Switching and Telephone Network

Figure 8.1 *Switched network*

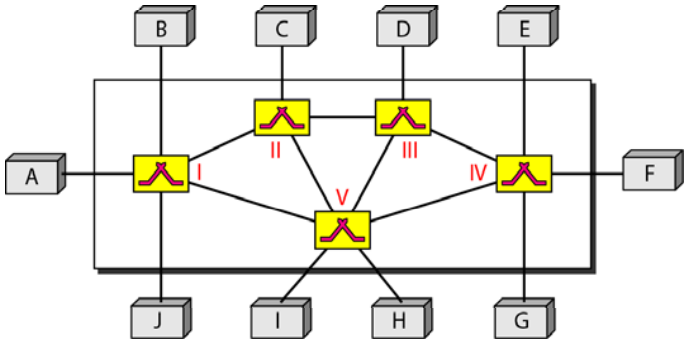
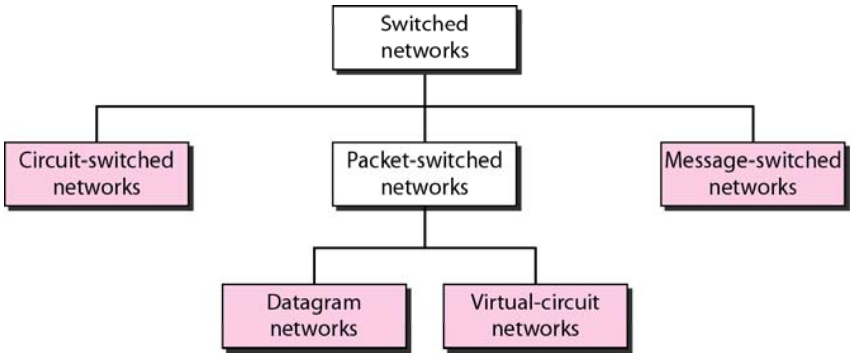


Figure 8.2 *Taxonomy of switched networks*

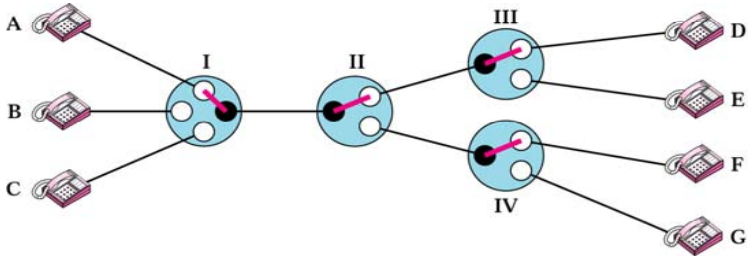


8-1 CIRCUIT-SWITCHED NETWORKS

- Circuit-switched network consists of a set of switches connected by physical links.
- Connection between two stations is a dedicated path made of one or more links.
- However, each connection uses only one dedicated channel on each link.
- Each link is normally divided into n channels by using FDM or TDM.

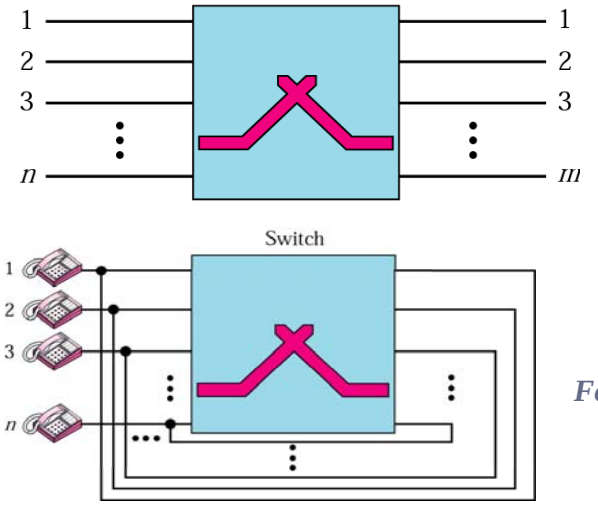
8.1 Circuit Switching

Circuit Switching: Physical Switching
(Physical path connection)



