Two Key Network-Layer Functions

forwarding: move packets from router's input to appropriate router output

routing: determine route taken by packets from source to destination.

- *routing algorithms*

A router is a switch that creates a connection between an input port and an output port.

Switching Techniques

In large networks there might be multiple paths linking sender and receiver. Information may be switched as it travels through various communication channels.

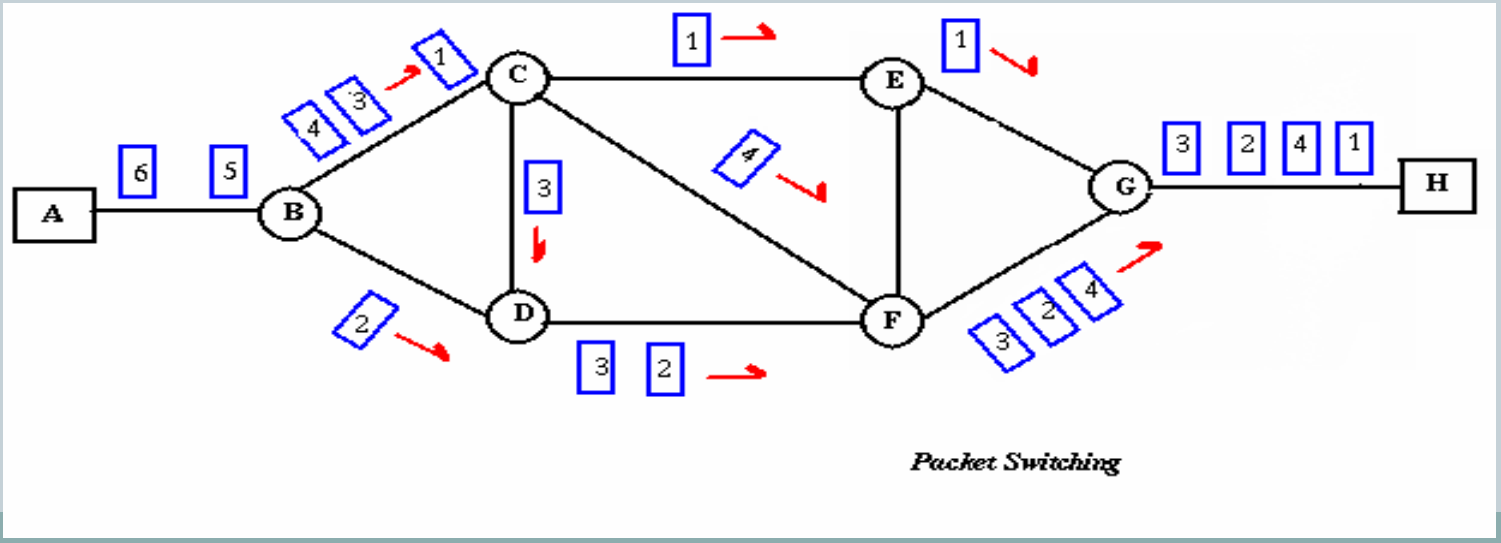
- Circuit Switching used in physical layer.
- Packet Switching used in network layer

Packet Switching

Packet switching is the approach used by some computer network protocols to deliver data across a local or long-distance connection. Examples of packet switching protocols are Frame Relay, IP, and X.25.

Packet switching entails breaking data into a number of parts that are then packaged in specially formatted units called packets. These are typically routed from source to destination using network switches and routers and then the data is reassembled at the destination.

