DATA NETWORKS:

When a network is to transfer a stream of data from a source to destination, it must assign to the data stream a route, that is, a sequence of links or channels connecting the source to the destination. The network should also allocate the data stream a portion of the capacity or BW in each channel along the route to be used. These decisions are performed by switches (or sometimes routers) in telephone exchanges. The process is called switching.

Till 1980's, OSI model was widespread and dominated the entire networking, commercially as well as by architecture. In 1990's TCP/IP has become firmly established as the dominant commercial architecture. Now the TCP/IP is the protocol of choice in many LAN-to- WAN environments.

DATA TRANSMISSION IN PSTN

The transmission medium is the physical foundation for all the data communications. The amount of data carried across the networks crossed the voice traffic level. The data is growing at a rate of 30 percent per year.With public switched telephone network, there is a possibility of carrying signals at higher speeds. Public switched telephone networks and electronic PABX's are designed to carry analog voice signals. They can be used for data transmission by employing suitable interfaces.

Data Rates in PSTN

Baud rate: The maximum rate of signal transitions that can be supported by a channel is known as baud rate. Baud rate is a close measure of information throughput, or the effective information data transfer rate from sender to receiver. Thus, baud rate is one that can be supported in a noiseless channel.

We know, a voice channel in a PSTN is band limited with a nominal bandwidth of 3.1 kHz. A maximum data rate that a noiseless or ideal voice channel can support can be obtained from the Nyquist theorem.

$$D = 2\,B \log_2 L \text{ bps}$$

where D = Maximum data rate (in Baud or bps)

B = Bandwidth of the channel

L = Number of discrete levels in the signals.

For a 3 kHz channel, and a binary signal, the maximum data rate is 6000 bps, if the signal level is two.

For higher data rates, we translate information rate into symbols per second. A symbol is any element of an electrical signal that can be used to represent one or more binary data bits. The rate at which symbols are transmitted is the symbol rate. This rate may be represented as a systems baud rate.

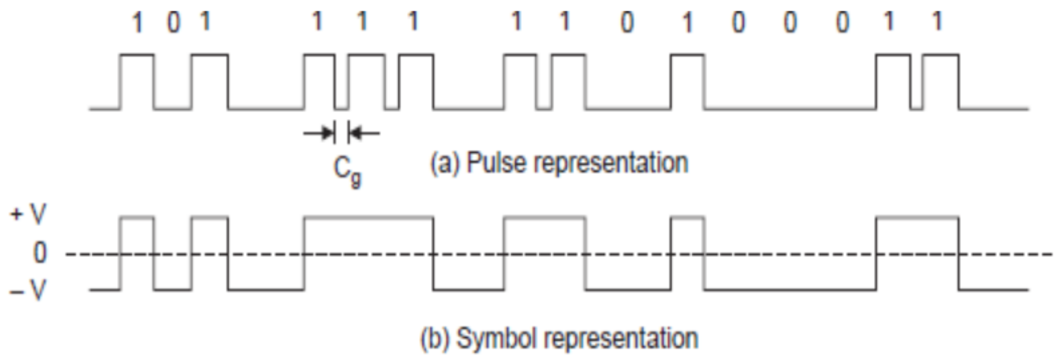


Fig.40: A symbol representation [1]

Bit rate: In the noisy channel, there is an absolute maximum limit for the bit rate. This limit arises because the difference between two adjacent signal levels becomes comparable to the noise level when the number of signal level is increased. For noisy channel, data rate is calculated by:

$$D_b = B \log_2 (1 + S/N)$$

Where D_b = Data rate in noisy channel (in bps)

B = Bandwidth of the channel

S/N = Signal to noise ratio.

