Data Communications and Networking
Fourth Edition

Forouzan

Chapter 8

Switching

Figure 8.1 *Switched network*
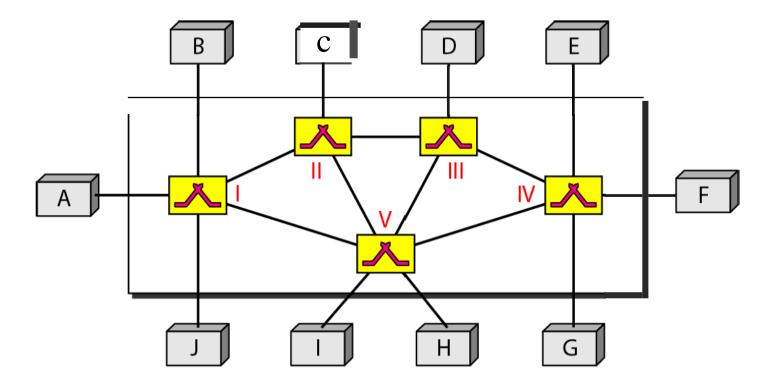
Figure 8.2 *Taxonomy of switched networks*

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                        ┌──────────────┐
                        │  Switched    │
                        │  networks    │
                        └──────┬───────┘
          ┌────────────────────┼────────────────────┐
┌──────────────────┐  ┌──────────────────┐  ┌──────────────────┐
│  Circuit-switched │  │  Packet-         │  │ Message-switched │
│     networks      │  │  switched        │  │    networks      │
└──────────────────┘  │  networks        │  └──────────────────┘
                      └────────┬─────────┘
                   ┌───────────┴───────────┐
          ┌──────────────┐        ┌──────────────┐
          │  Datagram    │        │ Virtual-circuit│
          │  networks    │        │   networks   │
          └──────────────┘        └──────────────┘
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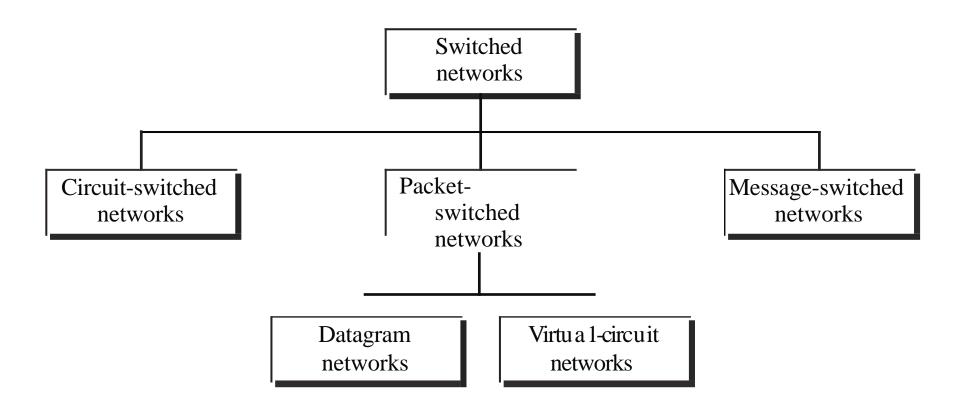
8.3

8-1   CIRCUIT-SWITCHED NETWORKS

A circuit-switched network consists of a set of switches connected by physical links. A 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.