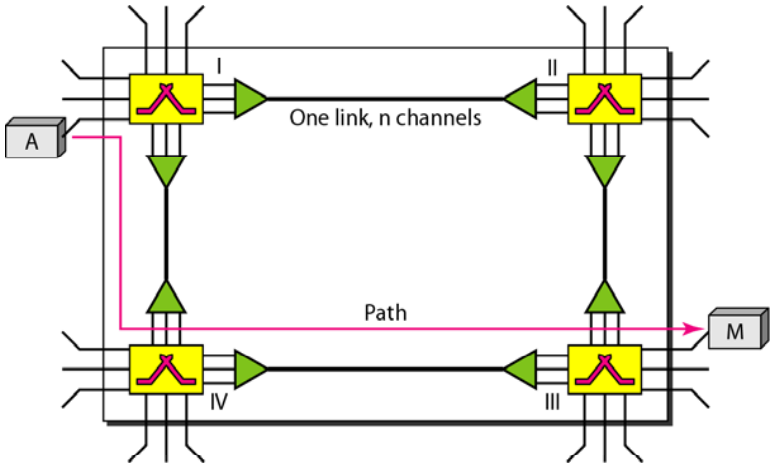
A circuit-switched network is made of a set of switches connected by physical links, in which each link is divided into *n* channels.

Circuit Switch



Folded switch

Trivial circuit-switched network

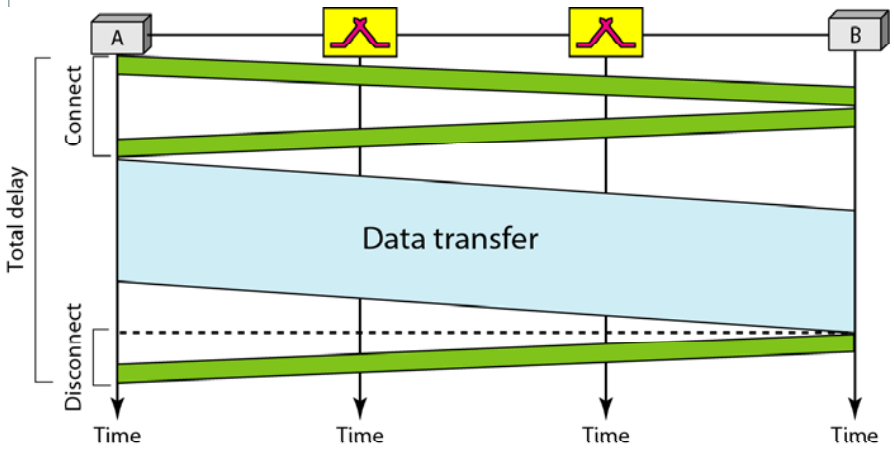


Note

In circuit switching, resources need to be reserved during the setup phase;

the resources remain dedicated for the entire duration of data transfer until the teardown phase.

Delay in a circuit-switched network



Note

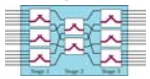
Switching at physical layer in traditional telephone network uses circuit-switching approach.

Circuit Switching: Physical Switching (Hardware connection)

