Lesson Seven

Switched Communication Networks

Specific Objectives

By the end of the lesson the learner should be able to:

(i) Define switching
(ii) Distinguish between circuit switching and packet switching
(iii) Distinguish between Frame Relay, ATM and X. 25
(iv) Distinguish between ISDN Integrated Services Digital Network and Multi-Purpose Label Switching

Switched communication Networks

A communication network consists of a network of nodes connected by point to point links. Data are transmitted from source to destination through intermediate nodes. The connections are usually made through a telephone company eg Telkom Kenya

The switching devices are

- Data Terminal Equipment DTE
- Data Circuit terminating Equipment DCE

Data switching techniques

Information passes through multi paths as it moves from the source to the destination in a large network. The information is switched as it travels through various communication channels using

- Circuit Switching-Connection Oriented
- Message Switching- Connectionless –Oriented
- Packet switching- Connectionless Oriented

Circuit switching

It's a technique that connects the sender and the receiver by a single path for the whole duration of message passing. In the case of a conversation, once a connection is established, a dedicated path is established between both ends. It always consumes network capacity even if there is no active transmission taking place.

Circuit switching includes phone systems and data that need to be transmitted live like sports and speeches

In telecommunications, a **circuit switching** network is one that establishes a fixed bandwidth circuit (or channel) between nodes and terminals before the users may communicate, as if the nodes were physically connected with an electrical circuit. The bit delay is constant during the connection, as opposed to packet switching, where packet queues may cause varying delay.

Packet switching

The desire is to have speedy, flexible, robust, responsive optimized channel capacity at a fair price.

Packet switching is a communications method in which packets are routed between nodes over data links shared with other traffic. In each network node, packets are queued or buffered, resulting in variable delay. This contrasts with the other principal paradigm, circuit switching, which sets up a limited number of constant bit rate and constant delay connections between nodes for their exclusive use for the duration of the communication.

Packet mode or **packet-oriented** communication may be utilized with or without a packet switch, in the latter case directly between two hosts. Examples of that are point-to-point data links, digital video and audio broadcasting or a shared physical medium, such as a bus network, ring network, or hub network.

(A) Circuit switching

Is a type of communications in which a dedicated channel (or *circuit*) is established for the duration of a transmission. It can be referred to as a methodology of implementing a telecommunications network in which two network nodes establish a dedicated communications channel (circuit) through the network before the nodes may communicate. The circuit guarantees the full bandwidth of the channel and remains connected for the duration of the communication session. The circuit functions as if the nodes were physically connected as with an electrical circuit.
A good example of the circuit-switching network is used for connecting voice circuits like the telephone system, which links together wire segments to create a single unbroken line for each telephone call.

Circuit-switching systems are ideal for communications that require data to be transmitted in real-time and are sometimes called *connection-oriented* networks

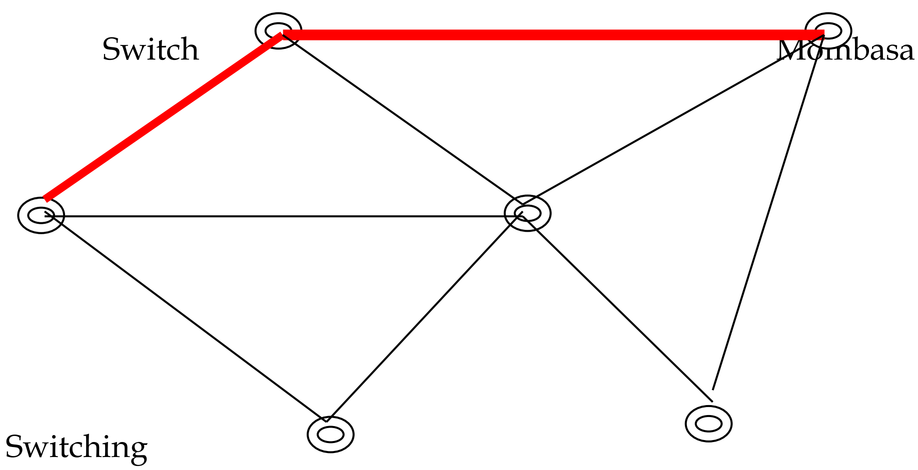

Fig 7.1 Circuit Switching

The circuit is established and maintained for the entire duration of the communication.

Two techniques are used for the implementation of a circuit in a link.

1. Frequency Division Multiplexing (FDM)
2. Time-Division Multiplexing (TDM).

Frequency Division Multiplexing (FDM):

The connections established across the link shares the frequency band of a link among themselves. Specifically, a frequency band is dedicated by the link to each connection for the duration of the connection.

Time division multiplexing:

Using a TDM link, time is divided into frames of fixed duration and each frame is divided into a fixed number of time slots. Whenever the network wants to establish a connection across a link, one time slot in every frame is reserved for the connection.

B Message Switching.

Circuit switching is the most appropriate technique for continuous transmission of data between source and destination. However, there are some drawbacks as listed below:

- Source and destination must be available at the time of data transfer.
- Nodes and links must be available in advance before the start of transmission and dedicated
- The channel should be available until the data transfer is completed.

When the source station does not have enough data to transmit continuously, resources are unnecessarily kept idle for the duration of time when there is no transfer of data. To avoid such situations, a different switching method called message switching is used. In this switching method, no dedicated physical path is established in advance. Instead, it is based on a technique called store and forward switching. When the source station has a message block to send, it is stored in the first switching node. Each node in the network is an electronic switching device.

