- **Frame Relay** is a virtual-circuit wide-area network that was designed in response to demands for a new type of WAN in the late 1980s and early 1990s. It operates at a higher speed (1.544 Mbps and recently 44.376 Mbps).

- **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*