Spaced Division Switching

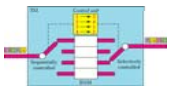
Crossbar Switch

Multi-stage Switch

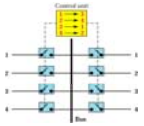


Time Division Switching

TSI: Time-Slot Interchange

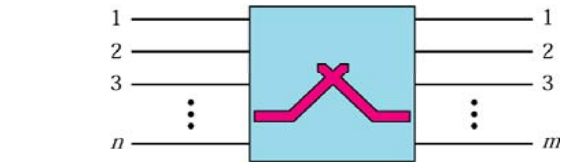


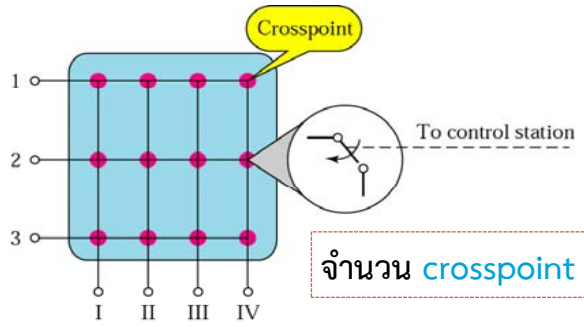
TDM bus



Spaced-division Switching

Crossbar Switch





จำนวน crosspoint = n x m จุด

Example

- As trivial example, let us use circuit-switched network to connect eight telephones in a small area.
- Communication is through 4-kHz voice channels.
- We assume that each link uses FDM to connect a maximum of two voice channels.
- Bandwidth of each link is then 8 kHz.

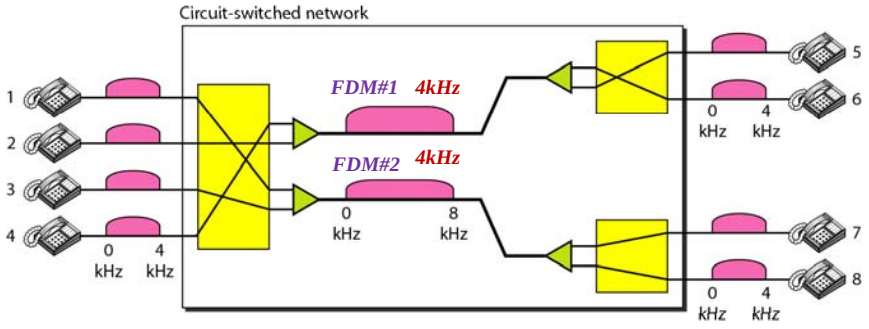
Figure shows the situation.
Telephone 1 is connected to telephone 7;
2 to 5; 3 to 8; and 4 to 6.

Of course the situation may change when new connections are made. The switch controls the connections.

Figure ***Circuit-switched network used in Example***

FDM#1: ***2 to 5; 4 to 6.***
FDM#2: ***1 to 7; 3 to 8;***

FDM -> 2 channels / device; 4kHz /channel

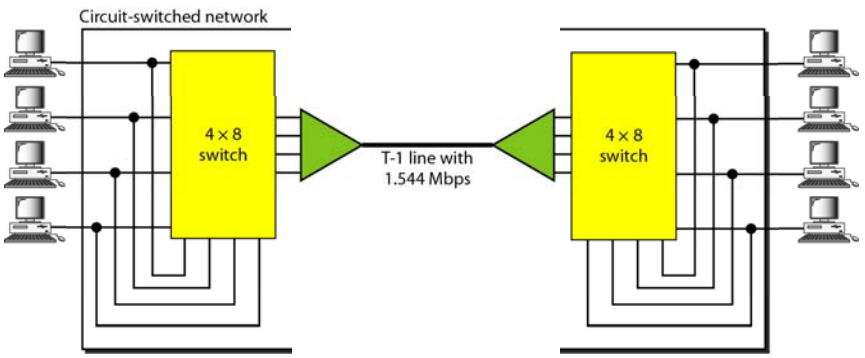


Example

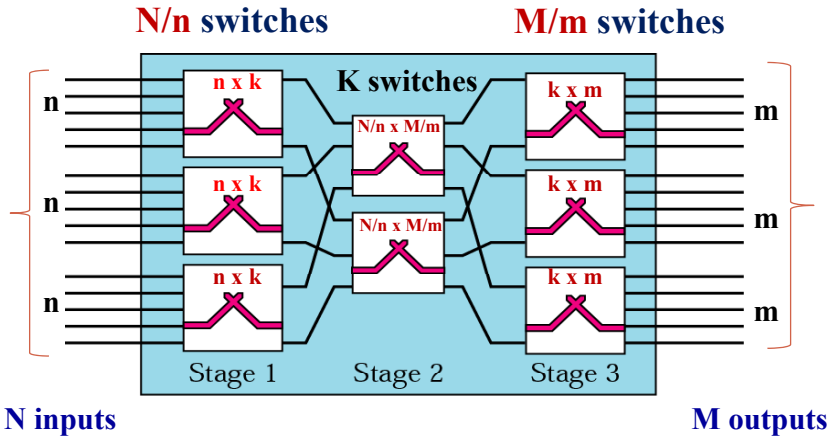
- As another example, consider circuit-switched network that connects computers in two remote offices of private company
- Offices are connected using T-1 line leased from communication service provider.