Nodes are equipped with enough buffers memory to hold the incoming message. As soon as a free channel is seized, the first node sends a copy of the stored message to the next node on the path through the communication channel, just seized. At each hop, the message is examined for errors. The message hops from one node to another node until it reaches the destination.

• A message is a logical unit of information and can be of any length.

• In message switching, if a station wishes to send a message to another station, it first adds the destination address to the message.

• Each message is treated as an independent unit.

• In message switching, each complete message is then transmitted from device to device through the internetwork *i.e.* message is transmitted from the source node to intermediate node.

• The intermediate node stores the complete message temporarily, inspects it for errors and transmits the message to the next node based on an available free channel and its routing information Because of this reason message switched networks are called store and forward network as shown in fig 8.2

• The actual path taken by the message to its destination is dynamic as the path is established as it travels along.

• When the message reaches a node, the channel on which it came is released for use by another message.

• As shown in Figure 8.2 message Ml is transmitted from A to H and M2 is transmitted A to G. Message Ml follows the route A –> B –> D –> F –> G and M2 follows the route A–> B –> C–> F–> G depending on the availability of free path at that particular moment.

• The first electromechanical telecommunication system used message switching for telegrams. The message was punched on paper tape off-line at the sending office and then read in and transmitted over a communication line to the next office along the way, where it was punched out on paper tape. An operator there tore the tape off and read it in on tape readers.

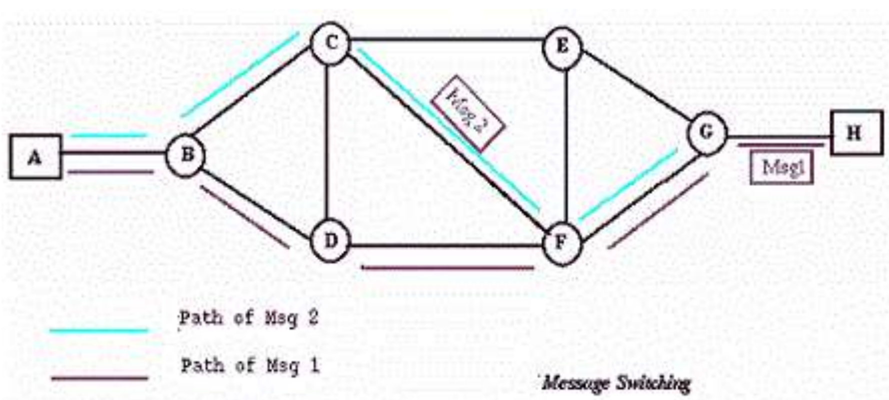

Fig 8.2 Message Switching

Advantages of Message Switching.

The various advantages of message switching are:

• Efficiency is improved by sharing a single channel by many messages.

• Source and destination stations are not simultaneously required to be ready. The network can store the message in case the receiver is not ready.

• Message switching systems can transmit single message to several destinations; however, in circuit switching this facility is not permitted.

• Message transfer is possible even when the transfer rates of the source and destinations differ circuit switching does not support this feature.

• Storing or re-routing the message may be used to restore it from node or link failure occurring during data transfer.

The primary drawback of message switching is that it is not suitable for real time or interactive traffic. It is not suitable for voice transmission.

Disadvantages of Message Switching.

The various disadvantages of message switching are:

1. As message length is unlimited, each switching node must have sufficient storage to buffer message.

2. Storing & forwarding facility introduces delay thus making message switching unsuitable for real time applications like voice and video.

Delay in Message Switching.

• A message switched network consists of store-and-forward switches interconnected by trunks. A single trunk is usually sufficient between a pair of switches.

• Multiple trunks can be provided to increase reliability. Each switch is equipped with a storage device wherein all incoming messages are temporarily stored for onward transmission.

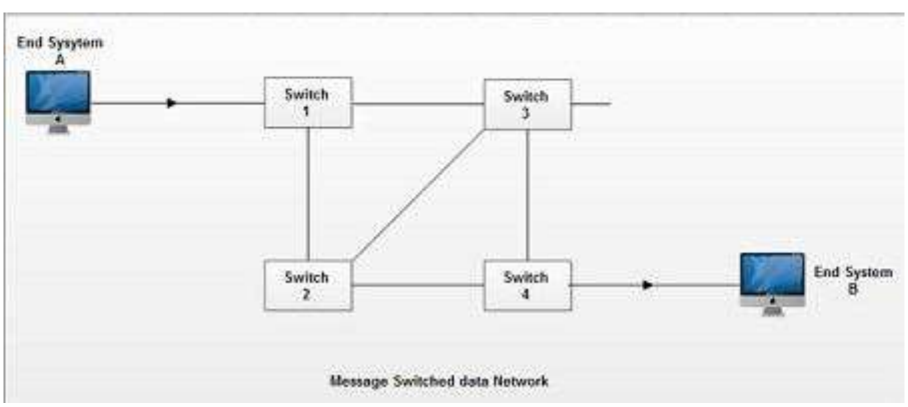

Fig 7.3 Message Switched Data Network

• The basic operation of the store-and-forward service is similar to the telegram service. A message along with the destination address is sent from switch to switch till it reaches endpoint.

• Let us say end system A wants to send a message to end system B as shown in Fig. 7.3 sends its message along with the address of the destination and its own address to entry switch 1. The addresses are included in the header of the message.

• Switch 1 accepts the message and analyzes the destination address. A routing table is maintained at each node.

• It contains entries indicating destination nodes and the corresponding outgoing trunks from the switch. There is a separate queue for each trunk.

