UNIT - 01

Evolution of Switching Systems

The business of telecommunication involves many participants. These include the users, the public telecommunications operators (PTO), providers of services that involve telecommunications, the manufactures of equipment and components (both hardware and software), financial investors and governments. Since the users must pay charges to cover the cost of providing network, they are usually called subscribers or customers.

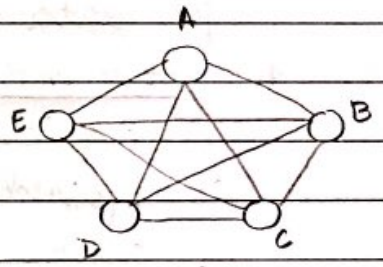
* Network structures:

a. Mesh network

If communication is required between n user stations, it is provided by a network consisting of a line from each station to every other station.

Same line can be used to convey calls from A to B and B to A as well.

This arrangement is used only if n is small and lines are short.



Number of lines required is given by

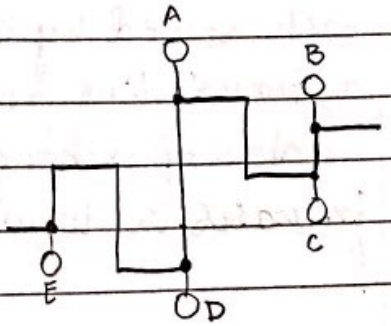
$$N = \frac{1}{2} n(n-1)$$

Ex: used for a small system servicing a number of telephones in the same office.

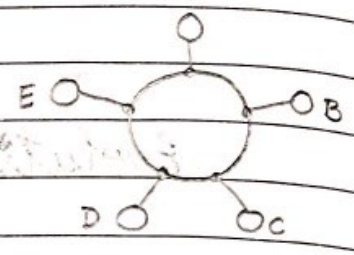
As n increases and lines become longer, this arrangement becomes too expensive.

b. Bus Network

Each station is connected to a single line forming a bus. Only one conversation at a time can take place.



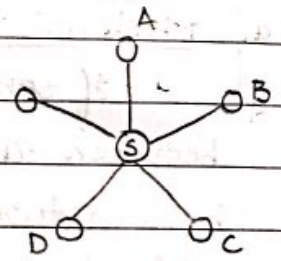
c. Ring Network:



All the stations are connected to a single line forming a ring. Only one conversation at a time can take place.

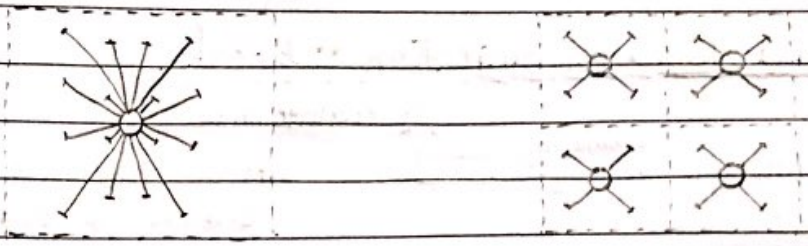
Thus bus and ring networks are useless for normal telephony. However these networks can be used for data communication by transmitting data over the common circuit at a much higher rate than it is generated by the individual terminals. When the common circuit is already in use a terminal that needs to send a message stores it until the circuit becomes free. These configurations are used for local area networks (LANs) for data transmission over short distances.

d. Star Network:



For telephony, two way communication is required on demand between any pair of stations and it must be possible for many conversations to take place at the same time. These requirements can be met by providing a line from each users station to a central switching center (telephone exchange) which connects the lines together as required. This network configuration is called a star network. The number of lines required is reduced to n

As the area covered by a star network and the number of stations serviced by it grows line costs increase. Then the network is divided into several smaller networks each served by its own exchange. The average length of a customer's line and the total line cost decreases with the number of exchanges but the cost of providing the exchanges increases.



Area with single exchange Area with several Exchanges

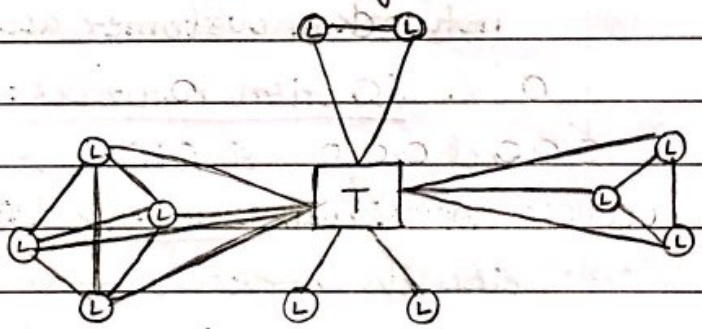
If an area is served by several exchanges, customers on each exchange will wish to converse with customers on other exchanges. It is therefore necessary to provide circuits between the exchanges which are called as junction circuits. which form a junction network.