- There are two 4 × 8 (4 inputs and 8 outputs) switches in this network
- For each switch, four output ports are folded into input ports to allow communication between computers in the same office
- Four other output ports allow communication between the two offices

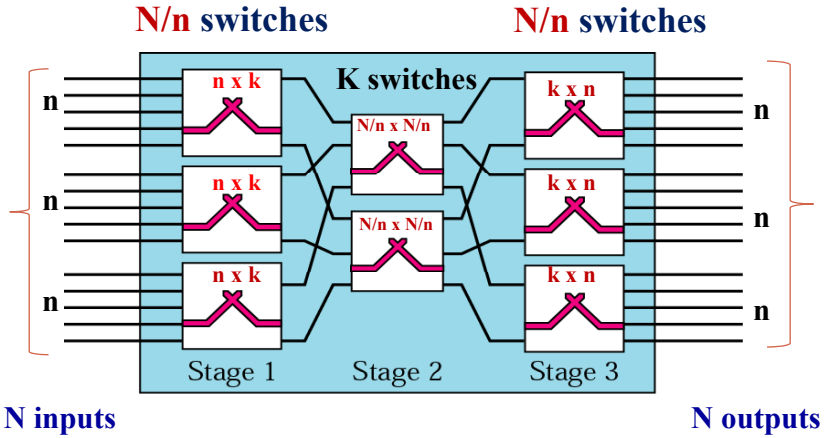
Circuit-switched network used in Example



Multistage Switch



Multistage Switch



Example

- Design three-stage, 200 × 200 switch (N = 200) with k = 4 and n = 20

Solution

- In the first stage, we have N/n or 10 Crossbars, each of size 20 × 4. (n x k)
- In the second stage, we have 4 crossbars, each of size 10 × 10. (N/n x N/n)
- In the third stage, we have 10 crossbars, each of size 4 × 20. (k x n)

- Total number of crosspoints is $2kN + k(N/n)^2$, or 2000 crosspoints.
- This is 5 percent of the number of crosspoints in a single-stage switch (200 × 200 = 40,000).

Note

In a three-stage switch, the total number of crosspoints is $2kN + k(N/n)^2$ which is much smaller than the number of crosspoints in a single-stage switch (N^2).

According to the Clos criterion:

$n = (N/2)^{1/2}$

$k >= 2n - 1$

Crosspoints $\geq 4N\ [(2N)^{1/2} - 1]$

Example 8.4

Redesign the previous three-stage, 200 × 200 switch, using the Clos criteria with minimum number of crosspoints

Solution

We let $n = (200/2)^{1/2}$, or n = 10.

We calculate $k = 2n - 1 = 19$.

In the first stage, we have 200/10, or 20 crossbars, each with 10 × 19 crosspoints.

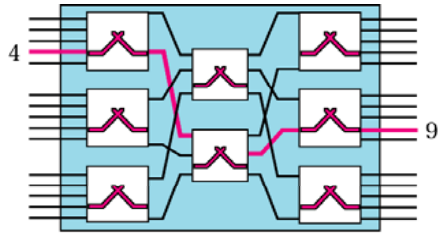
In the second stage, we have 19 crossbars, each with 20 × 20 crosspoints.

In the third stage, we have 20 crossbars each with 19 × 10 crosspoints.