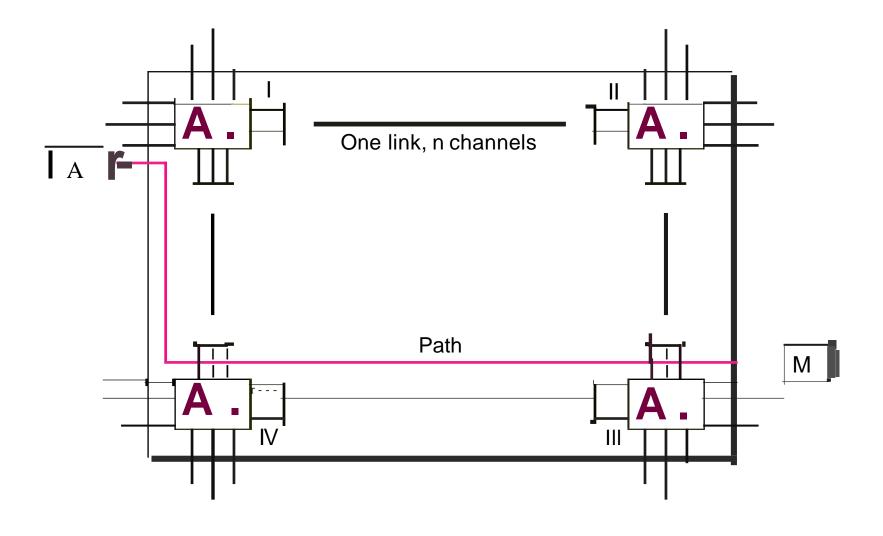*Topics discussed in this section:*

Three Phases
Efficiency
Delay
Circuit-Switched Technology in Telephone Networks

8.4

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

8.5

Figure 8.3 *A trivial circuit-switched network*

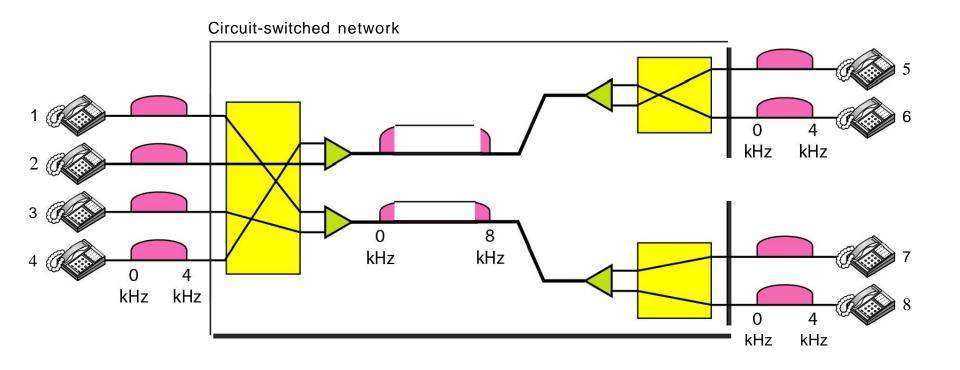Figure 8.3 A trivial circuit-switched network

In circuit switching, the resources need to be reserved during the setup phase; the resources remain dedicated for the entire duration of data transfer until the teardown phase.

Example 8.1

As a trivial example, let us use a 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. The bandwidth of each link is then 8 kHz. Figure 8.4 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 8.4 *Circuit-switched network used in Example 8.1*

Example 8.2

As another example, consider a circuit-switched network that connects computers in two remote offices of a private company. The offices are connected using a T-1 line leased from a 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 the input ports to allow communication between computers in the same office. Four other output ports allow communication between the two offices. Figure 8.5 shows the situation.

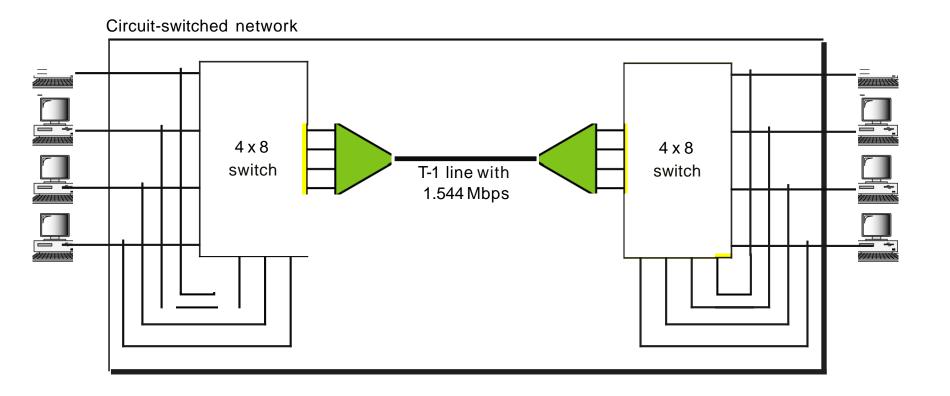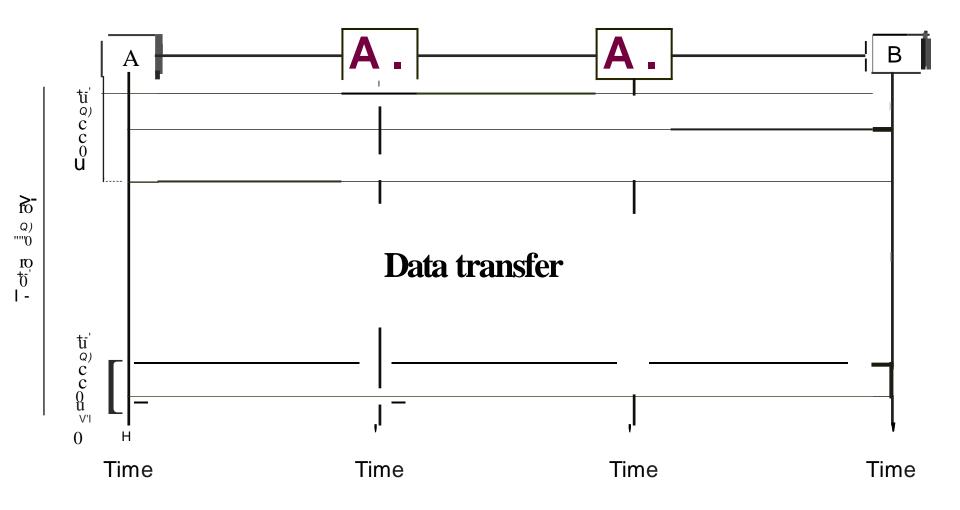# Figure 8.5 *Circuit-switched network used in Example 8.2*