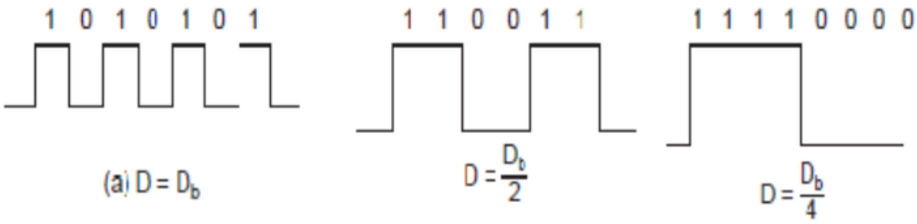
For S/N of 30 dB and 3 kHz Bandwidth noisy channel, D_b is 30000 bps

Relation between baud rate (or symbol rate) and bps : The baud rate and bit rate are related as

$$D_b = D \times n$$

where n = number of bits required to represent signal levels.

In the example considered for baud rate explanation n is assumed as one. Hence baud rate is equal to bps. Fig. 11.2 illustrates the relation between baud and bit rates.



For low-speed applications, the difference between baud and bit rate are insignificant. Thus 300 and 1200 bps modems originally used with personal computers were frequently referred to as 300 or 1200 baud modems.

Data Communications Link

In order to communicate from a terminal, computer or any equipment, the following six parts have to be put together in proper order.

1. The transmission medium that carries the traffic between source and destination.

2. Data communication equipment or data circuit terminating equipment (DCE).

3. Data terminal equipment (DTE).

4. Communication protocols and software.

5. Terminal devices.

6. Interface.

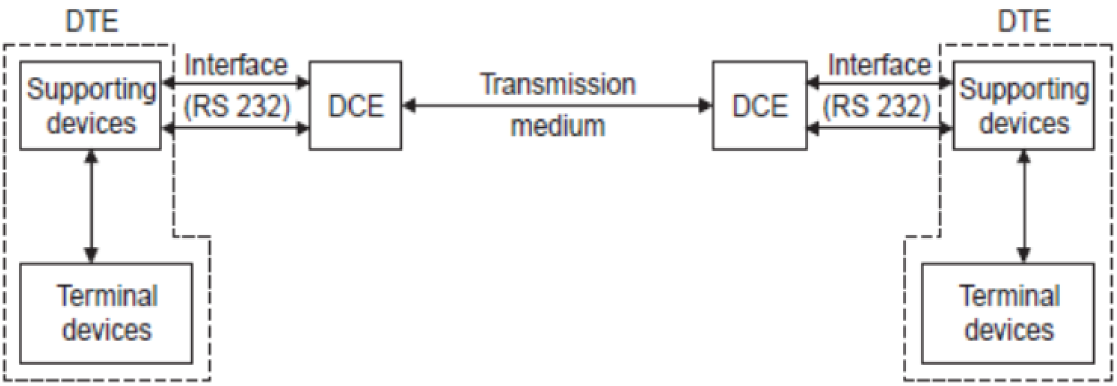


Fig. 41: Data communication link. [1]

Transmission medium. The transmission medium includes communication channels, path, links, trunks and circuits. The transmission medium may be a telephone lines, coaxial cable, twisted pair, Fiber cable, radio waves (free space), microwave link or satellite link.

Terminal devices. These are the end points in a communication link. Terminal devices are also called as nodes. For the two point network, the node points are the primary station and the remote or secondary station. A primary station is responsible for establishing and maintaining the data link between it and a secondary station. The terminal devices includes main frame computer, personal computer, peripherals such as printers, keyboards, FAX machines and data display terminals.

Data terminal equipment (DTF): The terminal devices, communication station, UART, and line control unit (LCU) grouped together and named as DTE.

