Module
4

Switched Communication Networks

Lesson
2

Switching Techniques: Circuit Switching

4.2.0 Specific Instructional Objectives

At the end of this lesson the student will be able to:
- Explain the need for packet switching
- Explain how packet switching takes place
- Explain different types of packet switching techniques
- Distinguish between virtual-circuit and datagram type packet switching
- Compare circuit switching with packet switching

4.2.1 Introduction

In the preceding lesson we have discussed about circuit switching. In circuit switching, network resources are dedicated to a particular connection. Although this satisfies the requirement of voice communication, it suffers from the following two shortcomings for data communication:

- In a typical user/host data connection, line utilization is very low.
- Provides facility for data transmission at a constant rate.

However, for information transmission applications, the circuit switching method is very slow, relatively expensive and inefficient. First of all, the need to establish a dedicated connection before sending the message itself inserts a delay time, which might become significant for the total message transfer time. Moreover, the total channel remains idle and unavailable to the other users once a connection is made. On the other hand once a connection is established, it is guaranteed and orderly delivery of message is ensured. Unfortunately, the data transmission pattern may not ensure this, because data transmission is bursty in nature. As a consequence, it limits the utility of the method. The problem may be overcome by using an approach known as message switching, which is discussed in Sec. 4.2.2. However, message switching suffers from various problems as discussed in Sec. 4.2.3. To overcome the limitations of message switching, another switching technique, known as packet switching was invented. Various aspects of packet switching have been discussed in Sec. 4.2.4.

4.2.2 Message Switching

In this switching method, a different strategy is used, where instead of establishing a dedicated physical line between the sender and the receiver, the message is sent to the nearest directly connected switching node. This node stores the message, checks for errors, selects the best available route and forwards the message to the next intermediate node.
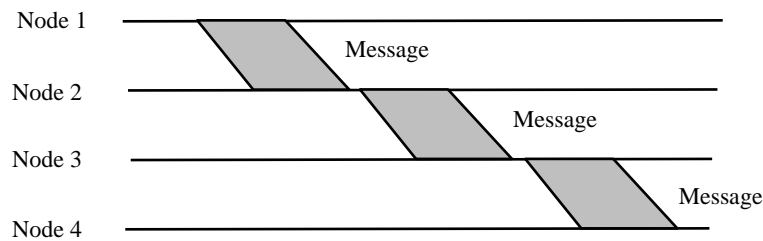
Figure 4.2.1   Message Switching Technique

The line becomes free again for other messages, while the process is being continued in some other nodes. Due to the mode of action, this method is also known as *store-and-forward technology* where the message hops from node to node to its final destination. Each node stores the full message, checks for errors and forwards it.

In this switching technique, more devices can share the network bandwidth, as compared with circuit switching technique. Temporary storage of message reduces traffic congestion to some extent. Higher priority can be given to urgent messages, so that the low priority messages are delayed while the urgent ones are forwarded faster. Through broadcast addresses one message can be sent to several users. Last of all, since the destination host need not be active when the message is sent, message switching techniques improve global communications.

However, since the message blocks may be quite large in size, considerable amount of storage space is required at each node to buffer the messages. A message might occupy the buffers for minutes, thus blocking the internodal traffic.

Basic idea:
- Each network node receives and stores the message
- Determines the next leg of the route, and
- Queues the message to go out on that link.

Advantages:
- Line efficiency is greater (sharing of links).
- Data rate conversion is possible.
- Even under heavy traffic, packets are accepted, possibly with a greater delay in delivery.
- Message priorities can be used, to satisfy the requirements, if any.

Disadvantages: Message of large size monopolizes the link and storage

---

4.2.3 Packet Switching

The basic approach is not much different from message switching. It is also based on the same 'store-and-forward' approach. However, to overcome the limitations of message switching, messages are divided into subsets of equal length called *packets*. This approach was developed for long-distance data communication (1970) and it has evolved