Circuit-switched network

4 x 8
switch

T-1 line with
1.544 Mbps

4 x 8
switch

Figure 8.6 *Delay in a circuit-switched network*

Data transfer

Time   Time   Time   Time

Note

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

8-2 DATAGRAM NETWORKS

In data communications, we need to send messages from one end system to another. If the message is going to pass through a packet-switched network, it needs to be divided into packets of fixed or variable size. The size of the packet is determined by the network and the governing protocol.

Note

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

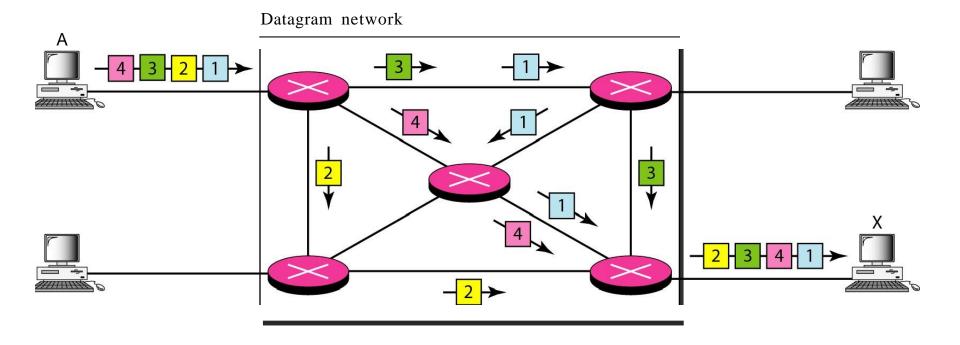# Figure 8.7 *A datagram network with four switches (routers)*

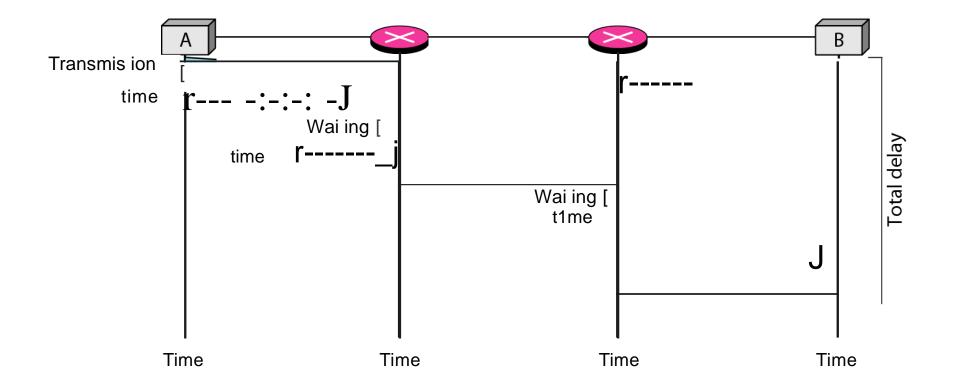**Figure** 8.8 *Routing table in a datagram network*