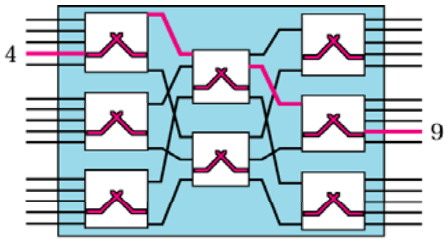
Total number of crosspoints is

$20(10 \times 19) + 19(20 \times 20) + 20(19 \times 10) = 15{,}200$

Switching path



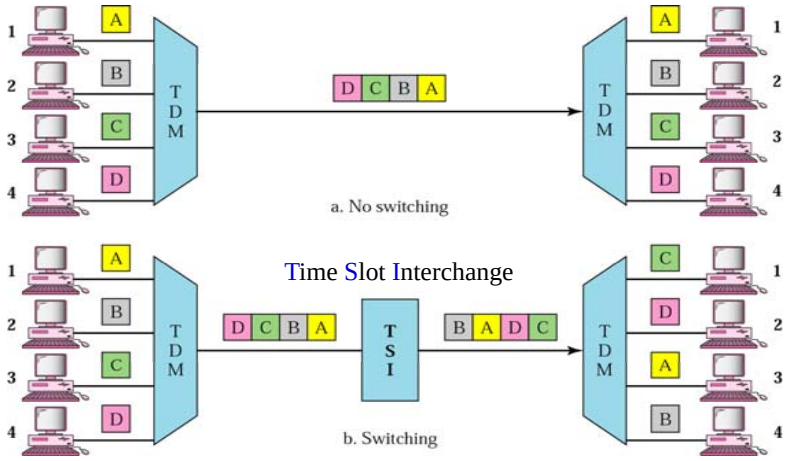
a. First option



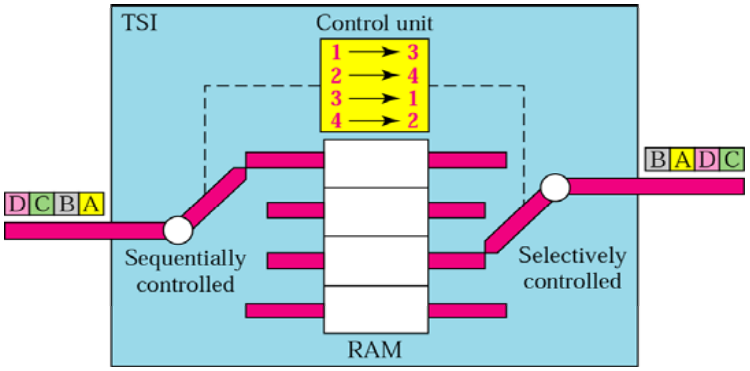
b. Second option

Time-division Switching

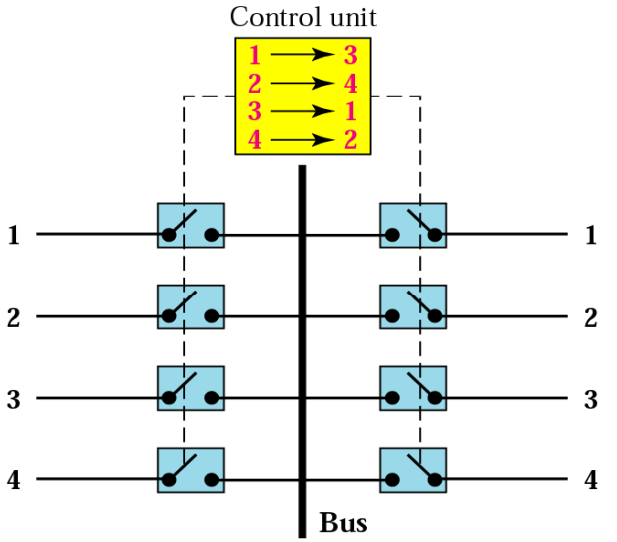
Time-division multiplexing, without and with a time-slot interchange



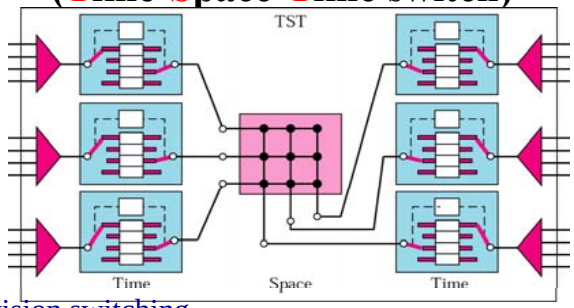
Time-slot interchange



TDM bus



Time- and Space-Division Switch Combination (Time-Space-Time switch)