If junctions are provided between all exchanges, the junction network has a mesh configuration. But connecting all exchanges directly is expensive hence connections between local exchanges is made via a central switching centre called a tandem exchange, thus making the junction network a star network

A multiexchange area usually has direct junctions between some exchanges.

The network of the area is a mixture of star network joining all the local exchanges to the tandem exchange and mesh networks connecting some of the local exchanges together.

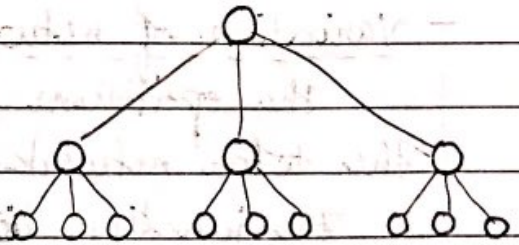
Multiexchange area



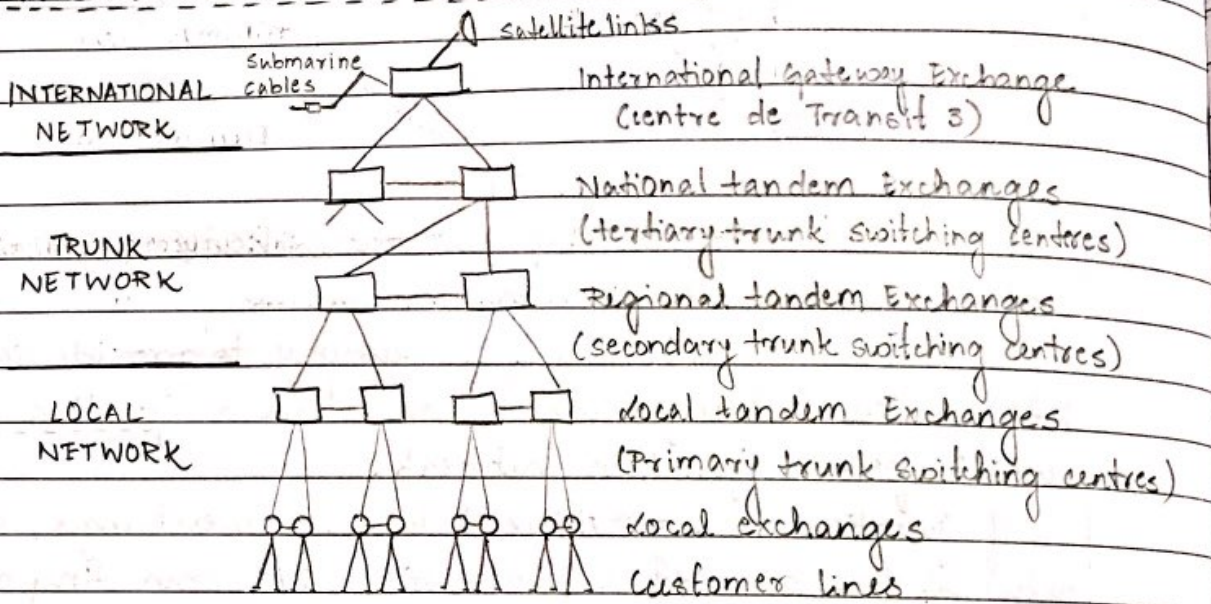
L : Local Exchange
T : Tandem Exchange

c. Tree Network:

A concatenation of star networks results in a tree network. In a large national network it is not fully interconnected and one or more higher levels of switching centres are introduced.



- National Telecommunication Network.



