8. Switching

1. Describe the need for switching and define a switch.

A network is a series of connected devices. Whenever we have many devices, the interconnection between them becomes more difficult as the number of devices increases. Some of the conventional ways of interconnecting devices are:

a) Point-to-point connection between devices as in a mesh topology
b) Connection between a central device and every other device – as in star topology.
c) Bus topology – not practical if the devices are at great distances

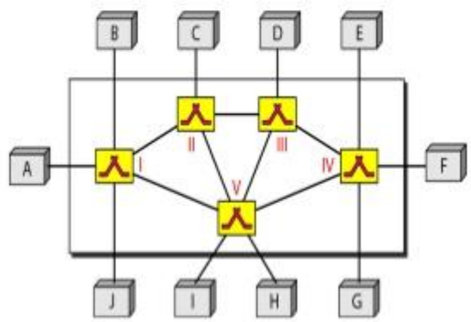
All these techniques require extensive cabling, dependence on a central server or a central bus.

The solution to this interconnectivity problem is *switching*. A switched network consists of a series of interlinked nodes, called *switches*. A switch is a device that creates temporary connections between two or more systems. Some of the switches are connected to the end systems (computers or telephones) and others are used only for routing.

In this diagram, A, B, C, and D are the end systems. The switches are labeled I, II, III, etc. Each switch is connected to multiple links.

The three broad categories of switching networks are:

1. Circuit-switched networks
2. Packet-switched networks
    a. Datagram networks
    b. Virtual-circuit networks
3. Message-switched networks



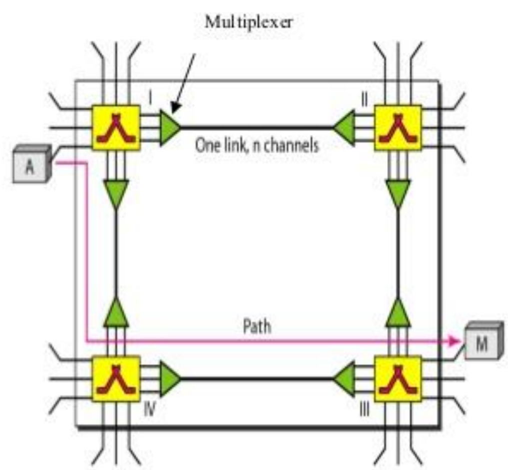
2. Describe circuit-switched networks.

1. A circuit-switched network consists of a set of switches connected by physical links. Switches are hardware/software devices that can create temporary connections between two or more devices.
2. The purpose of the switching nodes is to move data from node to node till it reaches its destination.
3. A *connection* between two stations is a dedicated path made of one or more links. Each link is divided into *n* channels by using FDM or TDM. Each connection uses only one dedicated *channel* on each link.

In this figure we have shown 4 switches and 4 links. Each link is divided into *n* channels using FDM or TDM.

The end systems (e.g., computers) are directly connected to a switch. When end system A needs to communicate with end system M, system A must request a connection to M that must be accepted by all switches as well as by M itself. This is called the *setup phase*.

A circuit (channel) is reserved on each link, and the combination of circuits or channels defines the dedicated path. After the dedicated path is established, data transfer can take place. After all data have been transferred, the circuits are torn down.



Important points:

a) Circuit-switching takes place at the physical layer in the OSI model.
b) Before communication process between 2 computers starts, they must reserve the resources such as channels, switch buffers, switch processing time, and these must be reserved during the entire duration of data transfer. In case data transfer is by FDM, a bandwidth must be reserved and if it is by TDM, a time slot must be reserved.
c) Data is sent in a *continuous flow* from source to destination. Data is not broken up into packets.
d) During the setup phase addressing is involved, but once data transmission begins, addressing is not involved.

Advantages of circuit-switching:

1. Since a circuit is dedicated to a data transmission there is no interference and no sharing of data.
2. The full bandwidth of the channel is guaranteed for the duration of the call.

Disadvantages of circuit-switching:

1. Takes a relatively long time to setup the circuit.
2. A channel is reserved for the duration of the connection even if no data transfer is taking place. The channel may not be utilized to its maximum.
3. Transmission takes place at a constant rate. The two devices that are interconnected must transmit and receive at the same rate. This limits the utility of the network in connecting a variety of computers.
4. Inflexible – once a circuit has been established, that path is taken by all parts of the transmission whether or not it remains the most efficient path.

3. Describe the three phases in circuit-switching networks before actual communication can take place.

The actual communication in circuit-switching requires 3 phases: connection setup, data transfer, and connection teardown.