• Since the destination node may be accessible via more than one route, decision to send the message to a particular next switch depends on the expected delay in its queue. Let us say, the message from A is put in the queue for node 2.

• The message received at switch 2 is again put in a queue of messages awaiting transmission to switch 4. When its turn comes, the message is sent to switch 4 which delivers it to the destination.

• Some of the basic features of store- and-forward message switching are:

• The store-and-forward service is unidirectional. After delivery of the message, the network does not send back any confirmation to the source. If end system B is required to send an acknowledgement to the message received from A, the acknowledgement is treated like any other message by the network and carries the addresses of the destination and the source.

• For switch -to- switch transfer of the message, the network may employ some error control mechanism. The message may be appended with error-checking bits and if any error is detected by the receiving switch, it may request the sending switch for retransmission of the message. Therefore, the sending switch is required to keep a copy of the message till an acknowledgement is received.

• Since the message is stored in a buffer at the switch at each stage of transmission, each switch-to-switch transfer is an independent operation. The trunks can operate at different data rates. Even the source and destination end systems can operate at different data rates.

• In message switching every message is treated as an independent entity by the network and, therefore, destination and source addresses are repeated on each message.

• Delay in Delivery. Fig 8.4 shows the timing diagram for routing a message through a message switched network. The message passes through the entry switch, two transit switches and finally through the exit switch to arrive at the destination.

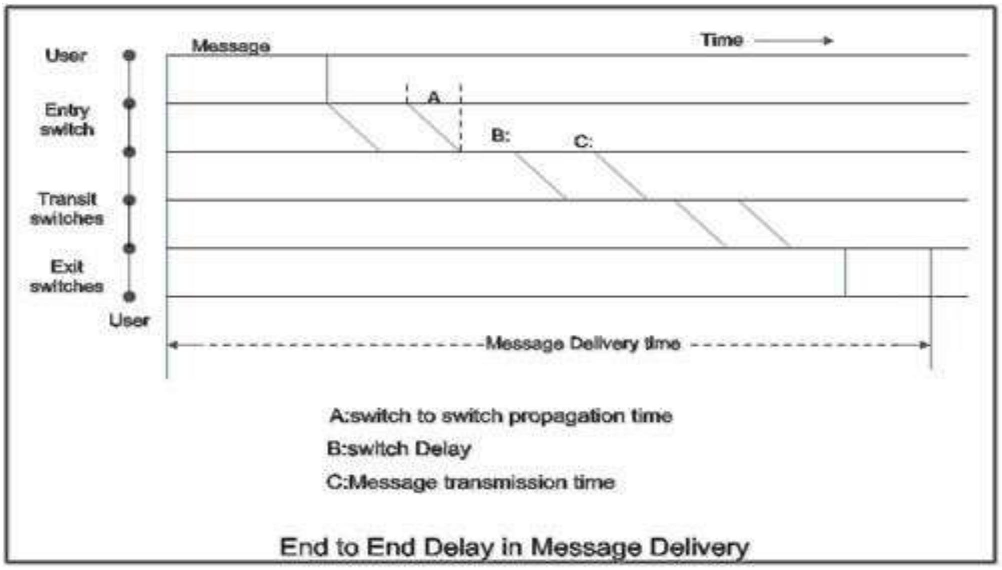

Fig 8.4 End to End Delay in Message Delivery

Message delivery time is the sum of the following components:

• Time required sending the message to the entry switch

• Switch delay

• Transmission time at each switch.

• The time required to send a message to the entry switch is determined by the transmission data rate and the message size.

• Propagation time to the entry switch is usually negligible. Switch delay is due to two factors:

1. Message processing at each switch (time required for error checking, routing etc.)

2. Waiting time in the queues at each switch.

• The transmission time at each switch is determined by the transmission data rate and propagation p time for transmission across the trunk.

• The total time required to deliver the message is the linear sum of all these components of time as they occur in a sequential manner.

• The delivery time varies from message to message because of random waiting times in queues and alternate routes between the same pair of entry and exit switches.

• Therefore, time relationship of the messages and their sequence are not guaranteed in a message switched network.

• As traffic increases there is increase in message delivery time; because the queues get longer and there may be congestion on the route.

C. Packet switching

It is a digital networking communications method that groups all transmitted data, regardless of content, type, or structure into suitably sized blocks, called packets and sends each packet individually. These packets are sent out from the computer and they travel around the network seeking out the most efficient route to travel as circuits become available. This does not necessarily mean that they seek out the shortest route.Each packet may go a different route, its header address tells it where to go and describes the sequence for reassembly at the destination computer, so that the packets are put back into the correct order. One packet also contains details of how many packets should be arriving so that the recipient computer knows if one packet has failed to turn up. A packet is handed over from node to node across the network. Each receiving node temporarily stores the packet, until the next node is ready to receive it, and then passes it onto the next node. This technique is called store-and-forward. When received, packets are reassembled in the proper sequence to make up the message. If a packet fails to arrive, the recipient computer sends a message back to the computer which originally sent the data, asking for the missing packet to be resent.