over time. In packet switching approach, data are transmitted in short packets (few Kbytes). A long message is broken up into a series of packets as shown in Fig. 4.2.2. Every packet contains some control information in its header, which is required for routing and other purposes.
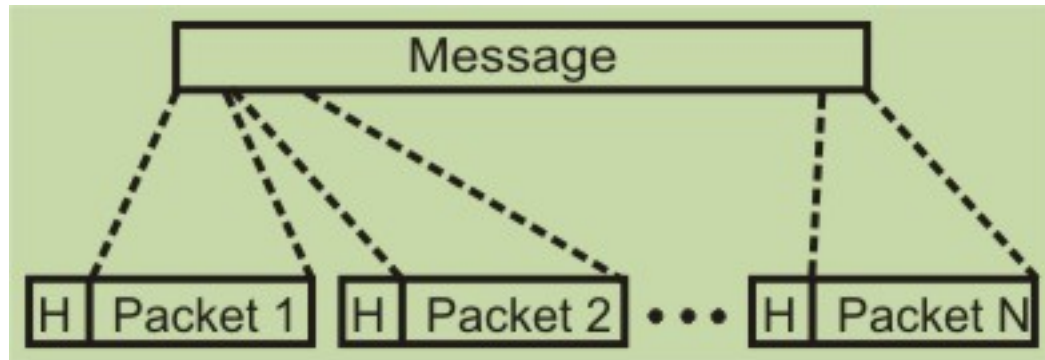

Figure 4.2.2 A message is divided into a number of equal length short packets

Main difference between Packet switching and Circuit Switching is that the communication lines are not dedicated to passing messages from the source to the destination. In Packet Switching, different messages (and even different packets) can pass through different routes, and when there is a "dead time" in the communication between the source and the destination, the lines can be used by other sources.

There are two basic approaches commonly used to packet Switching: **virtual-circuit** packet switching and **datagram** packet switching. In virtual-circuit packet switching a virtual circuit is made before actual data is transmitted, but it is different from circuit switching in a sense that in circuit switching the call accept signal comes only from the final destination to the source while in case of virtual-packet switching this call accept signal is transmitted between each adjacent intermediate node as shown in Fig. 4.2.3. Other features of virtual circuit packet switching are discussed in the following subsection.

4.2.3.1 Virtual Circuit Packet Switching Networks

An initial setup phase is used to set up a route between the intermediate nodes for all the packets passed during the session between the two end nodes. In each intermediate node, an entry is registered in a table to indicate the route for the connection that has been set up. Thus, packets passed through this route, can have short headers, containing only a *virtual circuit identifier* (VCI), and not their destination. Each intermediate node passes the packets according to the information that was stored in it, in the setup phase. In this way, packets arrive at the destination in the correct sequence, and it is guaranteed that essentially there will not be errors. This approach is slower than Circuit Switching, since different virtual circuits may compete over the same resources, and an initial setup phase is needed to initiate the circuit. As in Circuit Switching, if an intermediate node fails, all virtual circuits that pass through it are lost. The most common forms of Virtual Circuit

networks are X.25 and Frame Relay, which are commonly used for public data networks (PDN).
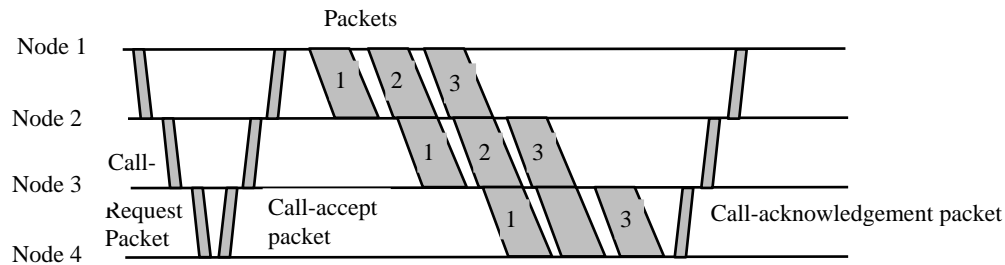

Figure 4.2.3 Virtual circuit packet switching technique

4.2.3.2 Datagram Packet Switching Networks

This approach uses a different, more dynamic scheme, to determine the route through the network links. Each packet is treated as an independent entity, and its header contains full information about the destination of the packet. The intermediate nodes examine the header of the packet, and decide to which node to send the packet so that it will reach its destination. In the decision two factors are taken into account:

- The shortest ways to pass the packet to its destination - protocols such as RIP/OSPF are used to determine the shortest path to the destination.
- Finding a free node to pass the packet to - in this way, bottlenecks are eliminated, since packets can reach the destination in alternate routes.