Destination address	Output port
1232	1
4150	2
9130	3

> **Note**

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*

Transmis ion time

Wai ing time

Wai ing t1me

Total delay

Time Time Time Time

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

8-3   VIRTUAL-CIRCUIT NETWORKS

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

<u>*Topics discussed in this section:*</u>

Addressing
Three Phases
Efficiency
Delay
Circuit-Switched Technology in WANs
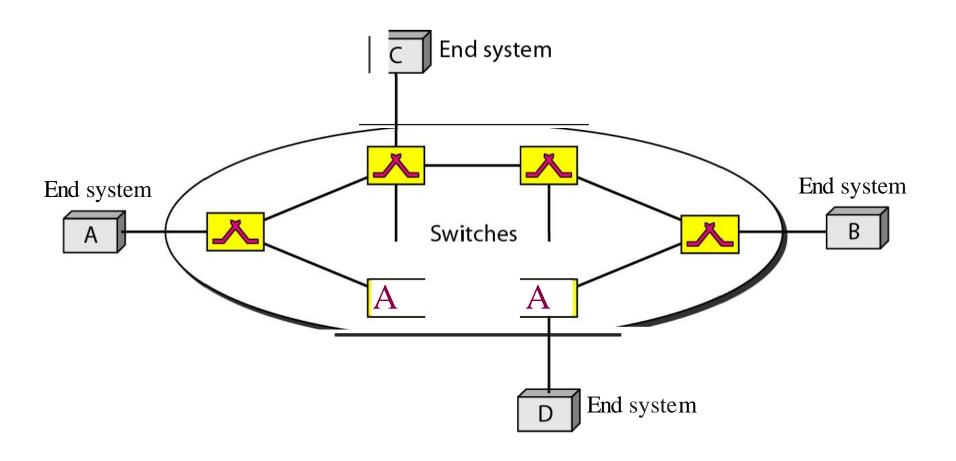
8.2

Figure 8.10   *Virtual-circuit network*

Figure 8.11   *Virlual-circuit identifier*
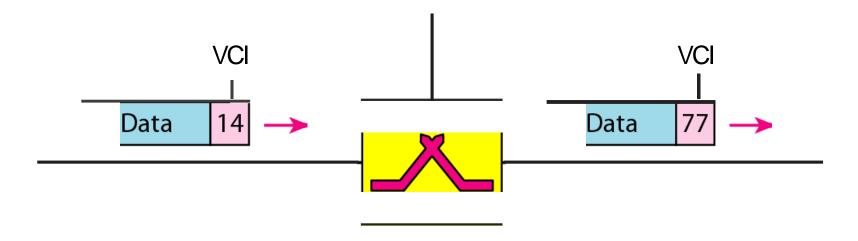
Figure 8.12 *Switch and tables in a virtual-circuit network*
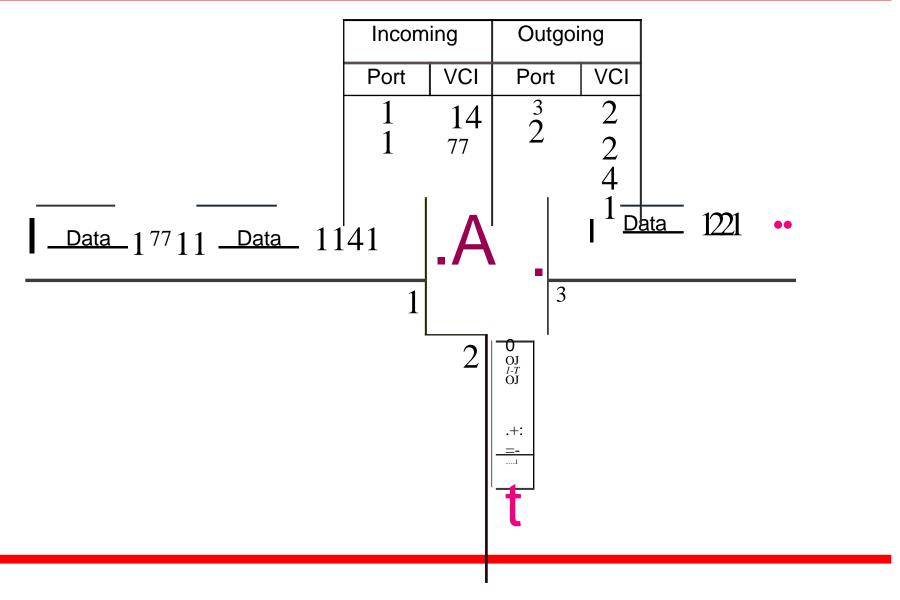
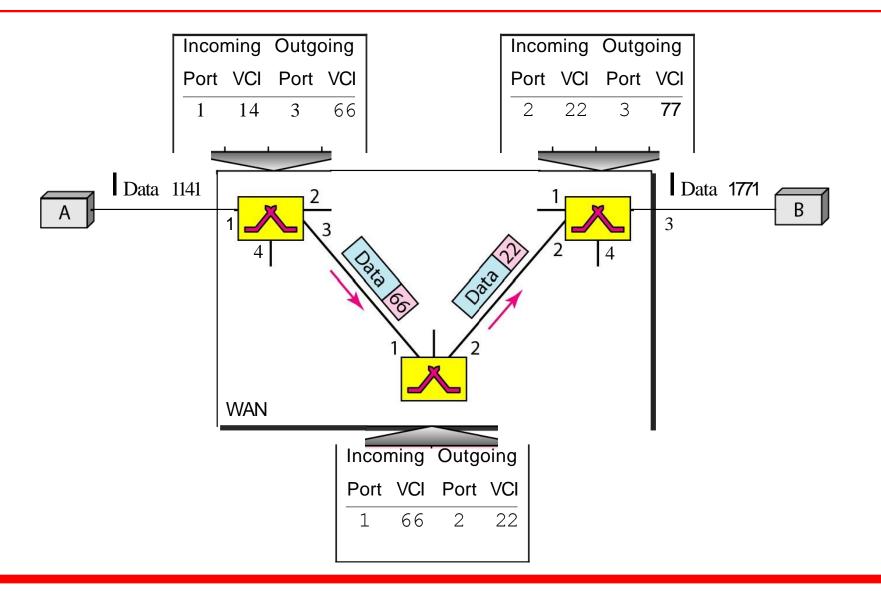# Figure 8.13 *Source-to-destination data transfer in a virtual-circuit network*