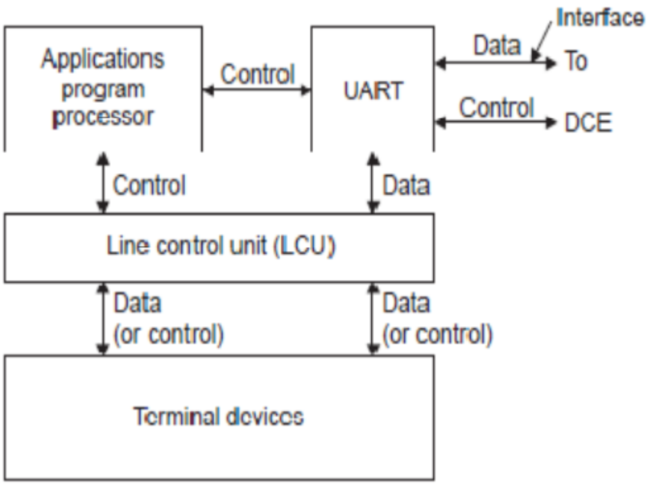


Fig.42: Data terminal equipment [1]

UART. The universal asynchronous receiver transmitter (UART) and the universal synchronous/asynchronous receiver transmitter (USART) perform the parallel to serial conversion (and vice versa at the receiving station).

Application program processor. An application program used by the DTE, called a protocol, defines a set of rules that determine requirements for the successful establishment of a data link and the transfer of actual information between stations. Protocols are key components of communication architectures. Protocols provide the rules for communication between counterpart components on different devices. The application programs also direct control information to the line control unit and UART to allow data flow from the peripheral currently serviced by the LCU to the UART and out to the DCE.

Line control unit (LCU). Data sent from one station to another usually originates in parallel binary form from one or more peripheral devices connected to that station through a LCU. The unit acts as an interface between terminal devices and UART and the application programme processor.

Interface.RS 232 interface is used to connect UART and the DCE. The RS-232 interface defines the electrical function of the pins and the mechanical function of the connector. The Electrical Industry Association (EIA) revised RS-232 C in 1989 and called the revision RS-232 D (connector with 25 pins). RS-232 is a standard connection for serial communication. All modems use RS 232 connections and all PCS have a RS 232 port.

Data communication equipment (DCE). The DCE is a modem. This device is used to convert the serial data stream into a form which is suitable for transmission. This serial data stream transferred through a transmission medium. At the receiver side, the serial data stream are converted back to digital and sent to DTE. DCE may be a modem or a computer based node in a data network.

SWITCHING TECHNIQUES:

Switches are hardware and/or software devices used to connect two or more users temporarily. Message switching, circuit switching and packet switching are the most important switching methods. The terminals of the message switching systems are usually teleprinters. In this switching, delays are incurred but no calls are lost as each messageis queued for each link.

Thus much higher link utilization is achieved. The reason for the delay is that the system is designed to maximize the utilization of transmission links by queuing message awaiting the use of a line. This switching is also called store and forward switching. The circuit switching sets up connection between the telephones, telex networks etc. which interchange information directly. If a subscriber or system to which connection to be made as engaged with other connection, path setup cannot be made. Thus circuit switching is also referred as lost call system. The modified form of message switching is called packet switching. Packet switching system carries data from a terminal or computer as short packets of information to the required destination.

Message Switching

In message switching, the messages are stored and relayed from secondary storage. So, message switching is best known by the term store and forward. In message switching, there is no direct link between the sender and the receiver. A message delivered to the destination is rerouted along any path before it reaches the destination. It was common in 1960's and 1970's.