1. **<u>Connection Setup Phase</u>** –
   a. Before the two systems can communicate, a dedicated circuit (i.e. a combination of channels and links) must be established. Connection setup means creating dedicated channels between the switches.
   b. For example, in fig above, when system A needs to connect to system M, it sends a setup request to switch I. This request contains the address of system M.
   c. Switch I finds a channel between itself and switch IV.
   d. Switch I then sends the request to switch IV. Switch IV finds a dedicated channel between itself and switch III.
   e. Switch III informs system M that system A wants to communicate.
   f. System M then sends an acknowledgement in the opposite direction to system A. Once A receives the acknowledgment, the connection is established.
   g. End-to-end addressing is required for creating a connection between the two end systems. In this example, it is the address of the computers A and M.
2. **<u>Data Transfer Phase</u>** – Once a dedicated path is established between the two systems, data transfer can take place
3. **<u>Tear-down Phase</u>** – When one of the systems needs to disconnect (e.g., after data transfer is completed or after a time-out event), a signal is sent to each switch to release the resources.

4. Discuss the following issues for circuit-switched networks: (1) efficiency, and (2) delay.

<u>Efficiency:</u> Circuit-switched networks are not as efficient as packet and message-switched networks. A channel is a resource and it is allocated during the entire duration of the connection. These resources are not available to other systems. E.g., once a dedicated path is established between two computers, the path may remain connected even when no data transmission is taking place.

Delay: The total delay is due to the time needed to create a connection, transfer data, and disconnect the circuit. The delay caused by the setup is the sum of (i) Propagation time of the source computer request, (ii) Request signal transfer time, (iii) Propagation time of the acknowledgement from the destination to the source, and (iv) Signal transfer time of the acknowledgment. The delay due to transfer is the sum of two parts: propagation time, and data transfer time.

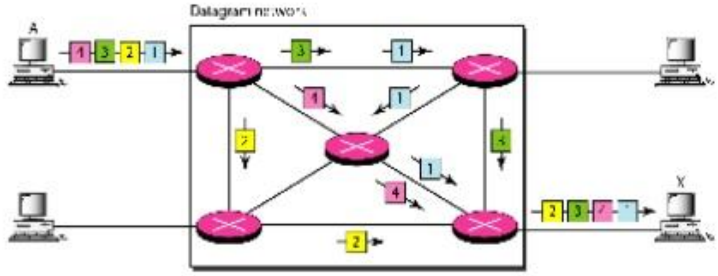
5. Describe Datagram networks (Packet-Switched network) or connectionless network.

A packet-switched network (or connectionless network) is a special kind of network which has the following characteristics:

1. **Create Packets:** Before transmission, a message is broken down into smaller segments called packets of a particular size. This size may be fixed or variable. The size of the packet is determined by the network and the protocol. Typically, packet size is 1000 bytes. Each packet contains user's data and some control information.
2. **What is a Packet:** Each packet contains a header which holds information about the order in which packets should be assembled. The TCP protocol also adds a *checksum;* this checksum number is used at the receiving end to determine whether any errors occurred during packet transmission.
3. **No resource allocation:** In packet switching, there is no resource allocation for a packet. This means that there is no reserved bandwidth on the links, and there is no scheduled processing time for each packet. Resources are allocated on demand. The allocation is done on a first-come, first-served basis.
4. **Delay:** When a switch receives a packet, the packet must wait if there are other packets being processed. This can create a delay. A switch uses its routing table to decide the port that is to be used.
5. **Packets are independent entities:** In a datagram network, each packet is treated independently of all others. Even if a packet is part of a multipacket transmission, the network treats it as though it existed alone. Packets in this approach are referred to as datagrams.
6. **Store-and-Forward:** The packets are passed from node to node and the nodes may store the data briefly before passing it to the next node.
7. **Different Routes:** The different packets of a message may follow different routes before they reach the destination. This may happen because a link is already involved in carrying packets from other sources and there is not enough bandwidth to carry more packets.
8. **Variable Delay due to different paths:** Since the packets can follow different routes there is a variable amount of delay and the packets may arrive out of order at the destination. Some packets may also be lost.
9. **Reordering of datagrams**: An upper-layer protocol will reorder the datagrams or ask for lost datagrams before passing them on to the application layer. The Internet Protocol (IP) transports data in packets called *datagrams.*
10. **Connectionless**: Datagram networks are also called *connectionless networks*. It means that a switch does not keep information about the connection state. There are no setup or teardown phases.
11. Datagram switching is done at the network layer.
12. The switches in a datagram network are traditionally referred to as *routers.*