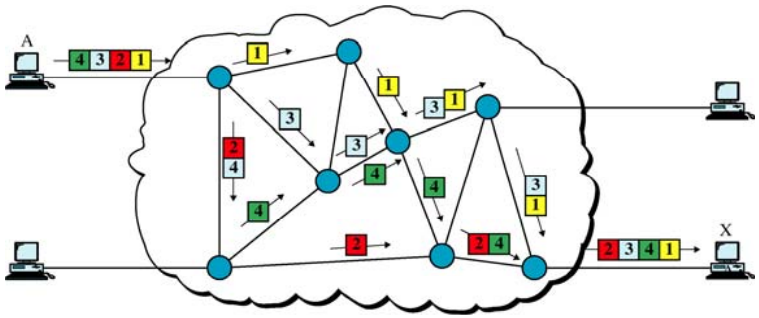


Space-division switching
- o Advantage : it is instantaneous
- o Disadvantage : No. of crosspoint required to make switching acceptable in terms of blocking

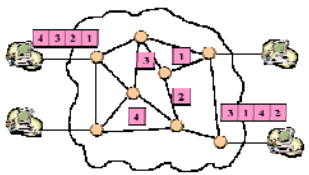
Time-division switching
- o Advantage : it needs no crosspoint
- o Disadvantage : processing each connection creates delays

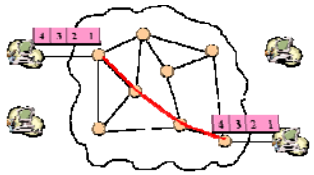
8.2 Packet Switching

Packet Switching: Virtual Switching
(Virtual path connection)



Packet Switching: Virtual Switching
(Virtual path connection)





SVC: Switched Virtual Circuit
PVC: Permanent Virtual Circuit

- No physical reserved paths -> Virtual paths

8-2 DATAGRAM NETWORKS

o In data communications, we need to send messages from one end system to another.

o If the message is going to pass through a packet-switched network, it needs to be divided into packets of fixed or variable size.

o The size of packet is determined by the network and governing protocol.

Note

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

Figure 8.7 *A datagram network with four switches (routers)*

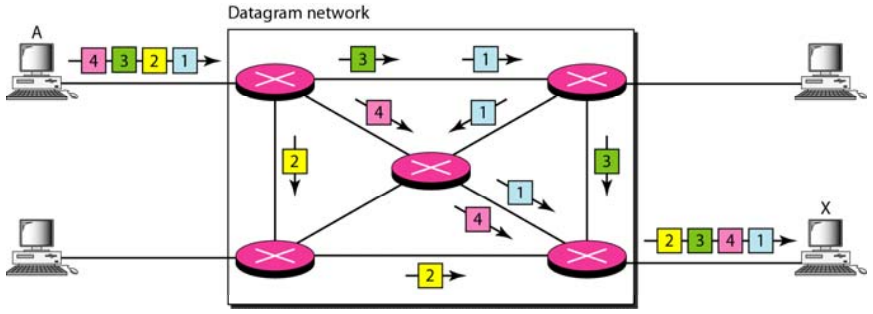
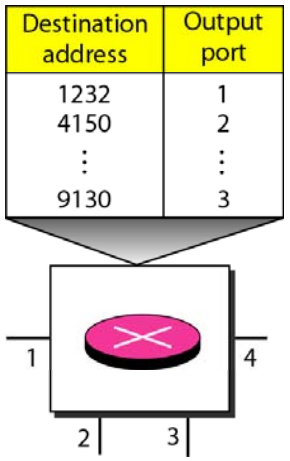