- two methods of packet switching: Datagram and virtual circuit



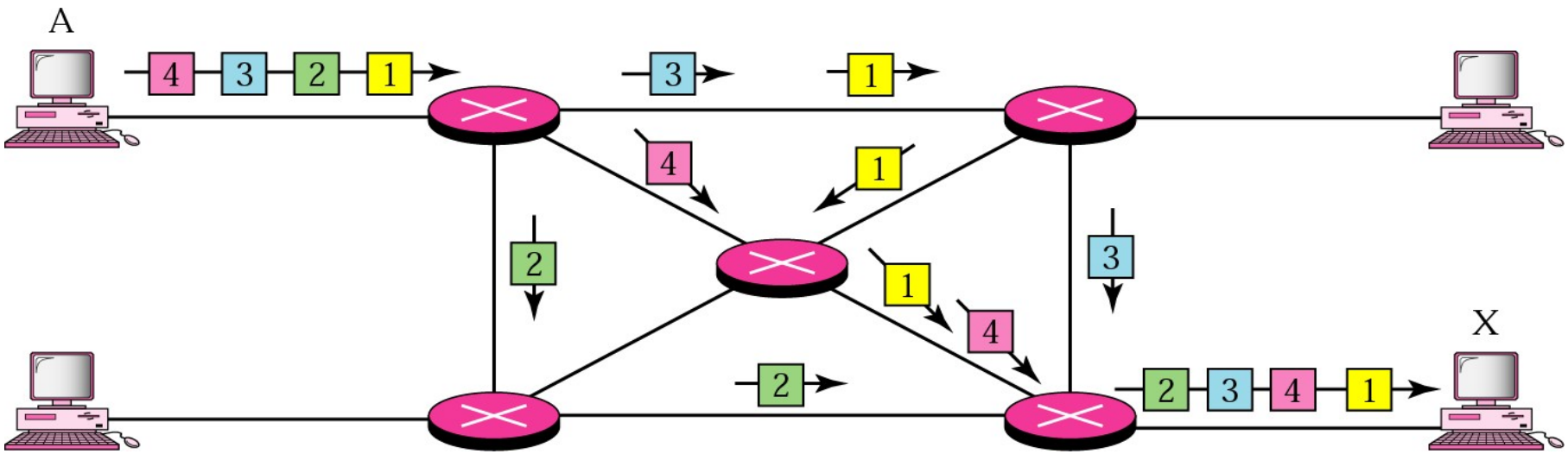
Packet Switching

- Each packet is tagged with appropriate source and destination addresses and the size of the packet can vary
- Since packets have a strictly defined maximum length, they can be stored in main memory instead of disk, therefore access delay and cost are minimized.
- Also the transmission speeds, between nodes, are optimized.
- With current technology, packets are generally accepted onto the network on a first-come, first-served basis. If the network becomes overloaded, packets are delayed or discarded (``dropped").

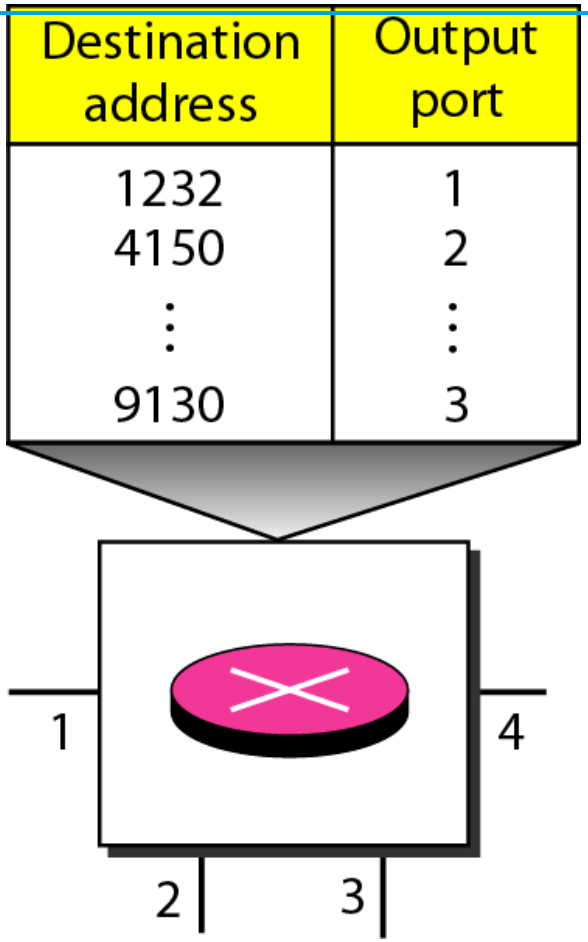
Datagram Approach: Connectionless service

- Each packet is a self-contained unit with complete addressing information attached.
- This fact allows packets to take a variety of possible paths through the network.
- So the packets, each with the same destination address, do not follow the same route, and they may arrive out of sequence at the exit point node (or the destination).
- Reordering is done at the destination point based on the sequence number of the packets.
- It is possible for a packet to be destroyed if one of the nodes on its way is crashed momentarily. Thus all its queued packets may be lost.

