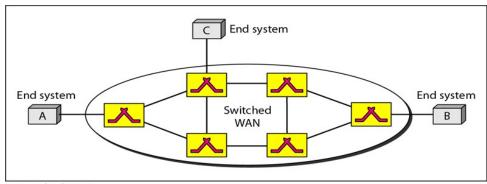
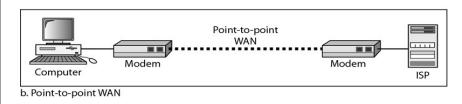
Data Communication and Computer Network

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

Switched WAN

- Network spread over large geographic area
 - > All nodes in WAN may not be directly connected to each other

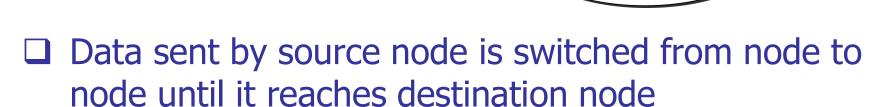
Router

Frame Relay network

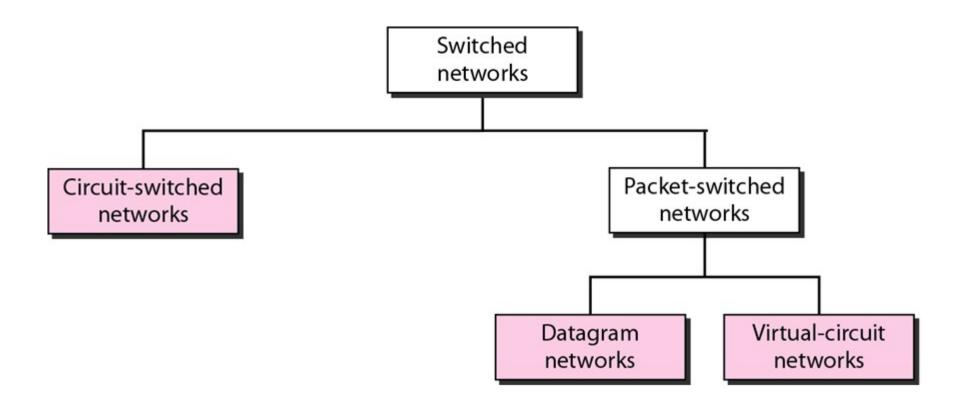
To the rest of

the Internet

- Some redundant connections (multiple paths) desirable for reliability
- Communication network: collections of nodes and connections
- Nodes of two types
 - > End devices
 - Switching nodes



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.)

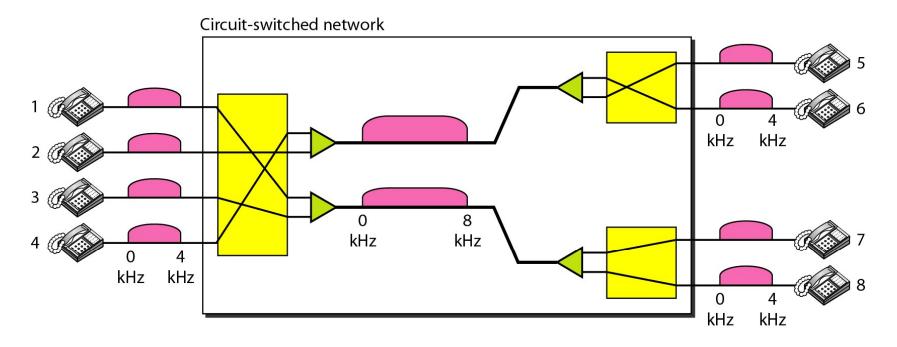
Advantages

- > 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

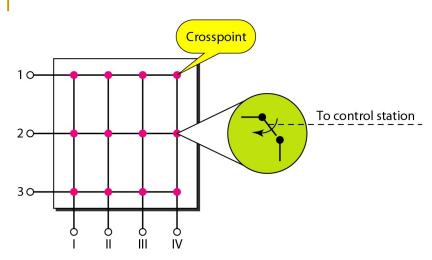
An example of Circuit-switched network



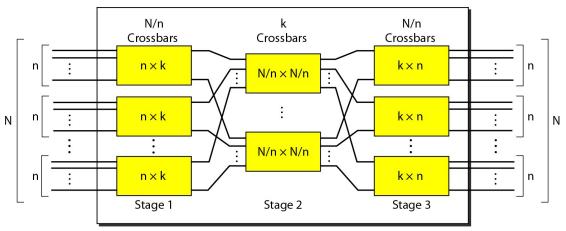
Here assumed that each link uses FDM to connect maximum two voice channels. Bandwidth of each link is then 8KHz.