Circuit-switched networks require dedicated point-to-point connections during calls. Packet switching features delivery of variable-bit-rate data streams over a shared network. The Internet is a good example of packet-switching technique where it uses the, TCP/IP. Packet-switching networks are more efficient if some amount of delay is acceptable

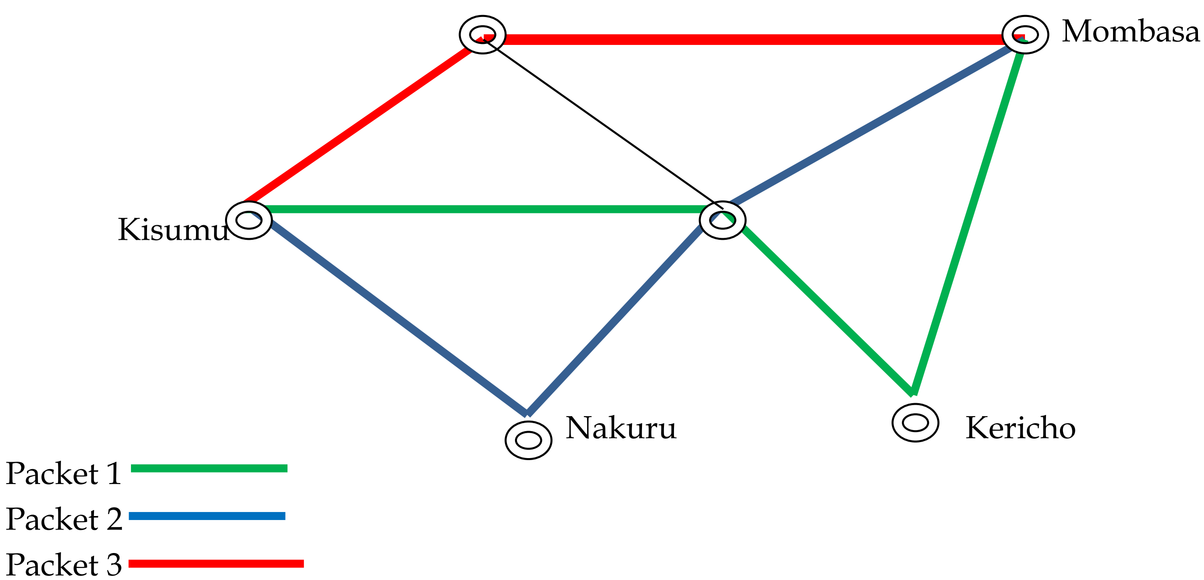

Fig 8.5 Packet Switching

Two major packet switching modes;

Connectionless packet switching / datagram switching

Each packet includes complete addressing or routing information. The packets are routed individually, sometimes resulting in different paths and out-of-order delivery,

Connection-oriented packet switching / virtual circuit switching.
A connection is defined and pre allocated in each involved node during a connection phase before any packet is transferred. The packets include a connection identifier rather than address information, and are delivered in order.

(i) **X.25 Packet Switched networks** allow remote devices to communicate with each other over private digital links without the expense of individual leased lines. Packet Switching is a technique whereby the network routes individual packets of HDLC data between different destinations based on addressing within each packet. An **X.25 network** consists of a network of interconnected nodes to which user equipment can connect. The user end of the network is known as **Data Terminal Equipment** (**DTE**) and the carrier's equipment is **Data Circuit-terminating Equipment** (**DCE**) . X.25 routes packets across the network from DTE to DTE.

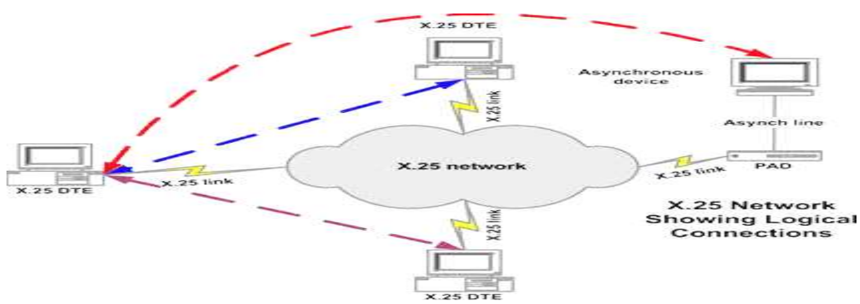

Fig 7.6 X.25 Network

The protocol known as **X.25** was developed by the organization now known as the International Telecommunications Union (ITU) and encompasses the first three layers of the **OSI 7-layered architecture** as defined by the International Organization for Standardization (ISO) as follows:

- **Layer 1: the Physical Layer** is concerned with electrical or signaling. It includes several electrical standards including V.35 , RS232 and X.21.
- **Layer 2: the Data Link Layer**, which is an implementation of the ISO HDLC standard called Link Access Procedure Balanced (LAPB) and provides an error free link between any two physically connected nodes. The Data Link Layer is responsible for error-free communication between any two nodes. Thus errors are checked and corrected for each hop all the way across the network. It is this feature that makes X.25 so robust, and so suitable for noisy, error-prone links. The downside is the latency forced on the system, because each frame has to be received in its entirety and checked before it can be forwarded to the next node. It is not unusual to have latencies of over half a second across X.25 networks. The larger the packet size and the lower the line speed the longer the latency period.

Thus X.25 packets tend to be short – 128 0r 256 bytes as opposed to 1500 bytes or more for more modern protocols. Modern protocols like Frame Relay or ATM take advantage of the low error rates of digital lines to avoid the latency problems of hop-to-hop error correction. They have no error correction and only rudimentary flow control, relying on higher-level protocols like TCP/IP to provide end-to-end error correction and flow control.

- **Layer 3: The Network Layer** that governs the end-to-end communications between the different DTE devices. Layer 3 is concerned with connection set-up and teardown and flow control between the DTE devices, as well as network routing functions and the multiplexing of simultaneous logical connections over a single physical connection.