Datagram approach



Routing table in a datagram network



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

Packet Switching:Virtual Circuit

- In the virtual circuit approach, a preplanned route is established before any data packets are sent.
- A logical connection is established when
  - ➢ a sender send a "call request packet" to the receiver and
  - ➢ the receiver send back an acknowledge packet "call accepted packet" to the sender if the receiver agrees on conversational parameters.
- The conversational parameters can be maximum packet sizes, path to be taken, and other variables necessary to establish and maintain the conversation.
- Virtual circuits imply acknowledgements, flow control, and error control, so virtual circuits are reliable.
- That is, they have the capability to inform upper-protocol layers if a transmission problem occurs.

Packet Switching:Virtual Circuit

- In virtual circuit, the route between stations does not mean that it is a dedicated path
- A packet is still buffered at each node and queued for output over a line.
- The difference between virtual circuit and datagram approaches:

➢ With virtual circuit, the node does not need to make a routing decision for each packet.

➢ It is made only once for all packets using that virtual circuit.

Packet Switching: Virtual Circuit

VC's offer guarantees that

- the packets sent arrive in the order sent
- with no duplicates or omissions
- with no errors (with high probability)

regardless of how they are implemented internally.

Figure 8.10 *Virtual-circuit network*

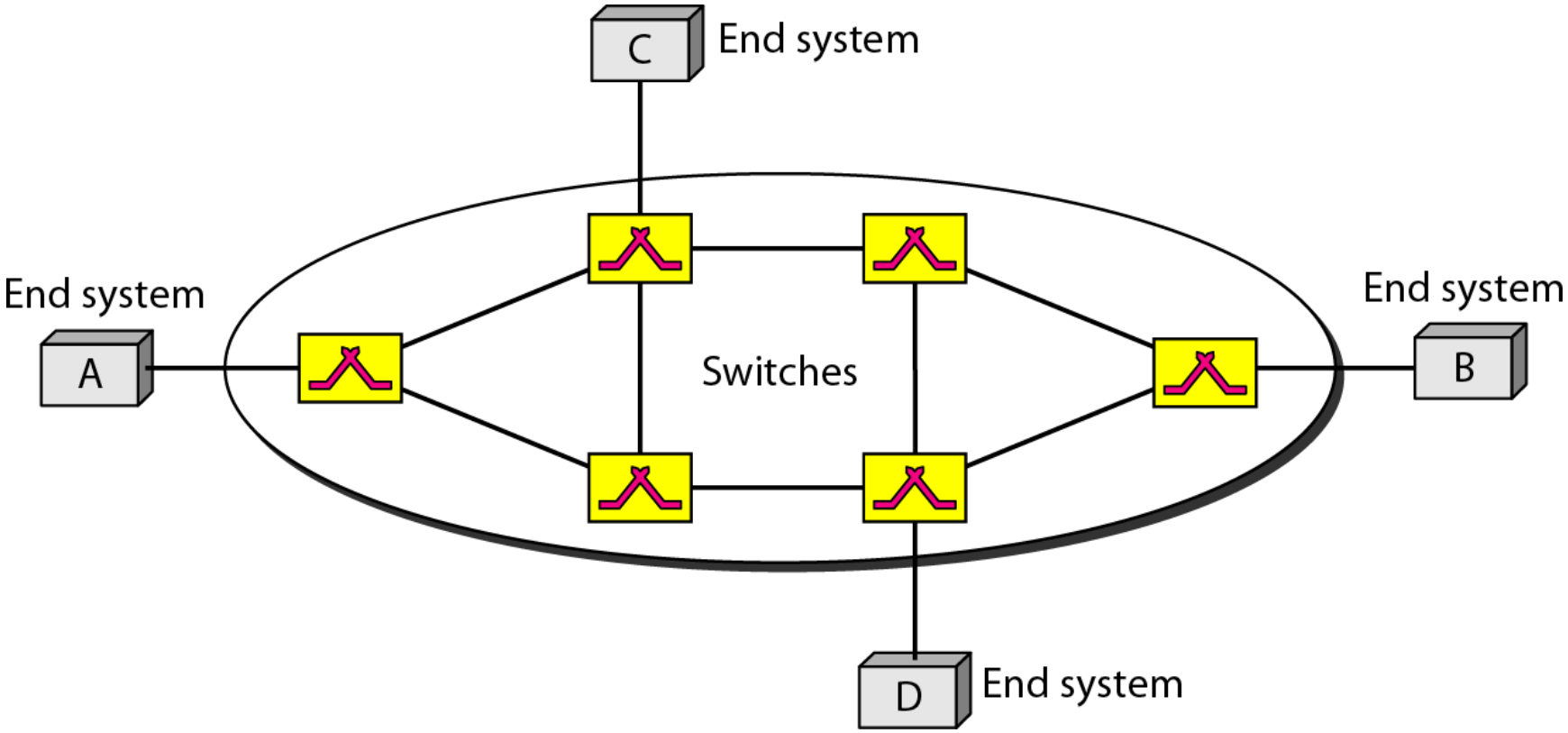


Figure 8.11 *Virtual-circuit identifier*