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

Switches in circuit-switched network

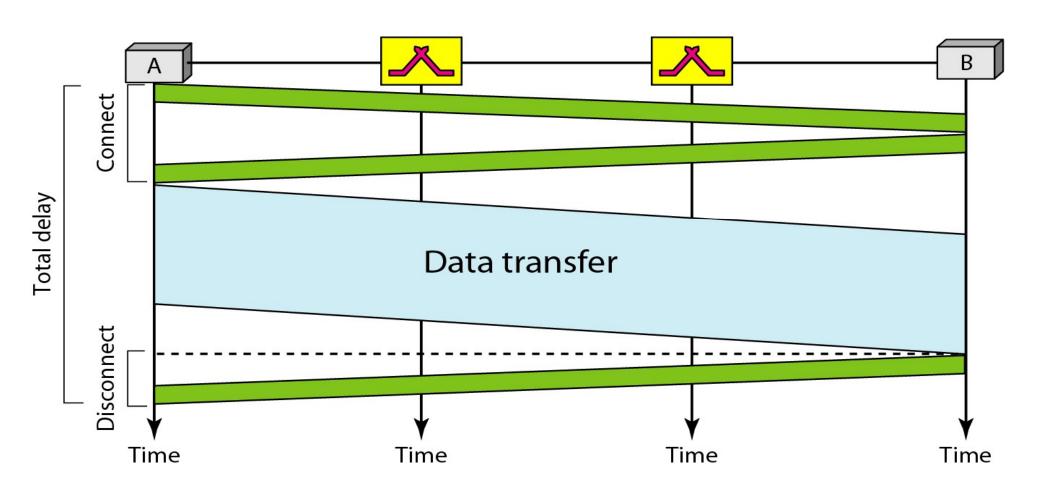


Crossbar switch with three inputs and four outputs



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

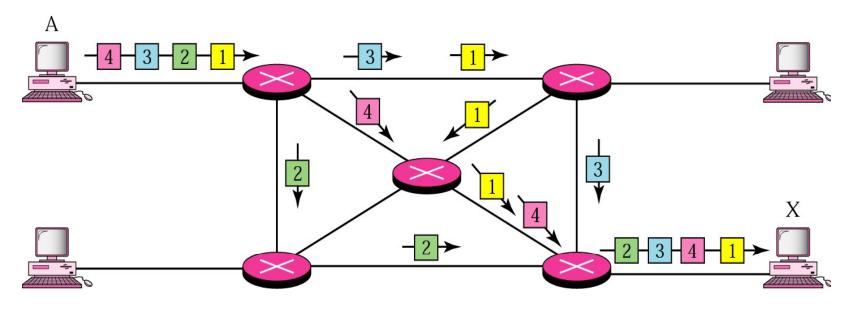
Advantages of packet switching

- ☐ 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

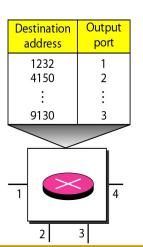
Datagram approach

- □ 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

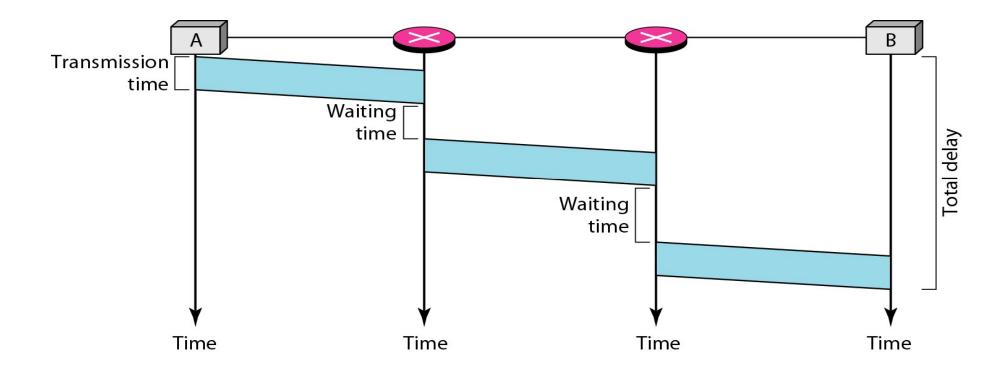
Datagram Approach



- ☐ 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



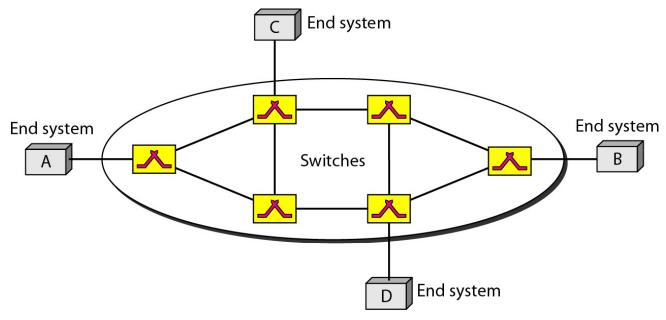
Delay in a datagram network



Virtual-circuit Approach

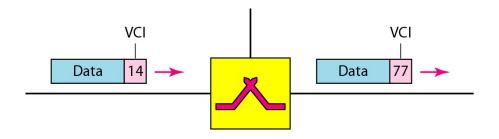
- ☐ A virtual-circuit network is a <u>cross between a circuit-switched network</u> and a datagram network. It has some characteristics of both.