Incoming		Outgoing	
Port	VCI	Port	VCI
1	14	3	66

Incoming		Outgoing	
Port	VCI	Port	VCI
2	22	3	77

Incoming		Outgoing	
Port	VCI	Port	VCI
1	66	2	22

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

Incoming		Outgoing	
Port	VCI	Port	VCI
1	14	3	

Incoming		Outgoing	
Port	VCI	Port	VCI
2	22	3	

VCI = 77

Switch 1

Switch 3

Switch2

Incoming		Outgoing	
Port	VCI	Port	VCI
1	66	2	
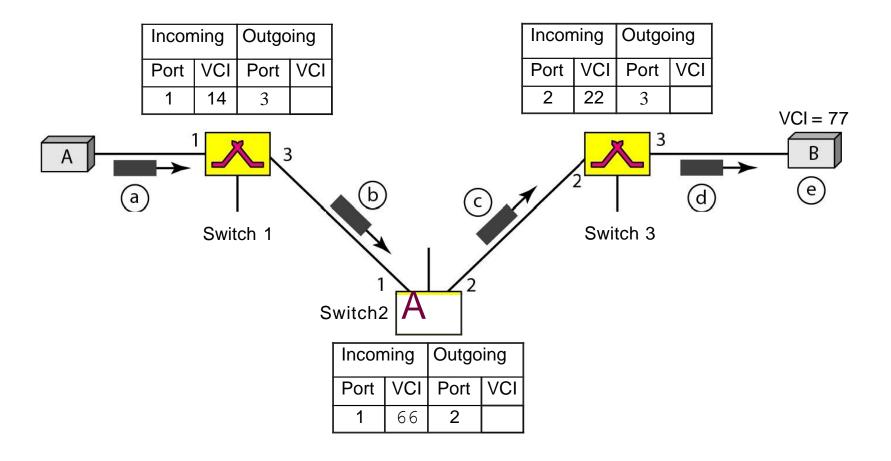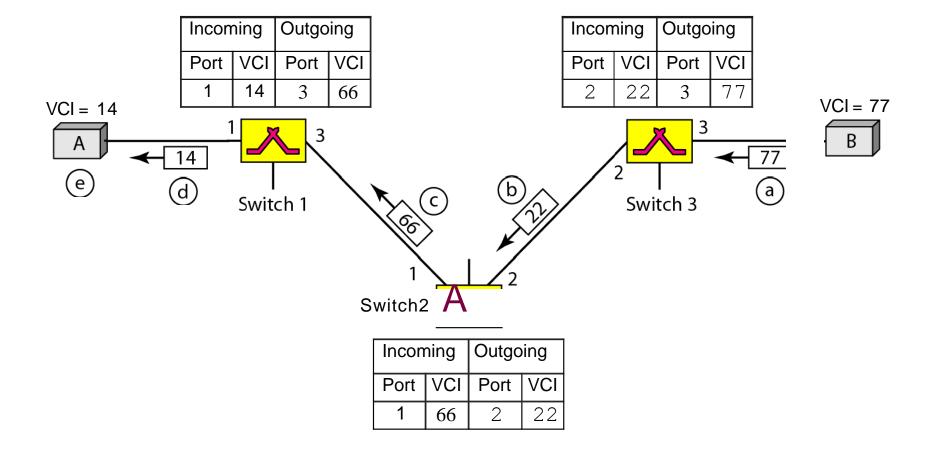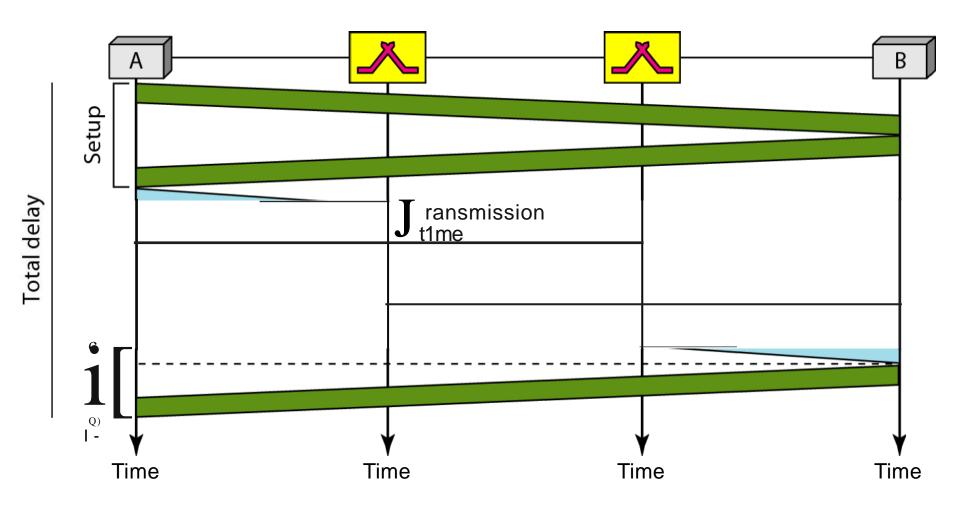
Figure 8.15 *Setup acknowledgment in a virtual-circuit network*