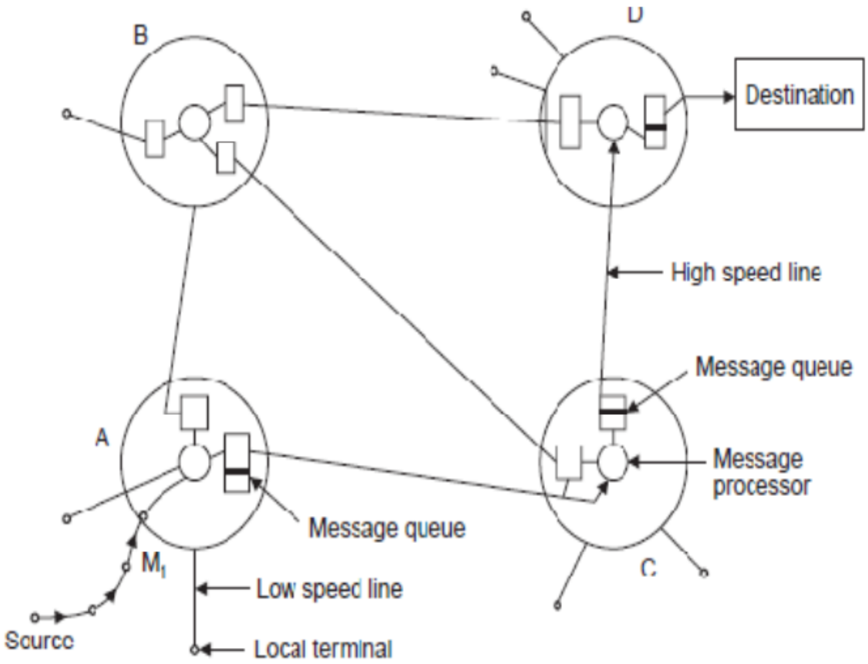


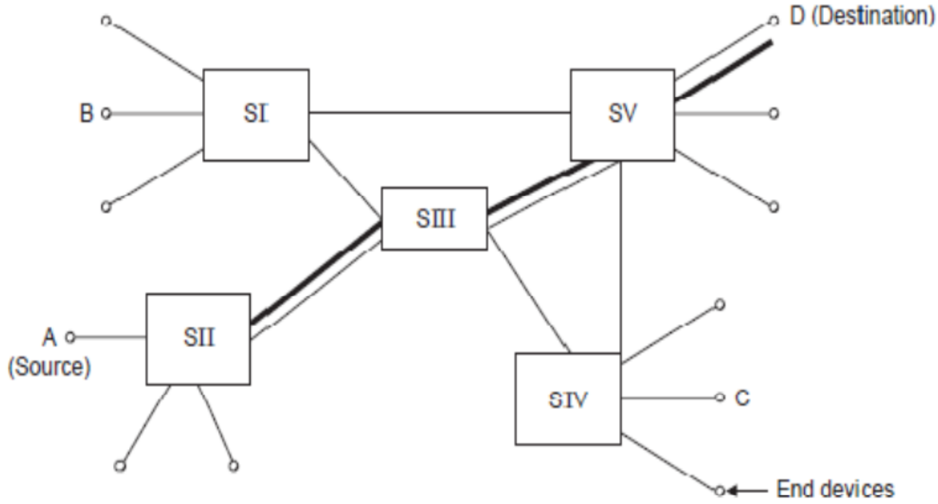
Fig.43: Message switching network.[1]

Message switching offers the possibility of greatly improved economy. The working of message switching is as follows. Source sends message M1 to the destination. Suppose that the transmission path selected is A—C—D. In message switching no complete connection is required. Thus the each message includes a header contains the destination address, routing information and priority information (for special cases).

Circuit Switching:

Circuit switching creates a direct physical connection between two devices such as phones or computers. In order to setup a direct connection over many links it is necessary that each link to

be simultaneously free. This implies that the average utilization of the links must be low if the probability of demand for connection is more. It is therefore used in voice networks mainly and not in networks designed for data transfer. A circuit switch is a device with *n* inputs and *m* outputs that creates a temporary connection between source and destination. The inputs *n* and outputs *m* need not be equal. In order to transmit information, a circuit switched network finds a route along which it has free circuits. The network connects the circuits together and reserves them for the transmission.



S1-SN → Switches, —Path between switches, ▬Path setup between end device A&D,

Fig.44: Circuit switching network.[1]

As the data transfer takes place in three phases, the time taken for the data transfer (T) is expressed as

$$T = T_p + T_d + T_r$$

where T_p = Path setup time $(N - 1)\, T_{rs}$

T_d = data transfer time = M/R

T_{rs} = average route selection time

T_r = data release time = NT_n

N = Number of switches in the path

M – Message length in bits

R = data rate in bits per sec

T_h = house keeping entries time.