- □ As in a circuit-switched network, there are setup and teardown phases in addition to the data transfer phase.
- Resources can be allocated during the setup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



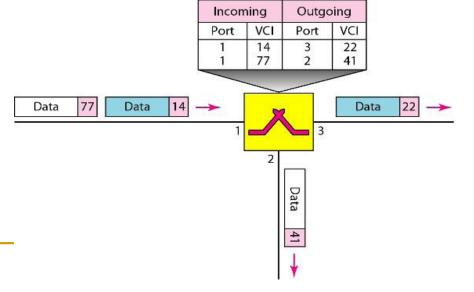
- ☐ In a virtual-circuit network, two types of addressing are involved: global and local (virtual-circuit identifier).
- ☐ Global Addressing: A source or a destination needs to have a global address-an address that can be unique in the scope of the network. However, a global address in virtual-circuit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

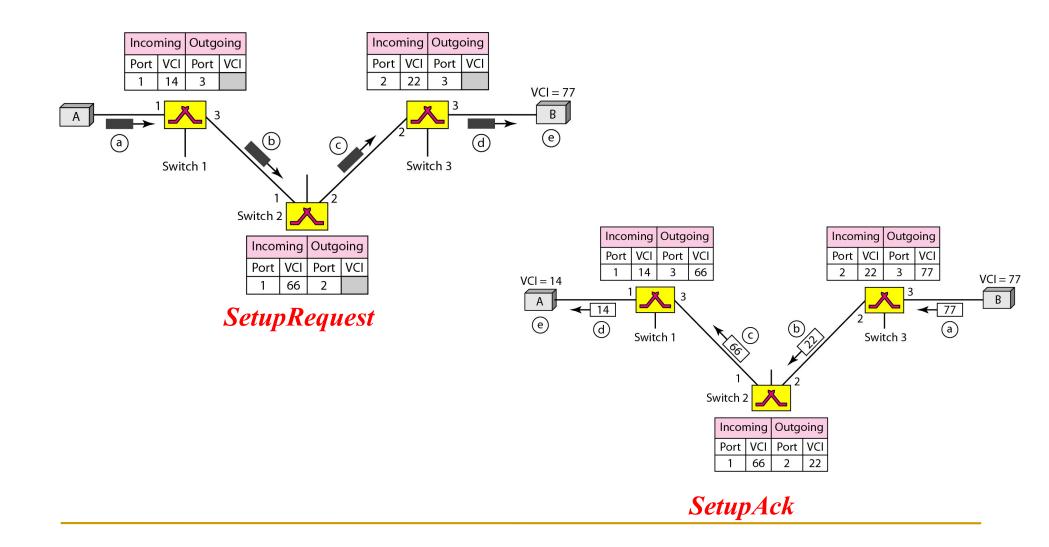
- □ Three phases of operations : Establish circuit, Data transfer, and Teardown circuit.
- □ Pre-planned route or 'circuit' established between source & destination before any data packets sent
- ☐ Each node maintains information about each virtual circuit passing through itself, in a table
- ☐ Each packet contains a Virtual Circuit Identifier (VCI) instead