Thus, in this method, the packets don't follow a pre-established route, and the intermediate nodes (the routers) don't have pre-defined knowledge of the routes that the packets should be passed through.
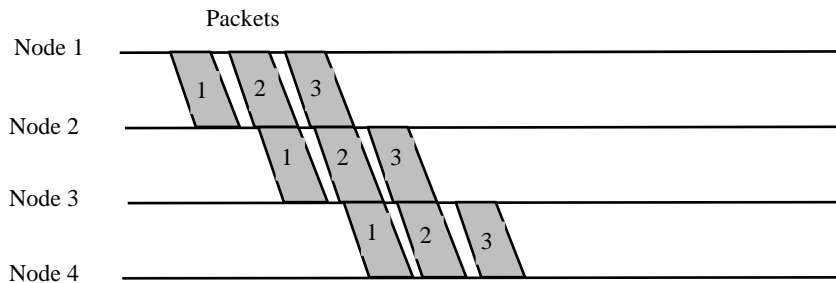

Figure 4.2.4   Datagram Packet switching

Packets can follow different routes to the destination, and delivery is not guaranteed (although packets usually do follow the same route, and are reliably sent). Due to the nature of this method, the packets can reach the destination in a different order

than they were sent, thus they must be sorted at the destination to form the original message. This approach is time consuming since every router has to decide where to send each packet. The main implementation of Datagram Switching network is the Internet, which uses the IP network protocol.

Advantages:
- Call setup phase is avoided (for transmission of a few packets, datagram will be faster).
- Because it is more primitive, it is more flexible.
- Congestion/failed link can be avoided (more reliable).

Problems:
- Packets may be delivered out of order.
- If a node crashes momentarily, all of its queued packets are lost.

4.2.3.3 Packet Size

In spite of increase in overhead, the transmission time may decreases in packet switching technique because of parallelism in transmission as shown in Fig. 4.2.5.
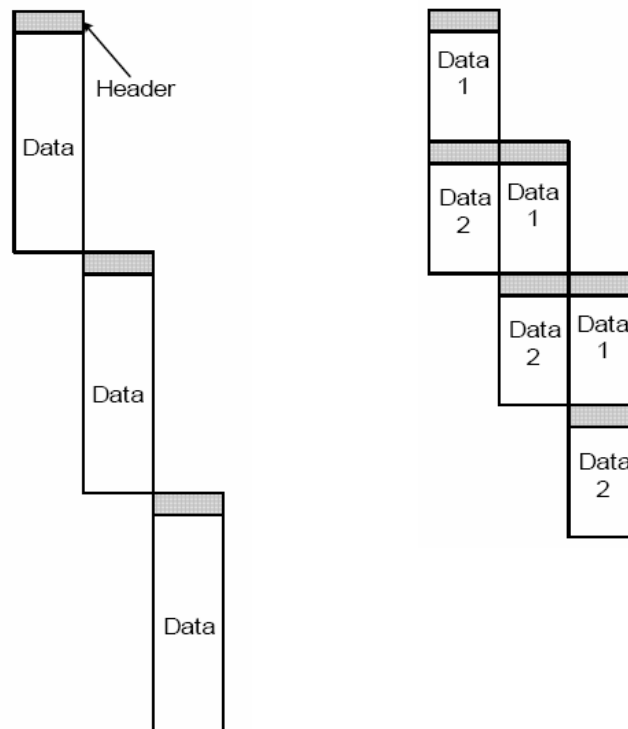
Figure 4.2.5 Reduction of transmission time because of parallelism in transmission in packet switching technique