Incoming		Outgoing	
Port	VCI	Port	VCI
1	14	3	66

Incoming		Outgoing	
Port	VCI	Port	VCI
2	22	3	77

VCI = 14

VCI = 77

Switch 1

Switch 3

Switch2

Incoming		Outgoing	
Port	VCI	Port	VCI
1	66	2	22

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.

Figure 8.16 *Delay in a virtual-circuit network*

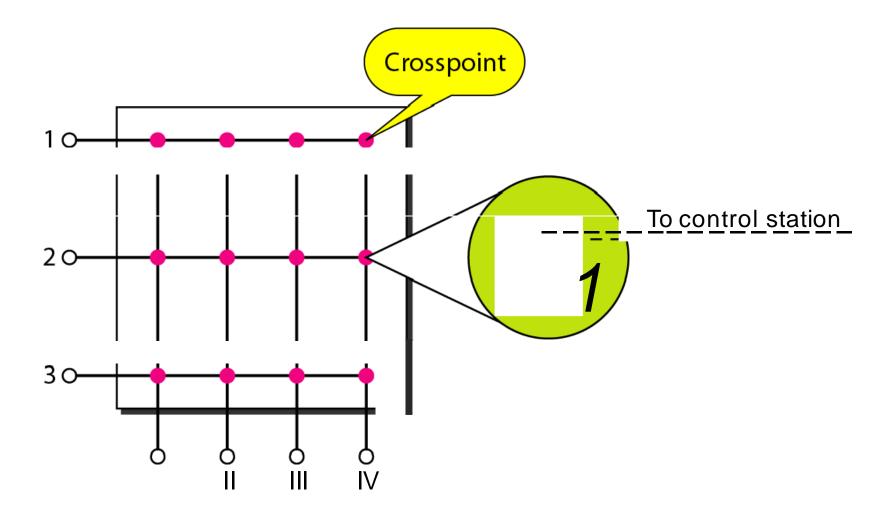**Switching at the data link layer in a switched WAN is normally implemented by using virtual-circuit techniques.**

8-4   STRUCTURE OF A SWITCH

We use switches in circuit-switched and packet-switched networks. In this section, we discuss the structures of the switches used in each type of network.
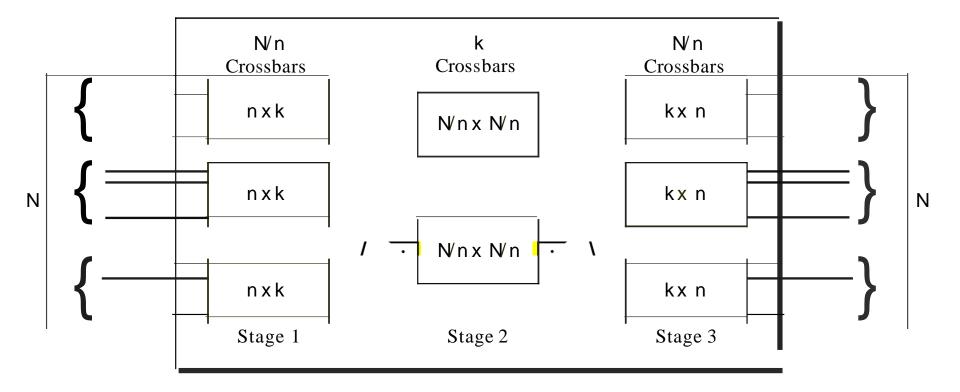
Topics discussed in this section:
Structure of Circuit Switches
Structure of Packet Switches

8.32

Figure 8.17 *Crossbar switch with three inputs andfour outputs*

Figure 8.18 *Multistage switch*

	N/n Crossbars	k Crossbars	N/n Crossbars	
N {	n x k	N/n x N/n	k x n	} N
{	n x k	N/n x N/n	k x n	}
{	n x k		k x n	}
	Stage 1	Stage 2	Stage 3	

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).