Advantages of packet-switching:

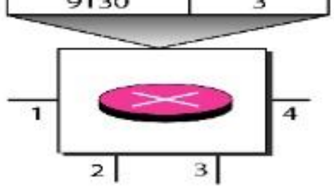
1. Packet-switching is more economical than transmission over private/dedicated lines.
2. If the data transmission time is short than packet-switching is more economical.
3. Different packets can travel along different routes till they reach their destination. Thus, a failure in one switch/node or a particular link does not affect data communication.
4. Packets are accepted even when network is busy.
5. Priority scheme can be used (some packets/messages have a higher priority than others)



6. Discuss the role of a routing table in datagram network.

In a datagram network, each switch has a routing table which is based on the destination address. The routing table is dynamic and is updated periodically. The destination addresses and the corresponding forwarding ports are stored in the tables.

Destination address	Output port
1232	1
4150	2
⋮	⋮
9130	3



Destination Address: -

1. Each packet in a datagram network carries a header.
2. This header contains data, and the destination address.
3. When a switch receives a packet, it checks the destination address, and from the routing table finds the corresponding port through which the packet should be forwarded.
4. This destination address remains the same as the packet travels from source to destination.

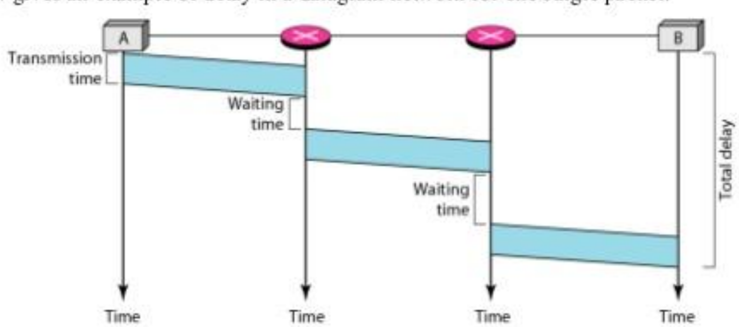
7. Discuss efficiency and delay with regard to datagram networks.

Efficiency: The efficiency of datagram network is better than that of circuit-switched network since resources are allocated only when there are packets to be transferred. If there is a delay in sending packets from one source, the channel can be used to send packets from another source.

Delay:

1. There may be greater delay in a datagram network than in a virtual-circuit network.
2. Even though there are no setup and teardown phases, each packet may experience a wait at a switch before it is forwarded.
3. Since packets in a message may travel through different switches over different paths, the delay is not uniform for all the packets of a message.

Figure below gives an example of delay in a datagram network for one single packet.



The packet travels through 2 switches. The various delays are as follows:

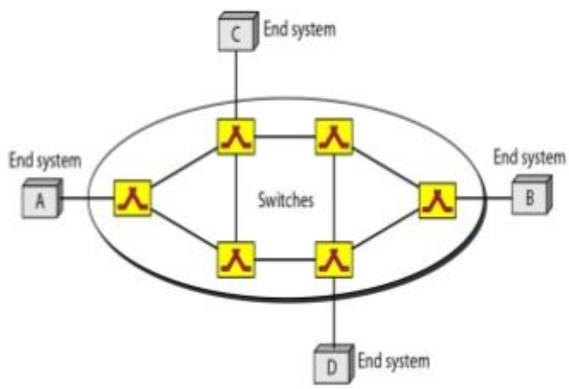
1. 3 transmission times (3T)
2. 3 propagation delays (slopes of the three lines) (3τ)
3. 2 waiting time W1 and W2 at each of the switches.

Thus, total delay $= 3T + 3\tau + W1 + W2$

8. Describe Virtual-circuit Network.

A virtual-circuit network has characteristics common to circuit-switching and packet-switching. The term 'virtual' indicates that although the path between the source and destination appears to be a physical path, actually it is a managed pool of circuit resources from which circuits are allocated as needed. The

1. Just as in circuit-switching, there are setup and teardown phases in addition to the data transfer phase. The call-request and call-accept packets are used to establish a connection (handshake) .
2. Resources can be allocated during the setup phase, as in a circuit-switched network, or on demand, as in a datagram network.
3. As in a datagram network, data are in packets, and each packet carries an *address* in the header. But, the address in the header is not of the destination computer, it is the address of the next switch and channel on which the packet is being carried.
4. As in circuit-switched network, all packets follow the same path established during the connection.
5. Virtual circuit networks involve two types of addresses:
   a. Global address, and
   b. Local address (or virtual-circuit identifier)
6. A virtual-circuit network is implemented in the data-link layer of the OSI model whereas circuit-switching is implemented in the physical layer.