However, question arises about the optimal size of size of a packet. As packet size is decreased, the transmission time reduces until it is comparable to the size of control information. There is a close relationship between packet size and transmission time as shown in Fig. 4.2.6. In this case it is assumed that there is a virtual circuit from station X to Y through nodes a and b. Times required for transmission decreases as each message is divided into 2 and 5 packets. However, the transmission time increases if each message is divided into 10 packets.
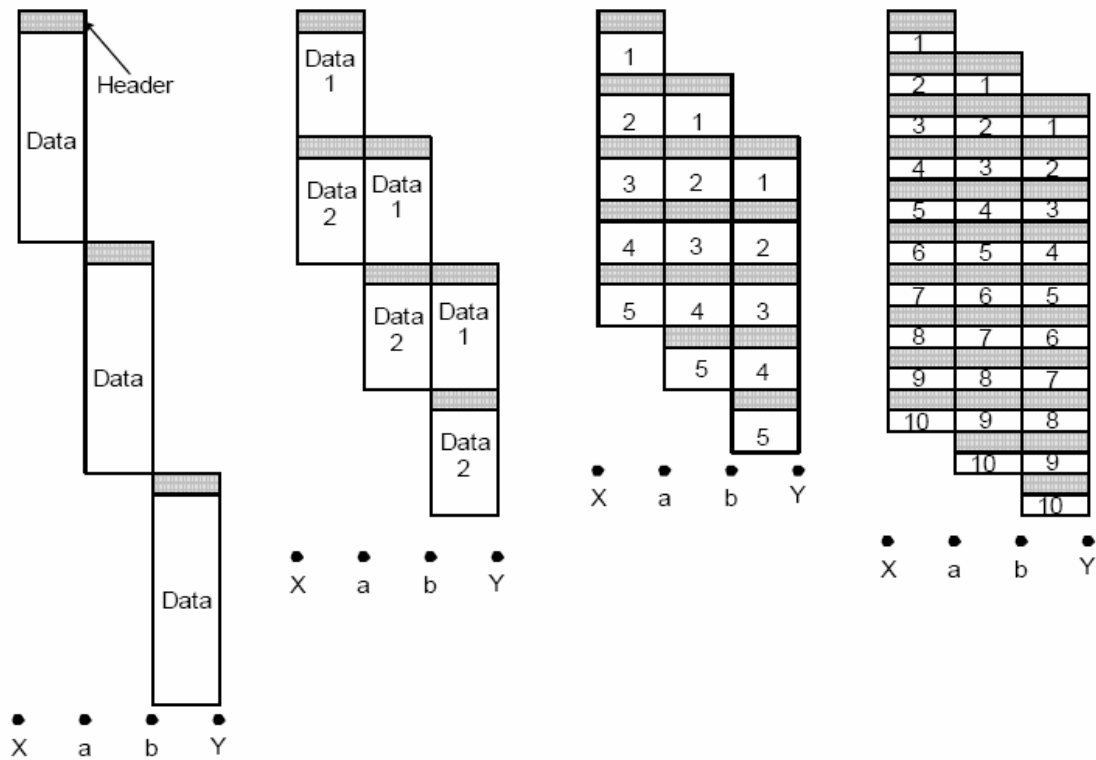

Figure 4.2.6 Variation of transmission time with packet size

4.2.3.4 Virtual Circuit Versus Datagram Packet Switching

Key features of the virtual circuit packet switching approach is as follows:
- Node need not decide route
- More difficult to adopt to congestion
- Maintains sequence order
- All packets are sent through the same predetermined route

On the other hand, the key features of the datagram packet switching are as follows:
- Each packet is treated independently
- Call set up phase is avoided
- Inherently more flexible and reliable

4.2.3.5 External and Internal Operations

There are two dimensions to the problem of whether to use virtual circuit or datagram in a particular situation:

- At the interface between a station and a network node, we may have connection-oriented or connectionless service.
- Internally, the network may use virtual circuits or datagrams.

This leads us to four different scenarios using different VC/DG combinations, which are discussed below.

Scenario 1: External virtual circuit, Internal virtual circuit
In this case a user requests a virtual circuit and a dedicated route through the network is constructed. All packets follow the same route as shown in Fig. 4.2.7.
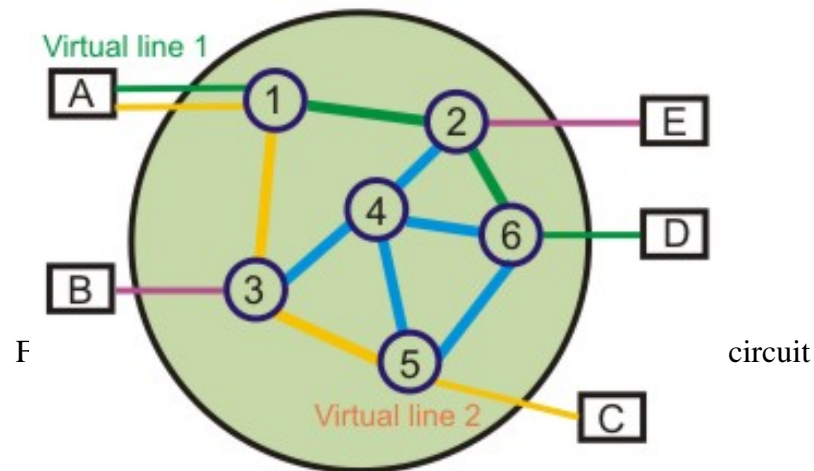
F circuit