Thus $T = (N - 1)\, T_{rs} + M/R = NT_h$

The propagation time is not considered as it is comparatively very small. In our case N = 3, If T_{rs} = 2 sec, T_n = 2 sec, R = 2400 bps and the message is 300 bytes long, the time for the data transfer is T = (3 − 1) × 2 + 300 × 8/2400 + 3 × 0.2 = 4 + 1 + 0.6 = **5.6 sec.**

Comparison of message and circuit switching :

Message switching	Cirtuit switching
The source and destination do not interact in real time	The source and destination are connected temporarily during data transfer.
Message delivery is on delayed basis if destination node is busy or otherwise unable to accept traffic.	Before path setup delay, may be there due to busy destination node. Once the connection is made, the data transfer takes place with negligible propagation time.
Destination node status is not required before sending message.	Destination node status is necessary before setting up a path for data transfer.
Message switching network normally accepts all traffic but provides longer delivery time because of increased queue length.	A circuit switching network rejects excess traffic, if all the lines are busy.
In message switching network, the transmission links are never idle.	In circuit switching, after path setup, if the users denied service, the line will be idle. Thus, the transmission capacity will be less, if the lines are idle.

Packet Switching:

There are three types of switching used in PSTN network.Circuit switching was designed for voice communication. Circuit switching creates temporary (dialed) or permanent (leased) dedicated links that are well suited to this type of connection. The circuit switching also limits the flexibility and not suitable for connecting variety of digital devices. More efficient utilization of the network requires greater control channel bandwidth and increased call processing capacities in the switches. But the circuit switching not providing these capabilities. Message switching overcomes the limitations of circuits switching. This switching stores the incoming messages into a computer memory and forwards it to the destination when available. This causes delay in switching. The packet switching overcomes all the limitations of message and circuit switching. Thus it is highly suitable for the data communication.

Packet Switching Principles

The data stream originating at the source is divided into packets of fixed or variable size. The data communication system typically hasbursty traffic. Thus, the time interval between consecutive packets may vary, depending on the burstiness of the data stream.

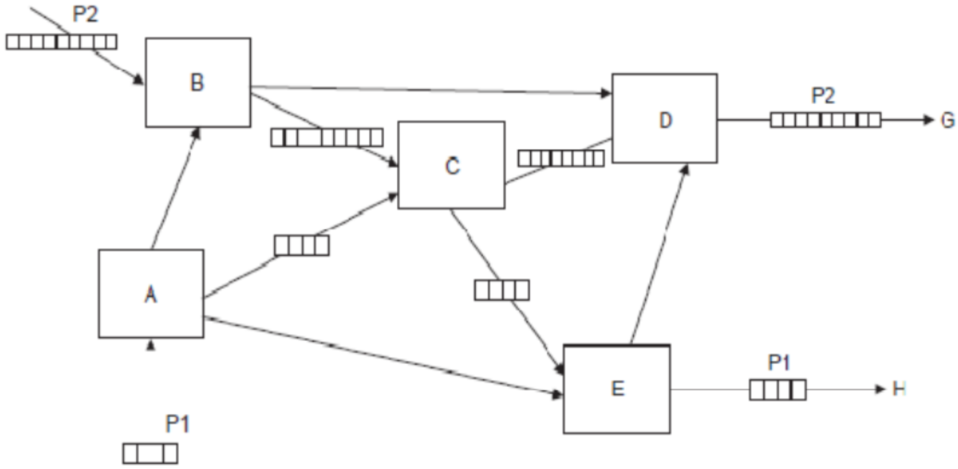


Fig.45: packet switching. [1]

Routing Control

From the previous section, it is clear that in packet switching, messages are broken into packets and sends one at a time to the network. Routing control decides how the network will handle the stream of packets as it attempts to route them through the network and deliver them to the intended destination. The routing decision is determined in one of two ways. They are