X.25 permits a DTE user on an **X.25 network** to communicate with a number of remote DTE's simultaneously. Connections occur on logical channels of two types:

- **Switched virtual circuits** (**SVC**'s) – SVC's are very much like telephone calls; a connection is established, data are transferred and then the connection is released. Each DTE on the network is given a unique DTE address which can be used much like a telephone number.
- **Permanent virtual circuits** (**PVC**'s) – a PVC is similar to a leased line in that the connection is always present. The logical connection is established permanently by the Packet Switched Network administration. Therefore, data may always be sent, without any call setup.

To establish a connection on an SVC, the calling DTE sends a **Call Request** Packet, which includes the address of the remote DTE to be contacted.

The destination DTE decides whether or not to accept the call (the Call Request packet includes the sender's DTE address, as well as other information that the called DTE can use to decide whether or not to accept the call). A call is accepted by issuing a **Call Accepted** packet, or cleared by issuing a **Clear Request** packet.

Once the originating DTE receives the Call Accepted packet, the virtual circuit is established and data transfer may take place. When either DTE wishes to terminate the call, a **Clear Request** packet is sent to the remote DTE, which responds with a **Clear Confirmation** packet.

The destination for each packet is identified by means of the **Logical Channel Identifier** (**LCI**) or **Logical Channel Number** (**LCN**). This allows the PSN to route the each packet to its intended DTE.

X.25 relies on the underlying robustness of HDLC LAPB to get data from node to node through the X.25 network. An X.25 packet makes up the data field of an HDLC frame. Additional flow control and windowing are provided for each Logical Channel at the X.25 level.

(ii) ATM (Asynchronous Transfer Mode)

Asynchronous Transfer Mode (ATM) is a new network technology designed for "integrated services" networks capable of carrying multimedia data as well as conventional computer data traffic. ATM is a connection-oriented service that transfers small, fixed-sized packets called cells through a switch-based network. Although it makes no promises of reliable delivery, cells that are actually delivered are guaranteed to be in-order. The cell used with ATM is relatively small compared to units used with older technologies. The small, constant cell size allows ATM equipment to transmit video, audio, and computer data over the same network, and assure that no single type of data hogs the line. The system architecture makes use of switches that set up logical circuits at both ends of the data stream, which ensures unprecedented quality of service

ATM is a switch-based network, with point-to-point links between switches. By contrast, many popular LANs such as Ethernet are multiple-access, shared-media networks. It is connection-oriented (as opposed to datagram-based). There is some signaling protocol capable of setting up virtual circuits and (if necessary) performing the necessary admission control tests.

ATM can support performance guarantees. We do assume a well-defined interface. Our network uses different versions of Rate-Controlled Static Priority Queueing (RCSP) as scheduling mechanisms (along with appropriate admission control tests) to provide performance guarantees

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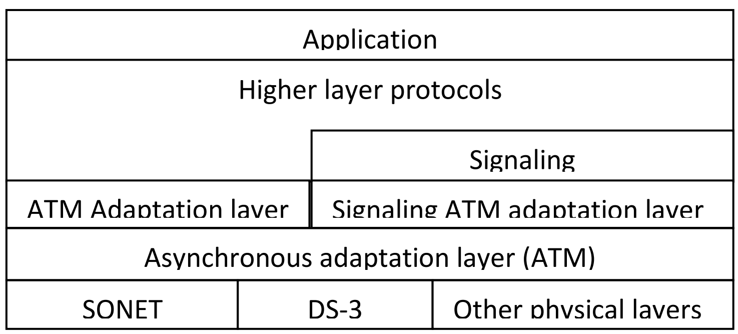


Fig 7.7 ATM Frame

ATM has a high bandwidth, high speed medium for normal operation such as optical fiber networks and low delay, cell relay technology for switching and multiplexing and a faster processing and switch speeds are possible. It allows variety of different applications and services eg video, data, voice etc to be supported on a single network and is connection-oriented. An ATM endpoint establishes a defined path known as a virtual channel (VC), also called virtual circuit, to the destination endpoint prior to sending any data on the network. Asynchronous Transfer Mode divides information in to blocks called cells which are fixed in size.

ATM is otherwise an unreliable transmission protocol because it does not acknowledge the receipt of cells sent.

(iii) Frame-Relay

Frame relay is a telecommunication service designed for cost-efficient data transmission for intermittent traffic between local area networks (LANs) and between end-points in a wide area network (WAN). Frame relay puts data in a variable-size unit called a frame and leaves any necessary error correction (retransmission of data) up to the end-points, which speeds up overall data transmission. For most services, the network provides a permanent virtual circuit (PVC), which means that the customer sees a continuous, dedicated connection without having to pay for a full-time leased line, while the service provider figures out the route each frame travels to its destination and can charge based on usage.

Frame relay is based on the older X.25 packet-switching technology which was designed for transmitting analogue data such as voice conversations. It is a fast packet technology , which means that the protocol does not attempt to correct errors.

Frame relay is often used to connect local area networks with major backbones and wide area networks. It's not ideally suited for voice or video transmission,

Frame relay header structure.