Scenario 2: External virtual circuit, Internal datagram
In this case, the network handles each packet separately. Different packets for the same external virtual circuit may take different routes as shown in Fig. 4.2.8. The network buffers packets, if necessary, so that they are delivered to the destination in the proper order.

Scenario 3: External datagram, Internal datagram
In this case each packet is treated independently from both the user's end and the network's point of view as shown in Fig. 4.2.9.

Scenario 4: External datagram, Internal virtual circuit
In this case, an external user does not see any connections - it simply sends packets one at a time as shown in Fig. 4.2.10. The network sets up a logical connection between stations for packet delivery. May leave such connections in place for an extended period, so as to satisfy anticipated future needs.

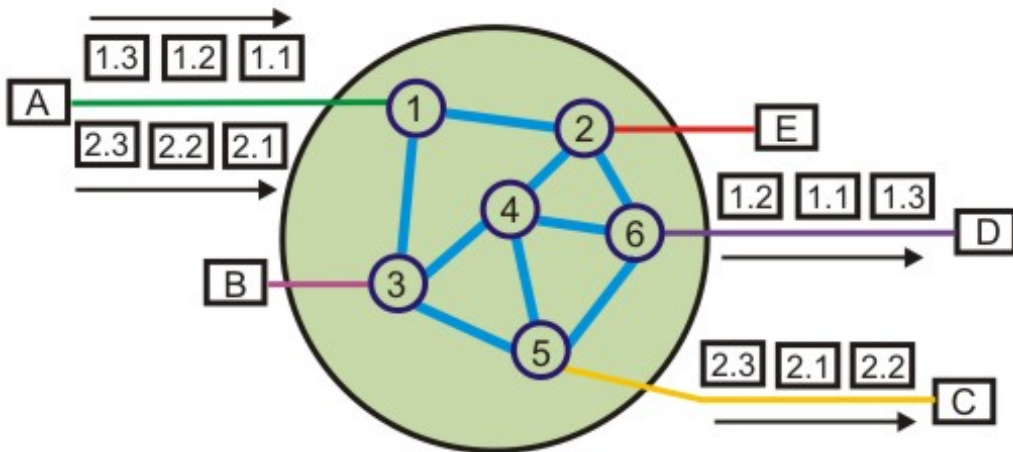A comparison of different switching techniques is given in Table 4.2.1

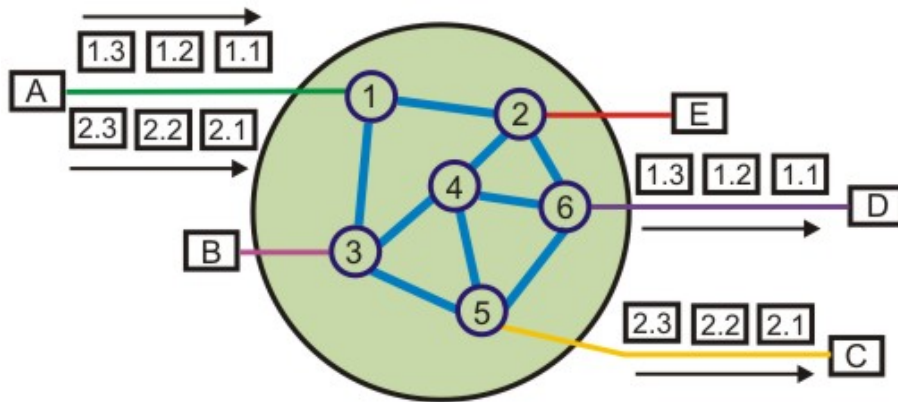Figure 4.2.8 External virtual circuit and internal datagram