Figure 8.8 *Routing table in a datagram network*

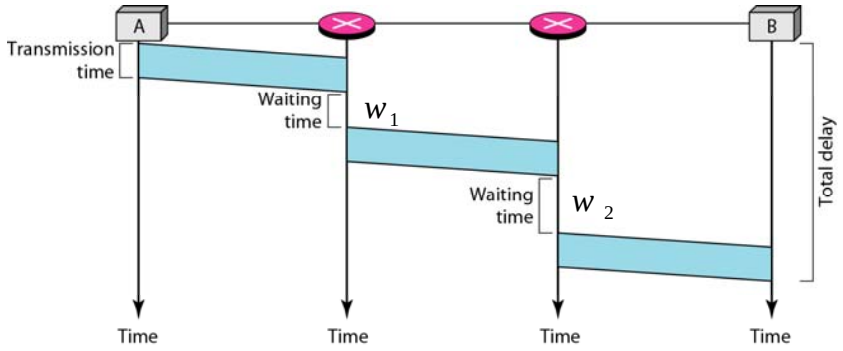


A switch in a datagram network uses a routing table that is based on the destination address.

The destination address in the header of a packet in a datagram network remains the same during the entire journey of the packet.

Figure 8.9 *Delay in a datagram network*

$$3T + 3\tau + w_1 + w_2$$



T = transmission time τ **= propagation time**

Note

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

8-3 VIRTUAL-CIRCUIT NETWORKS

- Virtual-circuit network is a cross between circuit-switched network and datagram network.
- It has some characteristics of both.