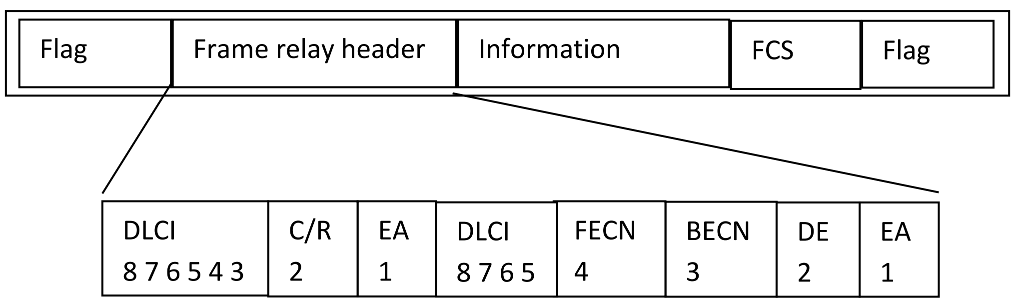


Fig 7.8 Frame Relay header structure

DLCI - 10-bit DLCI field represents the address of the frame and corresponds to a PVC.
C/R - Designates whether the frame is a command or response.
EA - Extended Address field signifies up to two additional bytes in the Frame Relay header, thus greatly expanding the number of possible addresses.
FECN - Forward Explicit Congestion Notification.
BECN - Backward Explicit Congestion Notification.
DE - Discard Eligibility.
Information - The Information field may include other protocols within it, such as an X.25, IP or SDLC (SNA) packet.

(iv) ISDN (Integrated Services Digital Network)

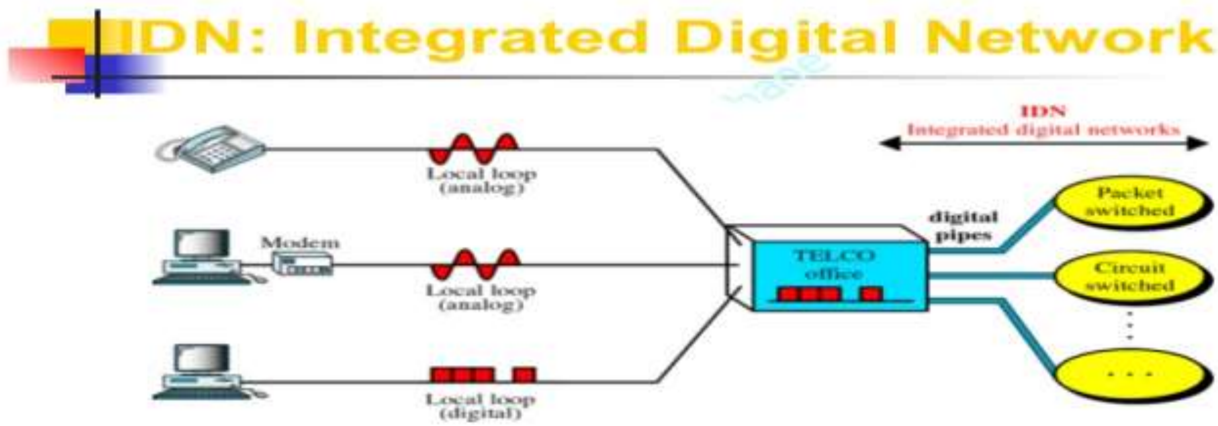
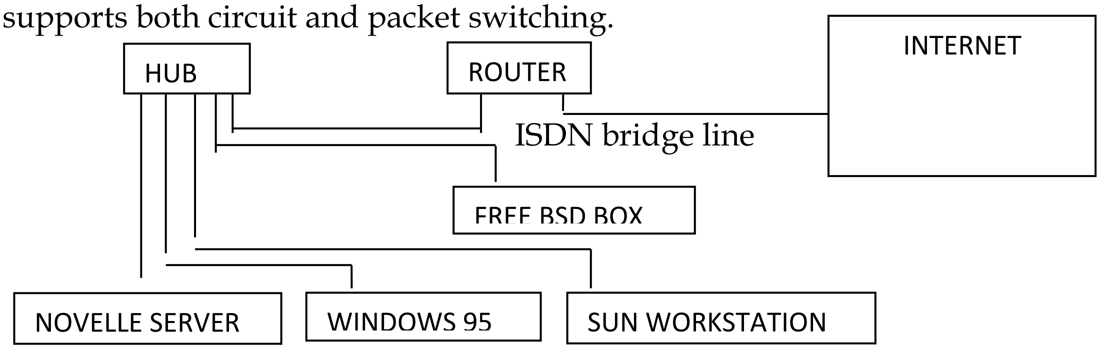


Fig 7.9 ISDN Network

This is a set of standards for digital transmission over ordinary telephone copper wire as well as over other media. Installations of an ISDN adapter, in place of a telephone modem receive allow Web pages at up to 128 Kbps compared with the maximum 56 Kbps rate of a modem connection. ISDN requires adapters at both ends of the transmission so your access provider also needs an ISDN adapter.
ISDN in concept is the integration of both analog or voice data together with digital data over the same network Broadband ISDN is intended to extend the integration of both services throughout the rest of the end-to-end path using fiber optic and radio media. Broadband ISDN encompasses frame relay service for high-speed data that can be sent in large bursts, the Fiber Distributed-Data Interface (FDDI), and the Synchronous Optical Network (SONET).
The three most important ingredients of ISDN are circuit switching, packet switching, and common channel signalling.
ISDN provides a fully integrated digital network for voice and data communication and
it supports both circuit and packet switching.



7.10 B-ISDN is broad band ISDN

(v) MPLS (Multi-Purpose Label Switching)

Multi-Protocol Label Switching (MPLS) is a switching technology that regulates data traffic and packet forwarding in a complex network. It is a connection-oriented methodology that traverses packets from source to destination node across networks for fast packet transmission. It encompasses packets in different network protocols which ensure end-to-end circuits over any type of transport medium using any network layer protocol.