1. Datagram and

2. Virtual circuit.

Datagram. In datagram, each packet within a stream is independently routed. A routing table stored in the router (switch) specifies the outgoing link for each destination. The table may be static or it may be periodically updated. In the second case, the routing depends on the router's estimate of the shortest path to the destination. Since the estimate may change with time, consecutive packets may be routed over different links. Therefore each packet must contain bits denoting the source and destination. Thus may be a significant overhead

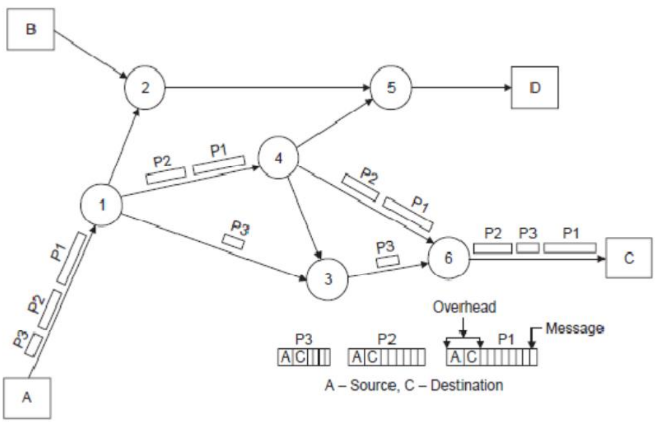


Fig.46: Concept of Data gram. [1]

The station A is assumed to send three packets of message namely P1, P2 and P3 (for explanation purpose named so). At first, A transmits these packets to node 1. Node 1 makes decision on routing of these packets. Node 1 finds node 4 as shortest compared to node 3. Thus it passes P1 and P2 to node 4. Accidently, if node 4 is not accessible, node 1 finds node 3 as shortest and sends packet P3 to node 3.

Node 3 and 4 sends its received messages to the destination C through node 6. It is shown that the order of the packet is changed due to the different routing of the packets. Thus in datagram, it is the responsibility of destination station to reorder the packets in proper sequence. Also if a packet crashes in a switching node, the destination C may not receive, all packets. In such a case also, it is the responsibility of station C to recover the lost packet.

Virtual circuit. In virtual circuit, a fixed route is selected before any data is transmitted in a call setup phase similar to circuit switched network. All packets belonging to the same data stream follow this fixed route called a virtual circuit. Packet must now contain a virtual circuit identifier. This bit string is usually shorter than the source and destination address identifiers needed for datagram. Once the virtual circuit is established, the message is transmitted in packets.

Suppose that end station B has two messages to send to the destination D. First B sends a control packet referred as call-request packet to node 2, requesting logical connection to D. Node 2 decides to route the request and the subsequent message packets through node 3 and 4 to destination D. If D prepared to accept the connection, it sends a call-accept packet to node 4. Node 4 sends the call-accept packet to B through node 3 and 2. Because the route is fixed for the duration of the logical connection, it is somewhat similar to a circuit switching network and is referred to as a virtual circuit.

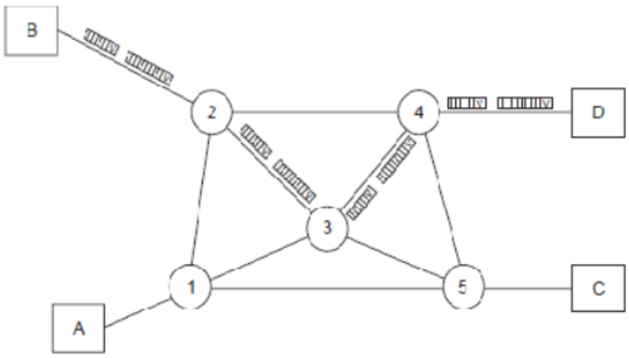


Fig.47: concept of virtual circuit. [1]

Packet size. If an organization has large amounts of data to send, then the data can be delivered to a packet assembler/disassembler (PAD). The PAD (software package) receives the data and breaks it down into manageable packets. In the data communication, a packet can be a variable length. Usually up to 128 bytes of data is in one packet. X-25 services have created packets upto 512 bytes, but the average is 128. The 128 byte capability is also referred to as fast select. There is a significant relationship between packet size and transmission time. The process of using more smaller packets (for example 30 byte information may be sent as a single packet with header of 3 byte or two packets with 15 byte each plus the header in each packet or 5 packets with 6 bytes plus header) increases the speed of transmission.