of destination address

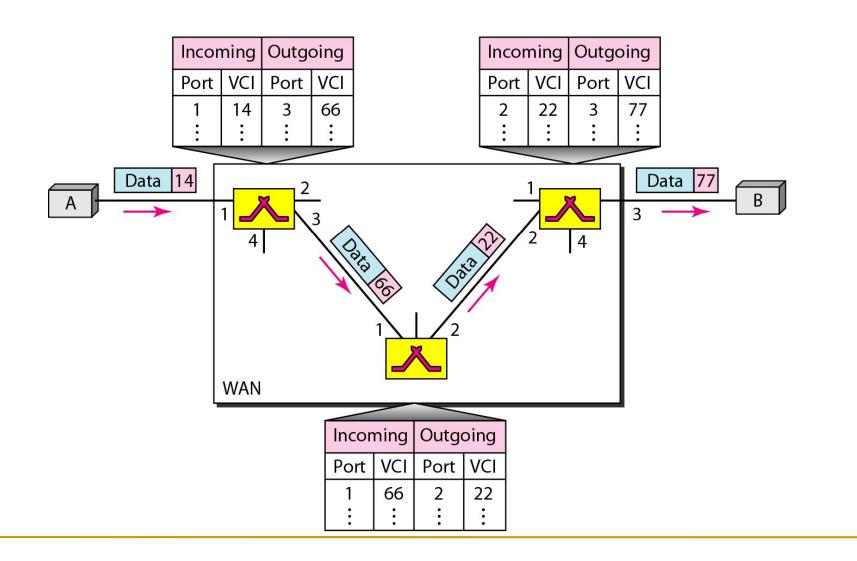
 □ The links in a path are NOT dedicated – may be shared among different virtual circuits



Setup Circuit Phase



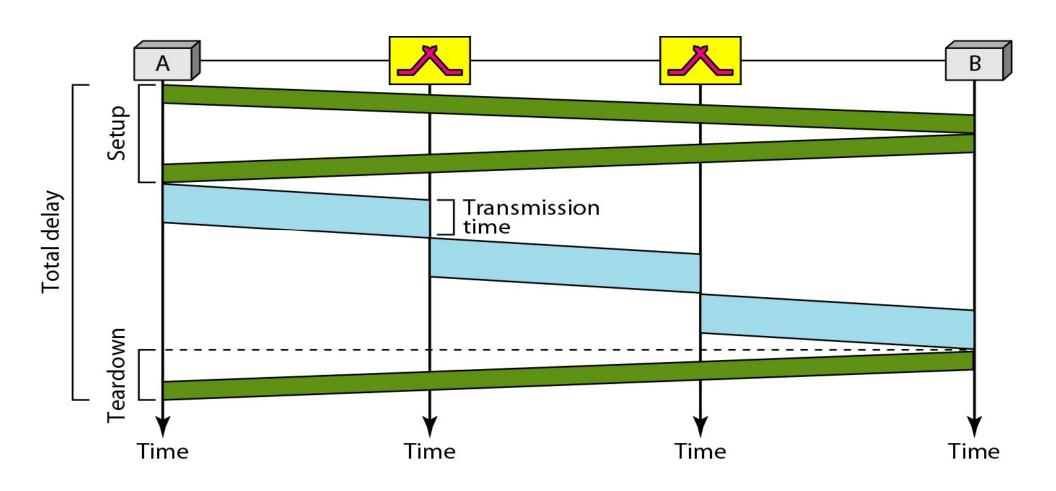
Data Transfer Phase



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 packetswitched 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

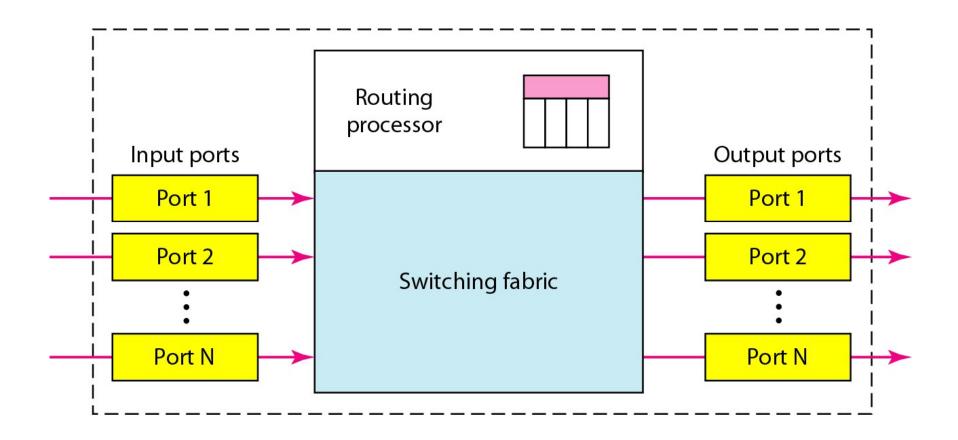
□ Virtual circuit

- 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