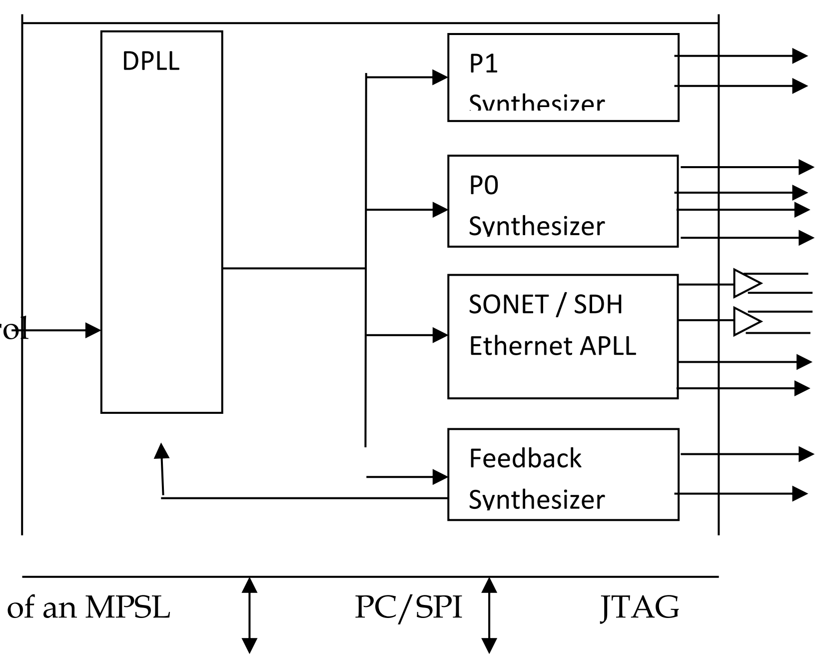
The core technology intents to remove protocol-dependency on specific data link layer technologies such as ATM, Frame Relay, Ethernet, and Synchronous Optical Network (SONET).

MPLS overcomes ATM setbacks with less overhead and connection-oriented services for frames with varying length. This maintains traffic engineering and out-of-band control, thus Frame Relay and ATM are less in need for installing large-scale networks, as MPLS performance is far superior to previous ones.

MPLS does the assignment of a particular packet to a particular FEC once, as the packet enters the network. The FEC to which the packet is assigned is encoded as a label. When a packet is forwarded to its next hop, the label is sent along with it. The label is then used as an index into a table which specifies the next hop, and a new label. The old label is replaced with the new label, and the packet is forwarded to its next hop.

MPLS can speed up the flow of network traffic and make it easier to manage. It is flexible, fast, cost-efficient and allows for network segmentation and quality of service. MPLS also offers a better way of transporting latency-sensitive applications like voice and video.

Software PLL control



7.11 Block diagram of an MPSL

Switching is process to forward packets coming in from one port to a port leading towards the destination. When data comes on a port it is called ingress, and when data leaves a port or goes out it is called egress.

A communication system may include number of switches and nodes. At broad level, switching can be divided into two major categories:

- **Connectionless:** The data is forwarded on behalf of forwarding tables. No previous handshaking is required and acknowledgements are optional.
- **Connection Oriented:** Before switching data to be forwarded to destination, there is a need to pre-establish circuit along the path between both endpoints. Data is then forwarded on that circuit. After the transfer is completed, circuits can be kept for future use or can be turned down immediately.

Summary

Circuit Switching

When two nodes communicate with each other over a dedicated communication path, it is called circuit switching. There 'is a need of pre-specified route from which data will travels and no other data is permitted. In circuit switching, to transfer the data, circuit must be established so that the data transfer can take place.

Circuits can be permanent or temporary. Applications which use circuit switching may have to go through three phases:

- Establish a circuit
- Transfer the data
- Disconnect the circuit

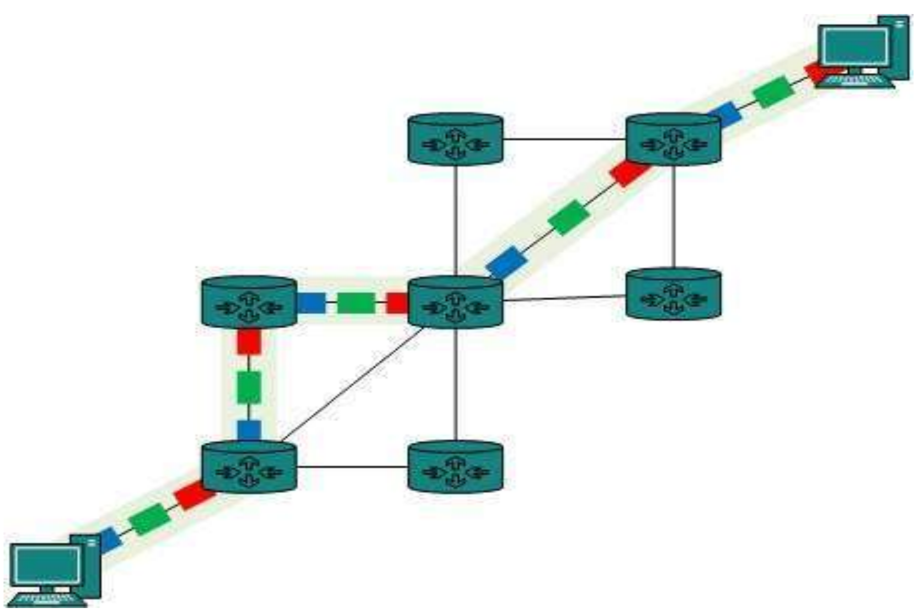


Fig 7.12 Circuit Switching

Circuit switching was designed for voice applications. Telephone is the best suitable example of circuit switching. Before a user can make a call, a virtual path between caller and callee is established over the network.