Comparison of Circuit Switching and Packet Switching:

There are two types of approaches in packet switching. Datagram and virtual circuit. The circuit switching is compared with these two approaches.

Datagram switching achieves higher link utilization than circuit switching especially when the traffic is busty. No dedicated path is required as circuit switching. But the datagram have the disadvantage over virtual circuit wire.

1. End to end delay may be so large or so random as to preclude applications that demant guaranteed delay.

2. The overhead due to source and destination identifiers and bits needed to delimit packets may waste a significant fraction of the transmission capacity if the packet are very short.

3. A datagram switch does not have the state information to recognize if a packet belongs to a particular application. Hence the switch cannot allocate resources (bandwidth and buffers) that the application may require.

Virtual circuits are more advantages and currently the packet switching network uses the virtual circuit approach. The overhead is comparable to circuit switching. As the packets arrives in sequence, no re-sequencing is needed. Statistical multiplexing of packets at the router or switch can achieve better utilization than in circuit switching. Since packets contains their virtual circuit identifiers (VCI), the switch can allocate resources depending on the VCI. During the connection setup phase, the switches may be notified that a particular VCI should be given extra resources.

Packet Formats

The format of a packet in packet switching network can vary significantly from one network to another. Generally header includes all related control information. In some cases, control information is communicated through special control packets.

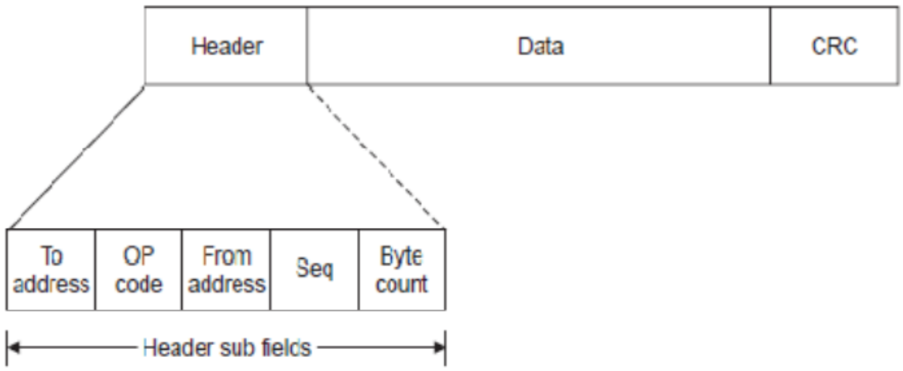


Fig.48: typical packet format [1]

A packet contains 3 major fields.

1.**Header.**It contains sub fields in addition to the necessary address fields. Other than the to and from address field, the following are the useful control information.

(*a*) **Op code.**It designates whether the packet is a message (text) packet or control packet.

(*b*) A **sequence number (Seq)**to reassemble messages at the destination node, detect faults and facilitates recovery procedures.

(*c*) **Byte count.**Used to indicate the length of a packet.

2. **Data.**A portion of a data stream to be transferred in the data field. Some packets may not contain a message field if they are being used strictly for control purposes.

3. **CRC.**The cyclic redundancy checks (CRC) field contains a set of parity bits that cover overlapping fields of message bits. The fields overlap in such a way that small numbers of errors are always detected. The probability of not detecting the occurrence of 2 large numbers of errors is 1 in 2M, where M is the number of bits in the cheek code.

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