Figure 8.10 *Virtual-circuit network*

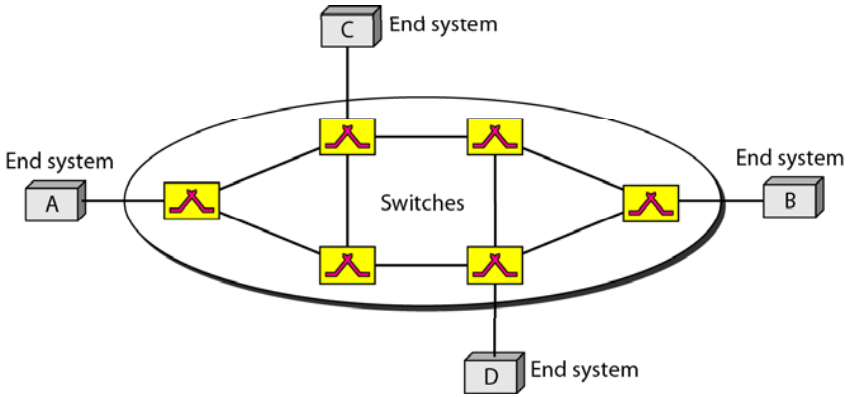


Figure 8.11 *Virtual-circuit identifier: VCI*

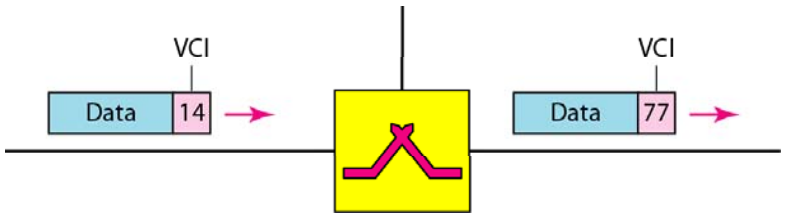


Figure 8.12 *Switch and tables in a virtual-circuit network*

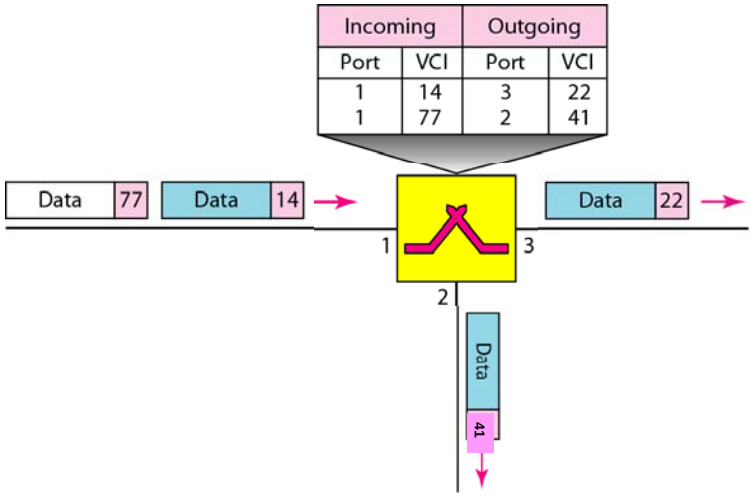


Figure 8.13 *Source-to-destination data transfer in a virtual-circuit network*

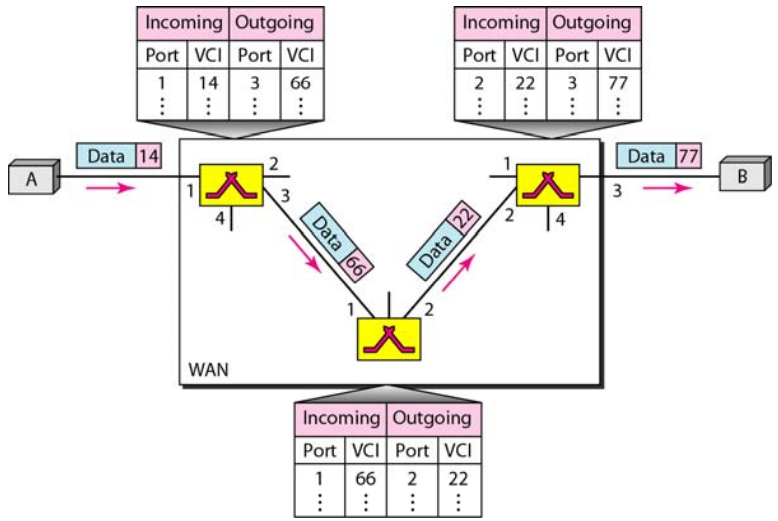


Figure 8.14 *Setup request in a virtual-circuit network*

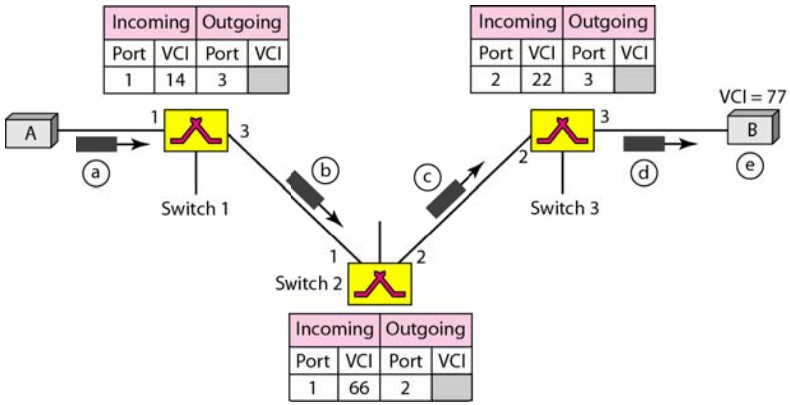


Figure 8.15 *Setup acknowledgment in a virtual-circuit network*

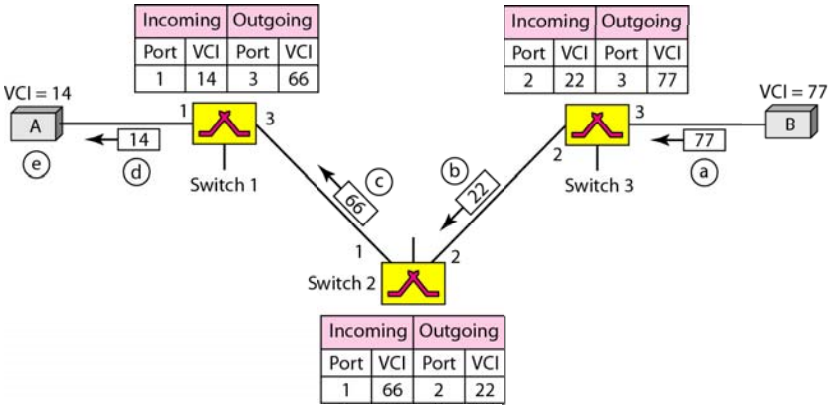


Figure 8.16 *Delay in a virtual-circuit network*

$$3T + 3\tau + \text{setup delay} + \text{teardown delay}$$