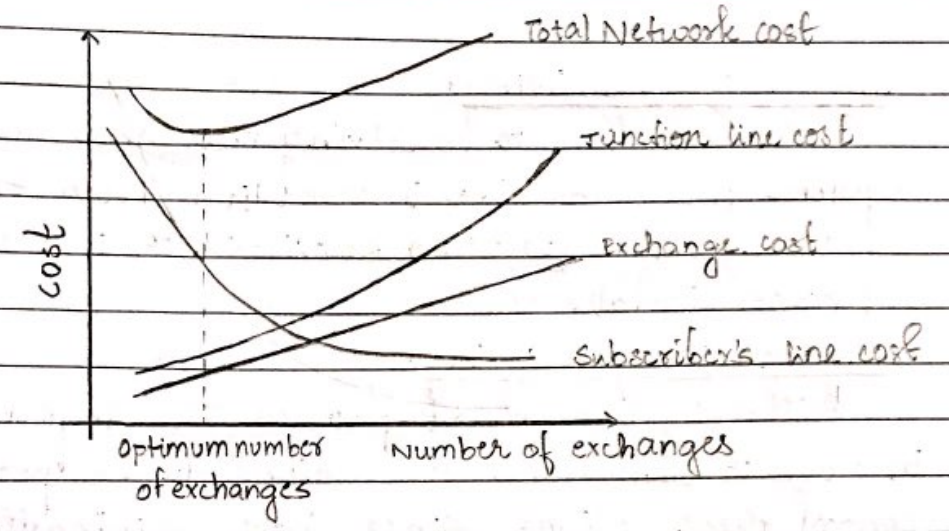
A national public switched telecommunications network (PSTN) consists :

1. Local networks : connects customer stations to their local exchanges. (also called as subscribers distribution networks, customer access networks or customer loop)
2. Junction networks : connects a group of local exchanges serving an area and a tandem or trunk exchange
3. Trunk network (Toll network) : provides long distance circuits between local areas throughout the country.
4. International network : provides linking of national networks of different countries. The national network is connected to the international network by one or more international gateway exchanges.

- Variation of network cost with number of exchanges :

The optimum number of exchanges is for which the total network cost is minimum.

The junction line cost increases with increase in the number of exchanges. Similarly the establishing of exchange cost also increases linearly with increase in exchanges. but the subscriber's line cost decreases.



* Network Services:

The public Telecommunications Operator (PTO) provides various services to its customers.

- PSTN: Public switched telephone network
- PDN: Public Data Network
- Telex: Public switched telegraph network
- PBX: Private Branch Exchange (leased from the PTO)
- Cellular Radio Networks providing mobile communications

The services provided over telecommunication networks can thus be divided into two categories:

a. Teleservices: provision of service depends on particular terminal apparatus (telephone or teleprinter)

b. Bearer Services: presents the customer with transmission capacity that can be used for any desired function (private circuits).

* Functions of a Switching System:

1. Attending: The system must be continually monitoring all the lines to detect call requests. The 'calling' signal is known as 'seize' signal because it obtains a resource from the exchange.

2. Information receiving:
In addition to receiving call and clear signals the system must receive information from the caller such as the called line (or other services). This is called the address signal.

3. Information processing:
The system must process the information received, in order to determine the actions to be performed and to control these actions. Since both originating and terminating calls are handled differently for different customers, class of service information must be processed in addition to the address information.

4. Busy Testing:
Having processed the received information, to determine the required outgoing circuit the system must make a busy test to determine whether it is free or already engaged on another call.
If found busy, based on the system the call is either lost or it is queued. (this is due to the traffic intensity: congestion)

5. Interconnection:
For a call between two customers, three connections are made in the following sequence:
a. a connection to the calling terminal
b. a connection to the called terminal
c. a connection between the two terminals.

6. Alerting:
Having made the connection, the system sends a signal to alert the called customer to the call i.e., by sending ringing current to the customer's telephone.

7. Supervision:
After the called terminal has answered, the system continues to monitor the connection in order to be able

to clear it down when the call has ended. The Automatic Message Accounting (AMA), a supervisory circuit keeps account of the call until tear down occurs.

8. Information sending:

If the called customer's line is located on another exchange the additional function of information sending is required. The originating exchange must signal the required address to the terminating exchange.

* Terminology:

North America	British
customer's loop	Local network Access network
central office	Exchange
End office Class 5 office	Local exchange
Inter-office trunk	Junction
Junctor	Trunk
Toll office	Trunk exchange
Toll network	Trunk network

* Standards:

Successful planning and operation of international telecommunications depends on cooperation between all the countries involved. The standardization which has made an effective international network possible is carried out through the International Telecommunications Union (ITU) founded in 1865, the oldest of the specialized agencies of the United Nations.

The work of the ITU is carried out through two bodies:

- ITU Telecommunications Sector (ITU-T) which was formerly the Comité Consultatif Télégraphique et Téléphonique (CCITT).

Its duties include the study of technical questions, operating methods and tariffs for telephony, telegraphy and data communications.