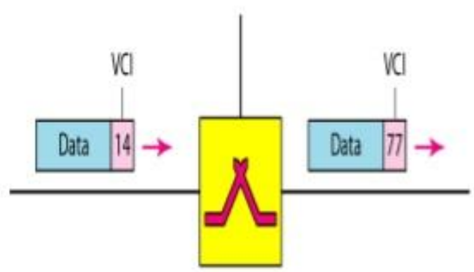


Addressing issues in Virtual-circuit Networks:

Virtual circuit networks involve two addresses:

Global address: A source or a destination must have a global address i.e., an address that is unique in the scope of the network. But a global address in virtual-circuit networks is used only to create a virtual-circuit identifier.

Virtual-circuit Identifier: The identifier that is actually used for data transfer is called the virtual-circuit identifier (VCI). A VCI is a small number that has only switch scope; it is used between two switches. When a frame arrives at a switch, it has a VCI; when it leaves, it has a different VCI. The VCI in a data frame changes from one switch to another in this fig.



Virtual-circuit Identifier
(Note the VCI is different at input and output)

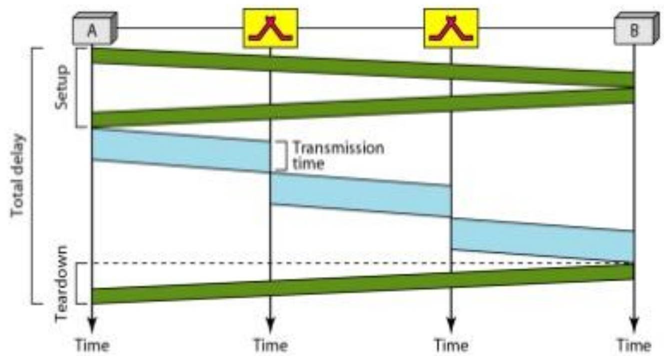
9. Discuss the efficiency and delay issues in a virtual-circuit network.

Efficiency: In virtual-circuit network, resource reservation can be made during the setup or can be on demand during the data transfer phase. In the first case, the delay for each packet is the same; in the second case, each packet may encounter different delays. But even if resource allocation is on demand the advantage is that the source can check the availability of the resources, without actually reserving it.

Delay: In a virtual-circuit network, there is a one-time delay for setup and a one-time delay for teardown. If resources are allocated during the setup phase, there is no wait time for individual packets. The following diagram shown delay in virtual-circuit network:

The packet is traveling through two switches (routers).

Times involved are:
3 transmission times *(3T)*,
three propagation times (3τ),
data transfer depicted by the sloping lines,
a setup delay,
a teardown delay



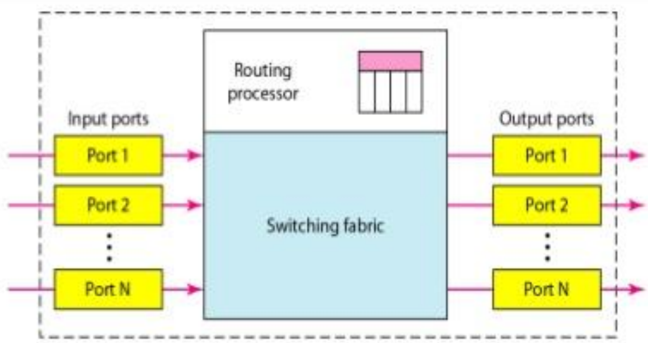
The total delay time is
Total delay = $3T + 3\tau$ + setup delay + teardown delay

10. Describe the structure of Packet switches.

A packet switch has 4 components:

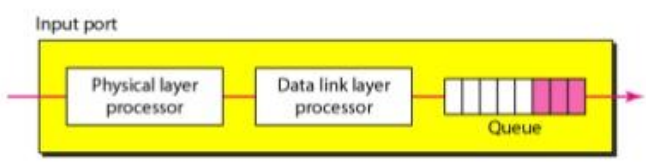
- Input ports.
- Output ports,
- The routing processor,
- The switching fabric

We now discuss each of these parts:



Input Ports: An input port performs the physical and data link functions of the packet switch.

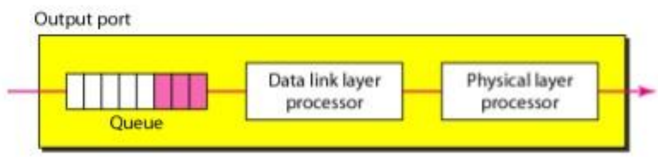
1. Construct bits from the received signal.
2. Removed packet from frame.
3. Detect and correct errors.