Example 8.3

Design a 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. In the second stage, we have 4 crossbars, each of size 10 × 10. In the third stage, we have 10 crossbars, each of size 4 × 20. The 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

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 a 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 10 × 10 crosspoints. In the third stage, we have 20 crossbars each with 19 × 10 crosspoints. The total number of crosspoints is 20(10 × 19) + 19(10 × 10) + 20(19 ×10) = 9500.

Figure 8.19 *Time-slot interchange*

Time-division switch

TSI

Control unit

1 ----+- 3
2 ----+- 4
3 ➝ 1
4 ➝ 2

IDICIBIAI

RAM

Sequentially controlled
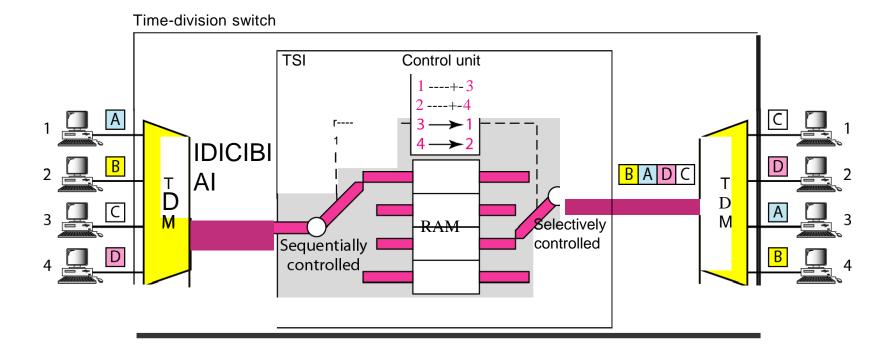
Selectively controlled

T D M

T D M

A B C D

B A D C

C D A B

Figure 8.20 *Time-space-time switch*
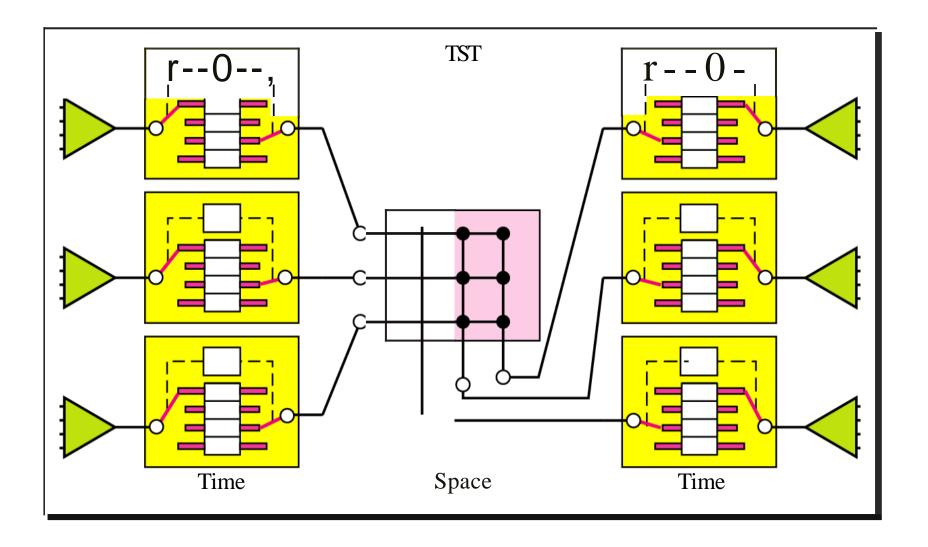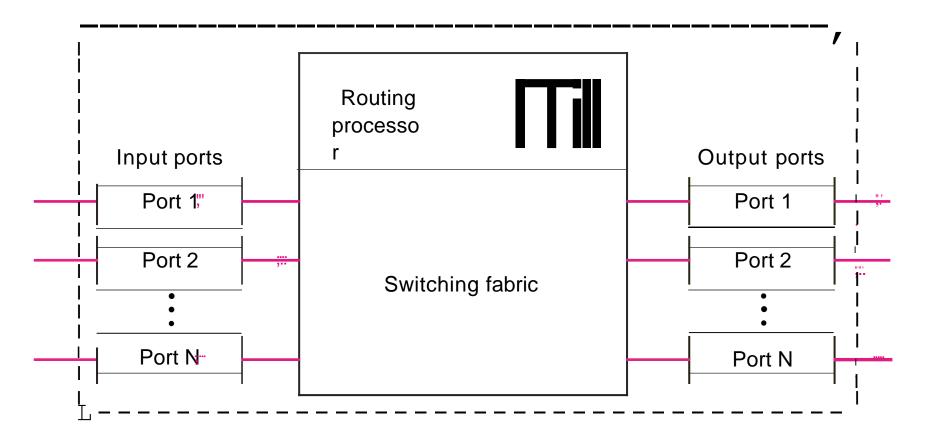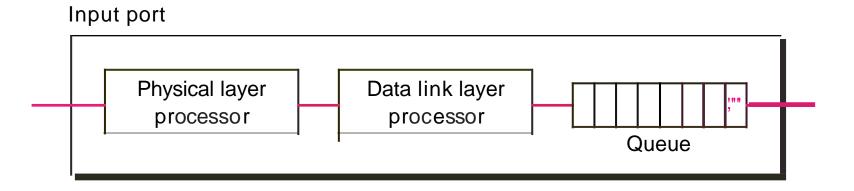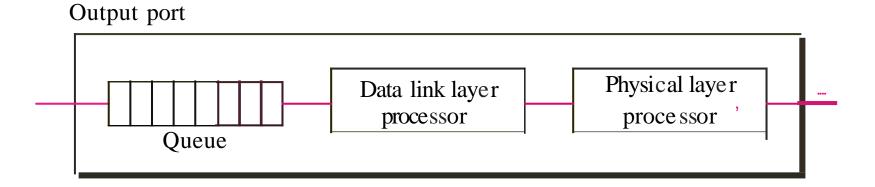
Figure 8.21 *Packet switch components*