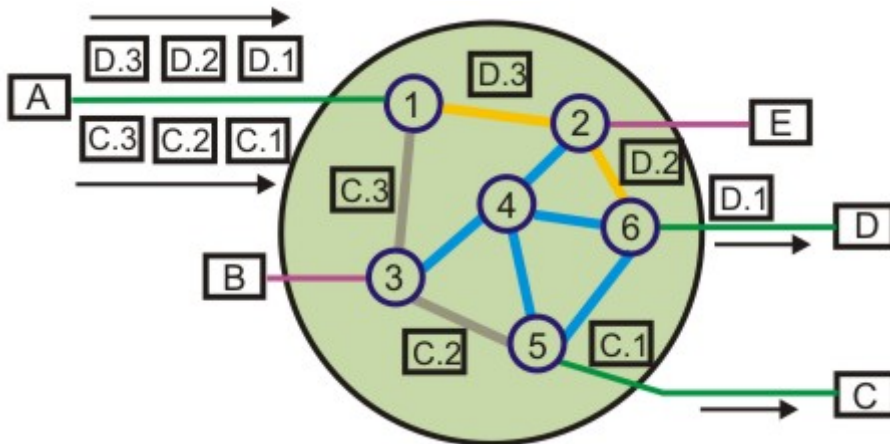Figure 4.2.9 External datagram and internal datagram

Figure 4.2.10 External datagram and internal virtual circuit

Table 4.2.1 Comparison of the three switching techniques

Circuit Switching	Datagram Packet	Virtual Circuit Packet
Dedicated path	No dedicated path	No dedicated path
Path established for entire conversation	Route established for each packet	Route established for entire conversation
Call set up delay	Packet transmission delay	Call set up delay, Packet transmission delay
Overload may block call set up	Overload increases packet delay	Overload may block call set up and increases packet delay
No speed or code conversion	Speed or code conversion	Speed or code conversio
Fixed bandwidth	Dynamic bandwidth	Dynamic bandwidth
No overhead bits after call set up	Overhead bits in each packet	Overhead bits in each packet

Fill In the Blanks:

1. A switched virtual circuit involves _____.
2. A permanent virtual circuit involves _____.
3. Two basic approaches are common to Packet Switching are _____ packet switching and _____ packet switching.
4. X.25 is a standard for _____ communications.

Ans:
1. creation of link as and when needed
2. permanent link
3. virtual circuit … datagram
4. packet switched communication

Short Answer Questions

Q-1. How the drawback of circuit switching is overcome in message switching?

Ans: Message switching is based on store and forward technique. Instead of establishing a dedicated path, the message is sent to the nearest directly connected node. Each node stores the message, checks for error and forwards it. It allows more devices to share the network bandwidth and one message can be sent to several users. Destination host need not be on at the time of sending message.

Q-2. What is the drawback of message switching? How is it overcome in packet switching?

Ans.: In message switching, large storage space is required at each node to buffer the complete message blocks. On the other hand, in packet switching, messages are divided into subset of equal length, which are generated in the source node and reassembled to get back the initial complete message in destination node. Moreover, to transmit a message of large size, link is kept busy for a long time leading to increase in delay for other messages.

Q-3. What are the key differences between datagram and virtual-circuit packet switching?

Ans: In datagram, the packets are routed independently and it might follow different routes to reach the destination in different order. In virtual-circuit packet switching, first a virtual connection is being established, and all the packets are sent serially through the same path. In this case, packets are received in order.

Q-4. Distinguish between circuit switching and virtual-circuit packet switching.

Ans: - In circuit switching, a dedicated path is established. Data transmission is fast and interactive. Nodes need not have storage facility. However, there is a call setup delay. In overload condition, it may block the call setup. It has fixed bandwidth from source to destination and no overhead after the call setup.

In virtual-circuit packet switching, there is no dedicated path. It requires storage facility and involves packet transmission delay. It can use different speed of transmission and encoding techniques at different segments of the route.

Q-5. How packet size affects the transmission time in a packet switching network?

Ans: Initially, transmission time decreases as packet size is reduced. But, as packet size is reduced and the payload part of a packet becomes comparable to the control part, transmission time increases.