The packet is now ready to be routed by the network layer.
The buffers (queues) hold the packet before it is sent to the switching fabric.

Output Port: The output port performs the same functions as the input port, but in the reverse order.

1. The outgoing packets are queued.
2. The packet is encapsulated in a frame,
3. The physical layer functions are applied to the frame to create the signal to be sent.



Routing Processor:

1. The routing processor performs the functions of the network layer.
2. The destination address is used to find the address of the next hop and, at the same time, the output port number from which the packet is sent out. This activity is sometimes referred to as table lookup because the routing processor searches the routing table.

Switching Fabrics:

The most difficult task in a packet switch is to move the packet from the input queue to the output queue. The speed with which this is done affects the size of the input/output queue and the overall delay in packet delivery. The common techniques are crossbar switch and Banyan switch.

11. Distinguish between connection-oriented and connectionless networks.

Delivery of a packet can be accomplished using either a connection-oriented or a connectionless network service.

In a **connection-oriented** service (circuit-switched network):

1. The source first makes a connection with the destination before sending a packet.
2. When the connection is established, a sequence of packets from the same source to the same destination can be sent one after another.
3. In this case, packets are sent on the same path in sequential order.
4. A packet is logically connected to the packet traveling before it and to the packet traveling after it.
5. When all packets of a message have been delivered, the connection is terminated.
6. In a connection oriented protocol, the decision about the route which the different packets will take is made only once, when the connection is established. Switches do not recalculate the route for each individual packet.
7. This type of service is used in a virtual circuit approach to packet switching. This is implemented at the physical layer of the OSI model.

In **connectionless service:**

1. The network layer protocol treats each packet independently.
2. Each packet has no relationship to any other packet.
3. The packets in a message may or may not travel the same path to their destination.
4. This type of service is used in the datagram approach to packet switching. The Internet has chosen this type of service at the network layer. The reason for this decision is that the Internet is made of so many heterogeneous networks that it is impossible to create a dedicated connection from the source to the destination without knowing the nature of the networks in advance.

12. What are the two approaches to packet switching?

The two approaches to packet switching are: Datagram networks and virtual-circuit networks. The characteristics of each of these are given below:

Issue	Datagram	Virtual-circuit
Circuit setup	Not needed	Required
Addressing	Each packet contains the full source and destination address	Each packet contains the short VCI (virtual circuit identifier)

Routing	Each packet is routed independently	Route is selected when VCI is setup. All packets follow the same route.
Congestion control	Difficult	Easy if enough buffers can be allocated in advance.
Code complexity	The code required for sending data is more complex.	Code responsible for data transfer is simple. It uses only the switching table to send data.
Packet Sequence	Packets can arrive out of sequence	Packets will arrive in sequence
Alternate names	Also called connectionless model	Also called connection-oriented model
Header	Every packet must carry the full address of the destination. The overhead (extra info) per packet is higher.	The connection request contains the full destination address. Each data packet contains only a small identifier called VCI. Packet overhead is small.
Quality of Service (QoS)	• Source has no way of knowing if the network can deliver the packet. • Since each packet is treated independently, it is possible to avoid routes / links that are not available. • Packets may follow different paths and arrive out of sequence – reordering at destination is necessary.	• Connection setup allows resource reservation. • If a switch / link fails, the connection is broken and a new connection must be established. • Packets arrive in sequence and reordering is not needed at destination.

13. Discuss the demerits of circuit switching *vis-a-vis* packet switching.

Demerits of Circuit Switching:

1. Circuit switching is suitable for voice communications. When circuit switched links are used for data transmission, the links are often idle and the bandwidth is wasted.
2. The data rate of circuit switched connections is very slow.
3. Circuit switching is inflexible. Once a circuit (path) has been established, that path must be taken by all parts of the transmission whether or not it remains the most efficient.
4. Circuit switching treats all transmission as equal. There is no priority among transmission of data.

14. Compare Circuit-switched and Packet-switched networks.

Item	Circuit Switched Network	Packet Switched Network
Call setup	Required	Not required
Dedicated physical path	Yes	No
Each packet follows same route	Yes	No
Packets arrive in order	Yes	No
Is a switch crash fatal?	Yes	No
Bandwidth available	Fixed	Dynamic
Time of possible congestion	At setup time	On every pcket
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Transparency	Yes	No
Charging	Per minute	Per packet