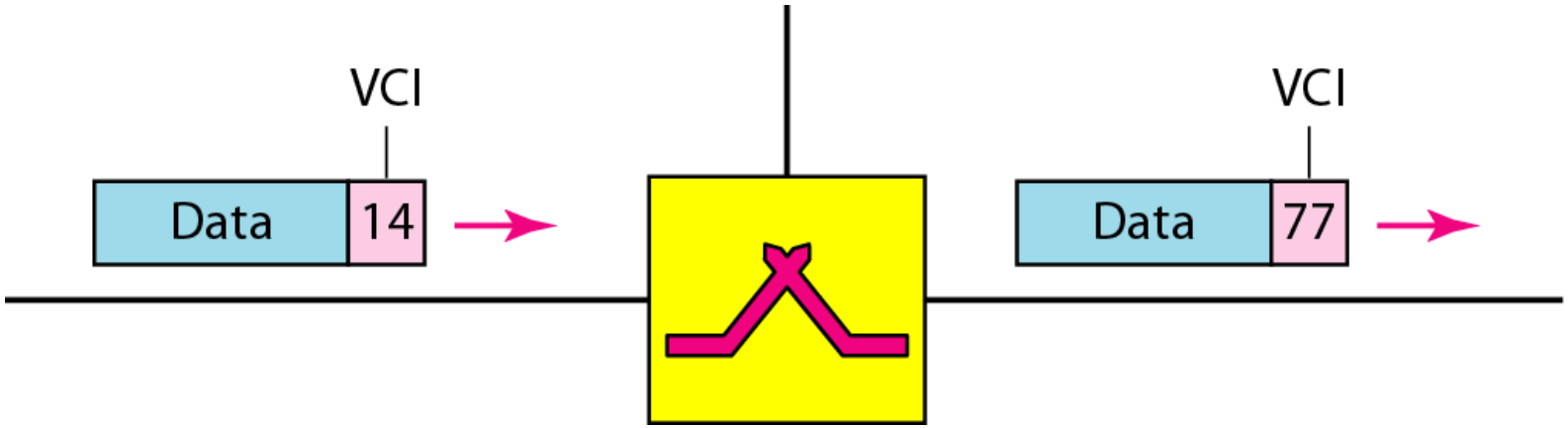


Figure 8.12 *Switch and tables in a virtual-circuit network*

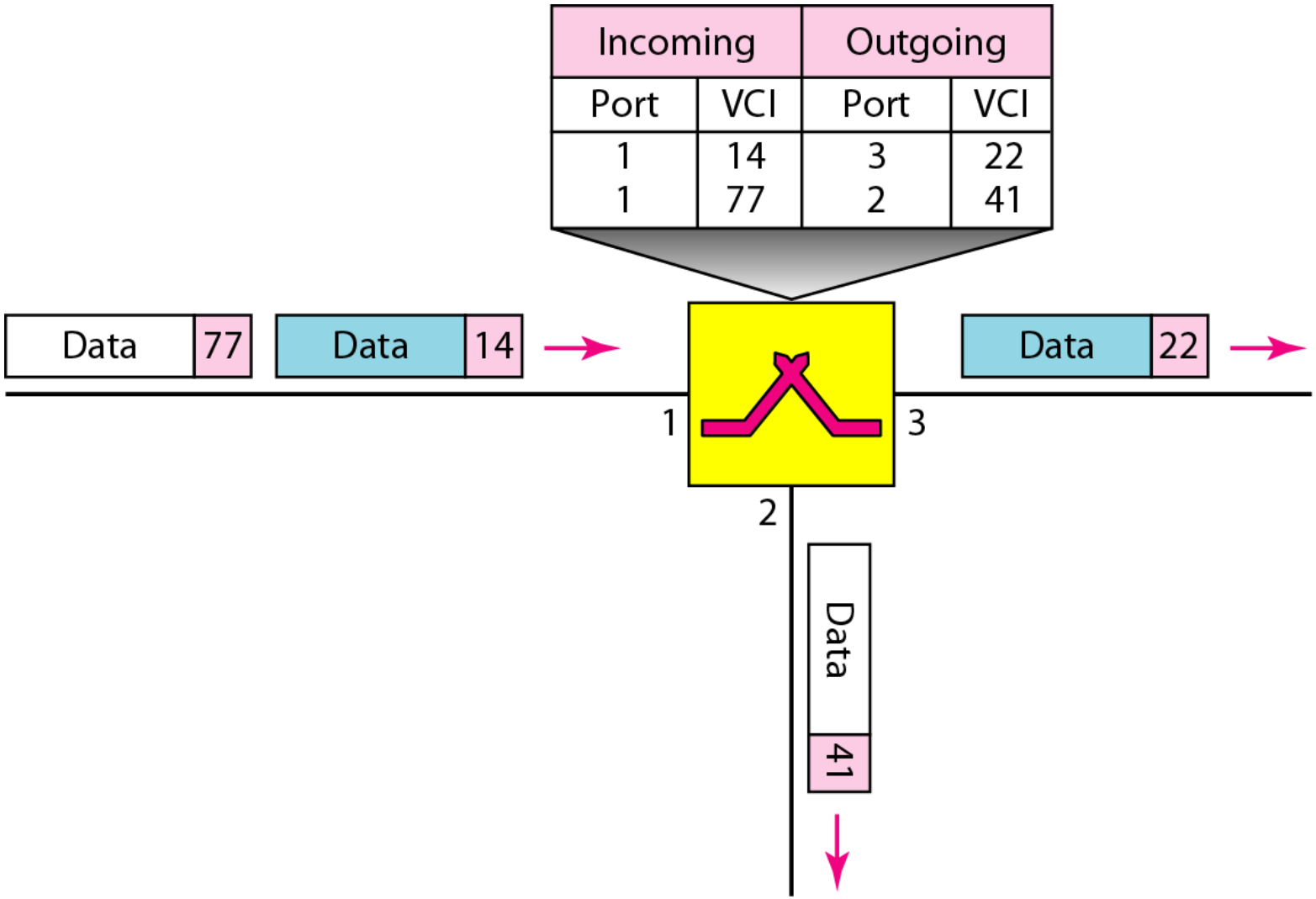


Figure 8.13 *Source-to-destination data transfer in a virtual-circuit network*

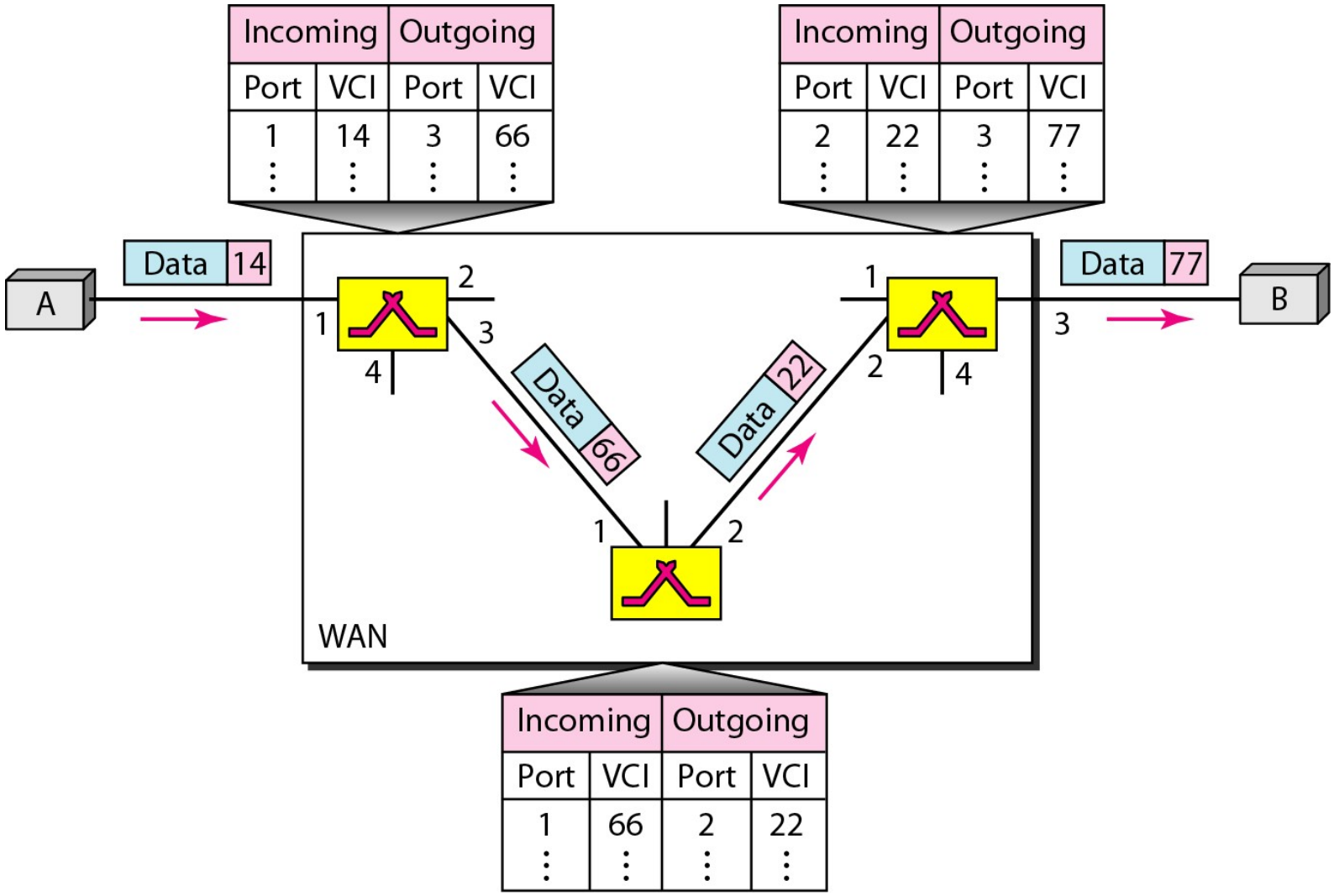


Figure 8.14 *Setup request in a virtual-circuit network*

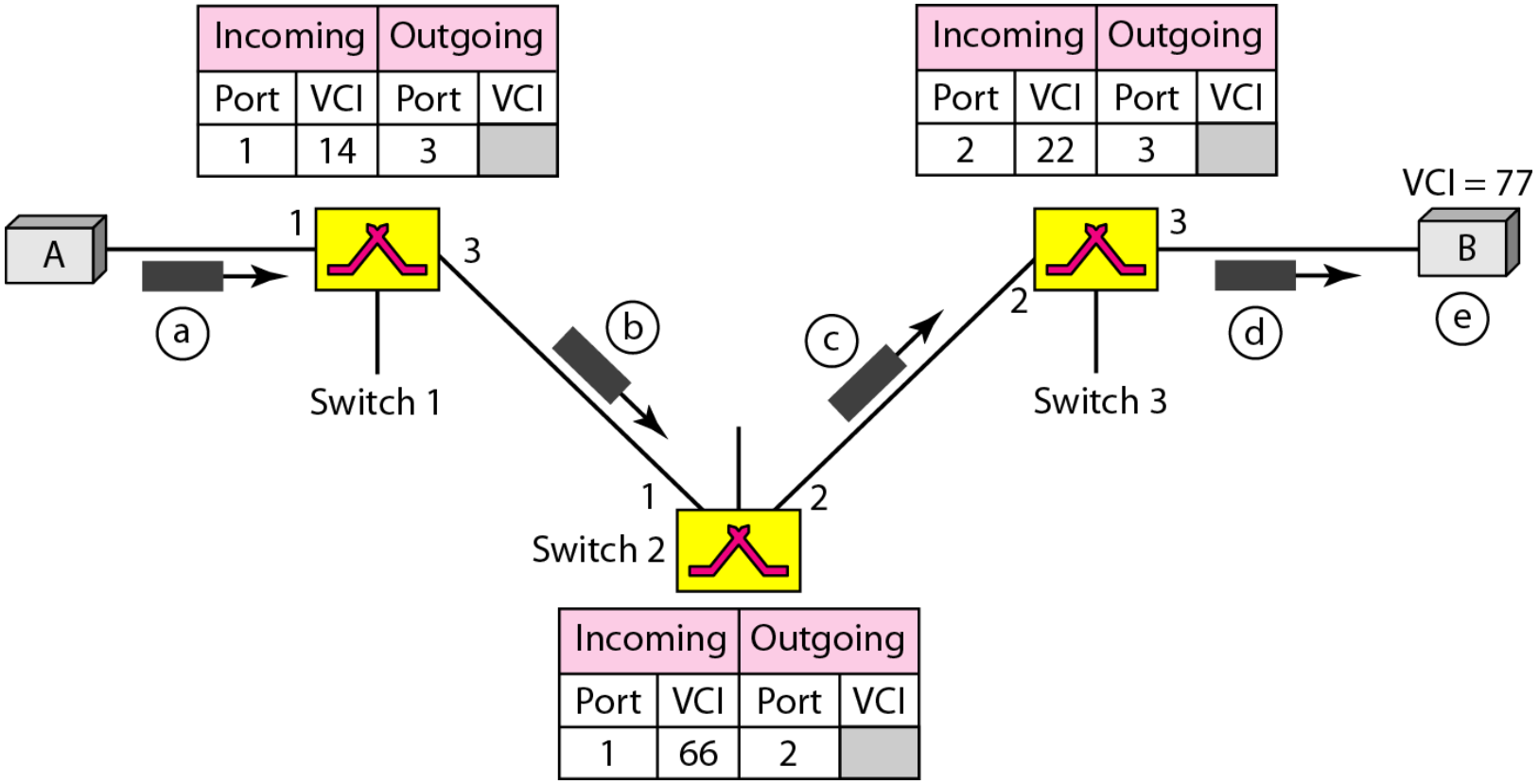
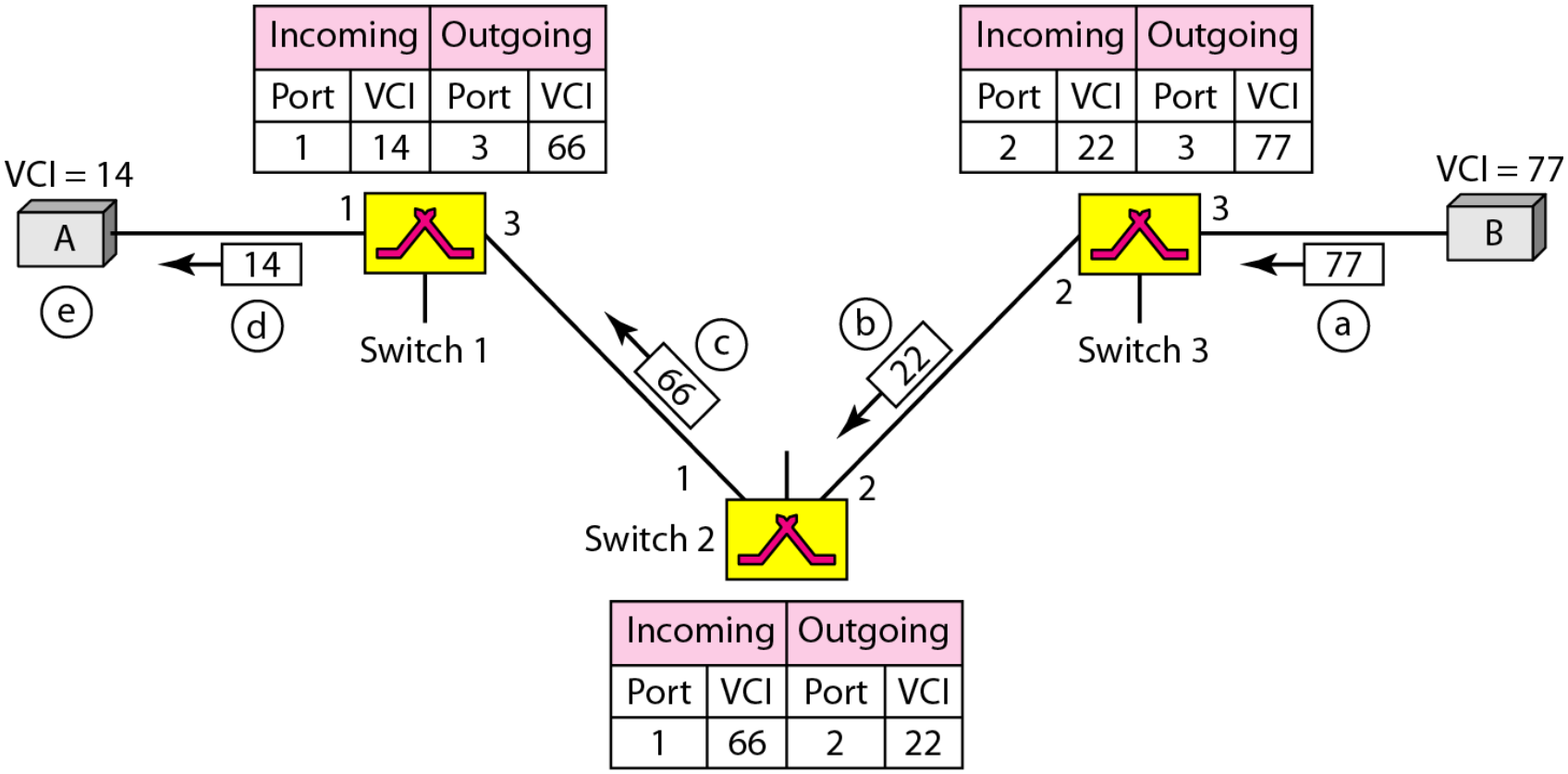