Input ports

Routing processor

Output ports

Switching fabric

Port 1

Port 2

Port N

Port 1

Port 2

Port N

Figure 8.22 *Input port*

Input port

Figure 8.23 *Outputport*
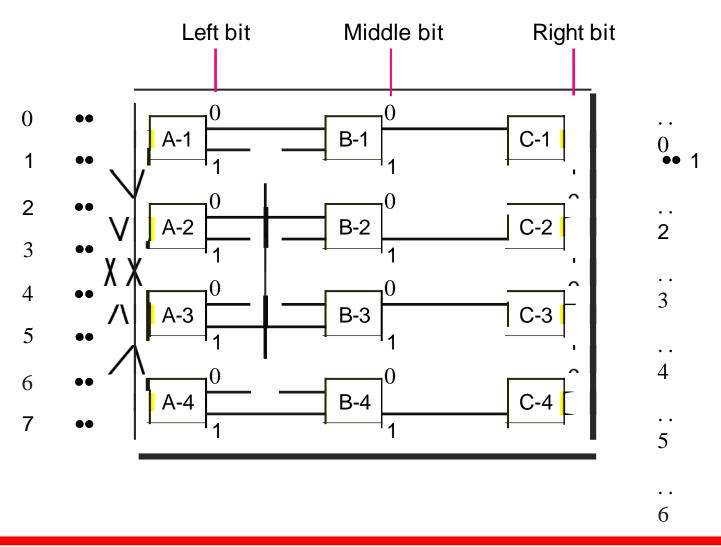
Output port

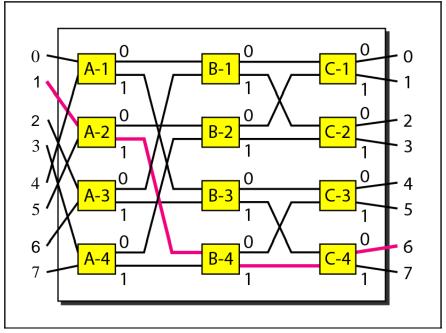Queue — Data link layer processor — Physical layer processor
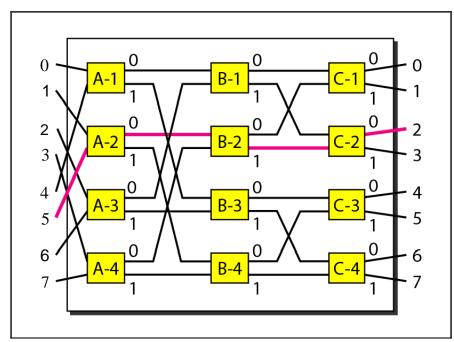
Figure 8.24 *A banyan switch*

Figure 8.25 *Examples of routing in a banyan switch*

a. Input 1 sending a cell to output 6 (110)

b. Input 5 sending a cell to output 2 (010)

Figure 8.26 *Butcher-banyan switch*

Banyan switch

0

1

2

3 Satcher   Trap
   switch   module

4

5

6

7

0

1

2

3

4

5

6

7