Message Switching

This technique was somewhere in middle of circuit switching and packet switching. In message switching, the whole message is treated as a data unit and is switching / transferred in its entirety.

A switch working on message switching, first receives the whole message and buffers it until there are resources available to transfer it to the next hop. If the next hop is not having enough resource to accommodate large size message, the message is stored and switch waits.

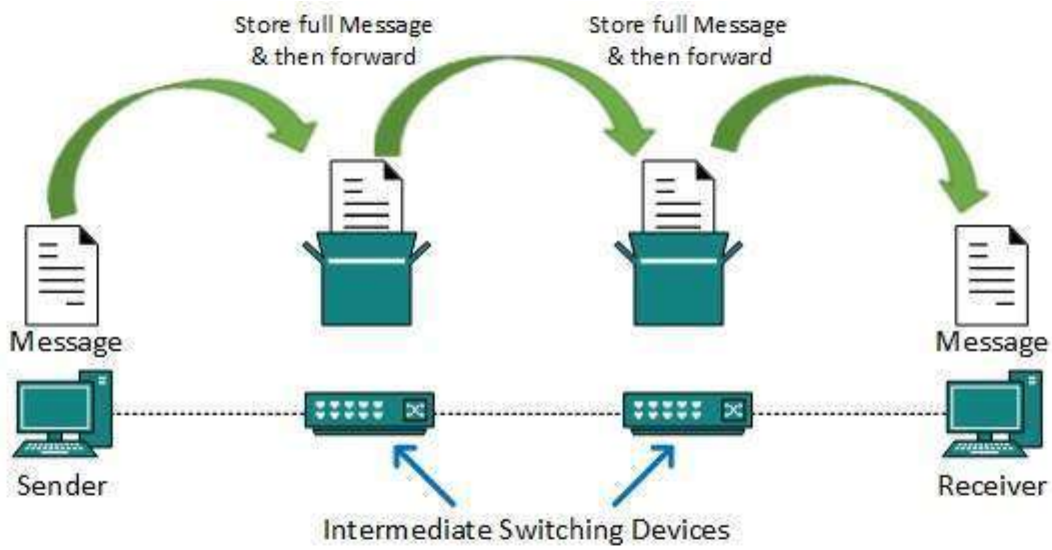


Fig 7.13 Message Switching.

This technique was considered substitute to circuit switching. As in circuit switching the whole path is blocked for two entities only. Message switching is replaced by packet switching. Message switching has the following drawbacks:

- Every switch in transit path needs enough storage to accommodate entire message.
- Because of store-and-forward technique and waits included until resources are available, message switching is very slow.
- Message switching was not a solution for streaming media and real-time applications.

Packet Switching

Shortcomings of message switching gave birth to an idea of packet switching. The entire message is broken down into smaller chunks called packets. The switching information is added in the header of each packet and transmitted independently.

It is easier for intermediate networking devices to store small size packets and they do not take much resources either on carrier path or in the internal memory of switches.

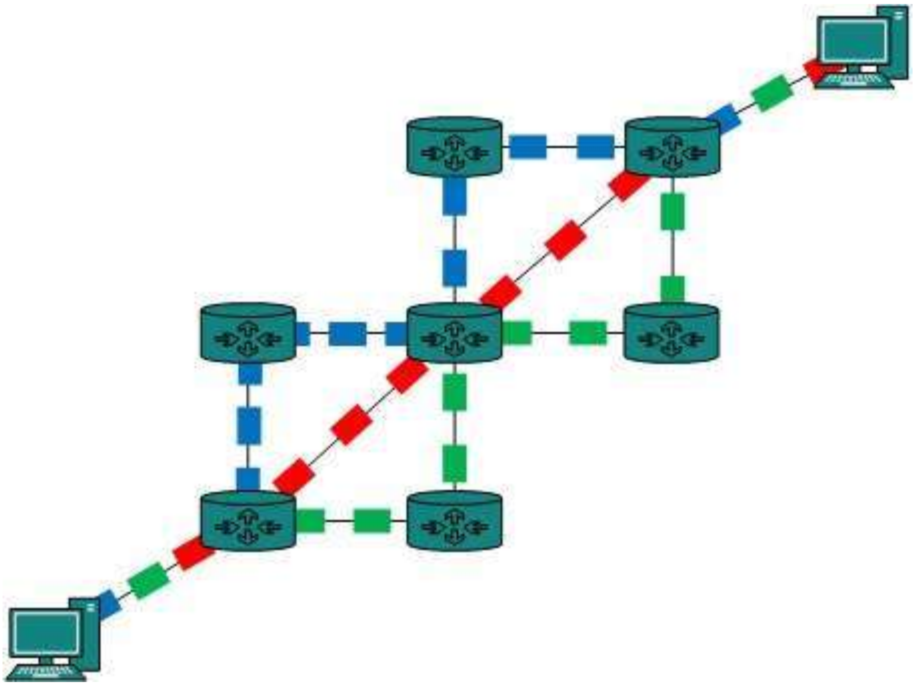


Fig 7.14 Packet Switching

Packet switching enhances line efficiency as packets from multiple applications can be multiplexed over the carrier. The internet uses packet switching technique. Packet switching enables the user to differentiate data streams based on priorities. Packets are stored and forwarded according to their priority to provide quality of service.

https://www.tutorialspoint.com/data_communication_computer_network/physical_layer_switching.htm