Figure 8.15 *Setup acknowledgment in a virtual-circuit network*



Note

In virtual-circuit switching, all packets belonging to the same source and
destination travel the same path;
but the packets may arrive at the destination with different delays
if resource allocation is on demand.

Advantages of packet switching

Advantages:

- Packet switching is cost effective, because switching devices do not need massive amount of secondary storage.
- Packet switching offers improved delay characteristics, because there are no long messages in the queue (maximum packet size is fixed).
- Packet can be rerouted if there is any problem, such as, busy or disabled links.
- The advantage of packet switching is that many network users can share the same channel at the same time. Packet switching can maximize link efficiency by making optimal use of link bandwidth.

Disadvantages of packet switching

Disadvantages:

- Protocols for packet switching are typically more complex.
- It can add some initial costs in implementation.
- If packet is lost, sender needs to retransmit the data.
- Another disadvantage is that packet-switched systems still can't deliver the same quality as dedicated circuits in applications requiring very little delay - like voice conversations or moving images.

Issue	Datagram network	Virtual-circuit network
Circuit setup	Not needed	Required
Addressing	Each packet contains the full source and destination address	Each packet contains a short VC number
State information	Routers do not hold state information about connections	Each VC requires router table space per connection
Routing	Each packet is routed independently	Route chosen when VC is set up; all packets follow it
Effect of router failures	None, except for packets lost during the crash	All VCs that passed through the failed router are terminated
Quality of service	Difficult	Easy if enough resources can be allocated in advance for each VC
Congestion control	Difficult	Easy if enough resources can be allocated in advance for each VC

Comparison of datagram and virtual-circuit networks