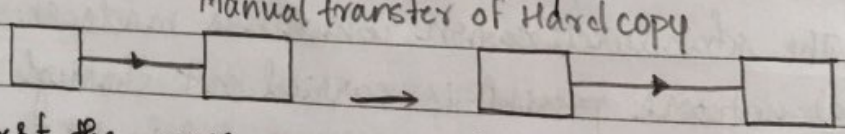
- ITU Radiocommunication sector (ITU-R) which was formerly the comité Consultatif International des Radiocommun-ications (CCIR). It studies all technical and operating questions relating to radio communications including point-to-point communications, mobile services and broadcasting.

* Switching Fabric:

It is a combination of hardware and software that controls traffic to and from a network node with the use of multiple switches. Data comes in one port and out on another port.

* Message Switching:

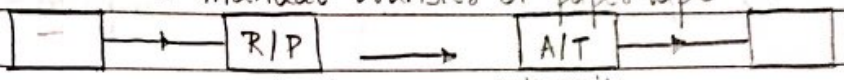
If a customer wishes to send a message from A to B although there was no telegraph circuit between A and B, and then if there was a circuit between A and C and one between C and B, this could be achieved by the process known as message switching. The operator at A sent the message to C, where it was written down by the receiving operator. This operator recognised the address of the message as being at B and then retransmitted the message over the circuit to B. This is a manual process.



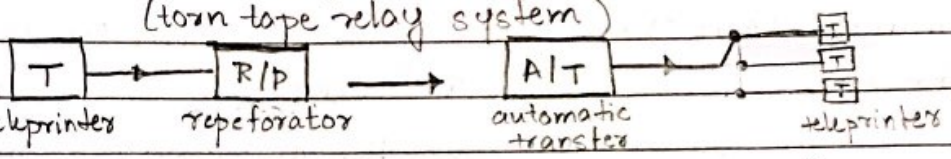
First the message received at C was automatically recorded on punched tape and subsequently torn off the receiver by the operator, who read the address from the tape. The message was then retransmitted automatically from the same tape. This is known as a torn-tape relay system.

later the outgoing route was also selected automatically.

manual transfer of paper tape

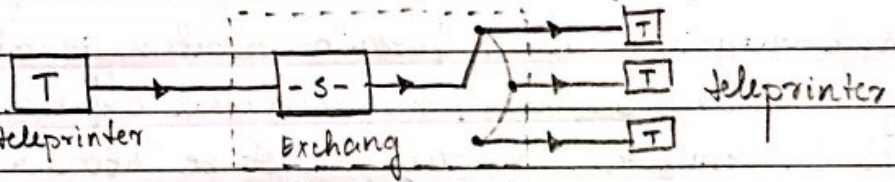


manual transfer of paper tape with automatic route selection (torn tape relay system)



Finally the paper tape was eliminated by storing the messages electronically and analyzing their addresses by electronic logic. A modern message switching centre is thus a special purpose electronic computer.

Automatic message switching system



In a message switching centre an incoming message is not lost when the required outgoing route is busy. It is stored in a queue with any other messages for the same route and retransmitted when the required circuit becomes free. Message switching is thus an example of a delay system or a queuing system.

Message switching is still used for telegraph traffic and a modified form of it known as packet switching is used extensively for data communications. A data communications network may need to handle a wide variety of traffic. Some messages may be very short. The desired quick response to a message is not obtained if it has to wait for the completion of a large file transfer. This problem is solved by dividing long messages into smaller units known as packets. A packet switch sends each of these as a separate message. Thus, packets of different messages are interleaved on an outgoing circuit and a

short message (ex: a single packet) doesnot wait for the transmission of a long message to be completed.

* Circuit Switching:

Invention of the telephone introduced a new requirement, simultaneous both-way communication in real time. Message switching could not meet this requirement because of its inherent delays. It became necessary to connect the circuit of a calling telephone to that of the called telephone on demand and to maintain this connection for the duration of the call. This is called circuit switching.

It is inherent in circuit switching that if the required outgoing circuit from a switch is already engaged on another call, the new call offered to it cannot be connected. The call cannot be stored as in message switching, hence it is lost. Circuit switching is thus an example of a lost call system.

* Electronic Switching Systems:

In electromechanical exchanges, common controls mainly use switches and relays which were originally designed for use in switching networks. Advances led to the development of Stored Program Control (SPC) which enables a digital computer to be used as a central control and perform different functions with the same hardware by executing different programs.

The facilities provided to an individual customer can be readily altered by changing the customers class of service data stored in a central electronic memory. Thus some of these facilities can be altered ~~electronically~~ or controlled by customers.

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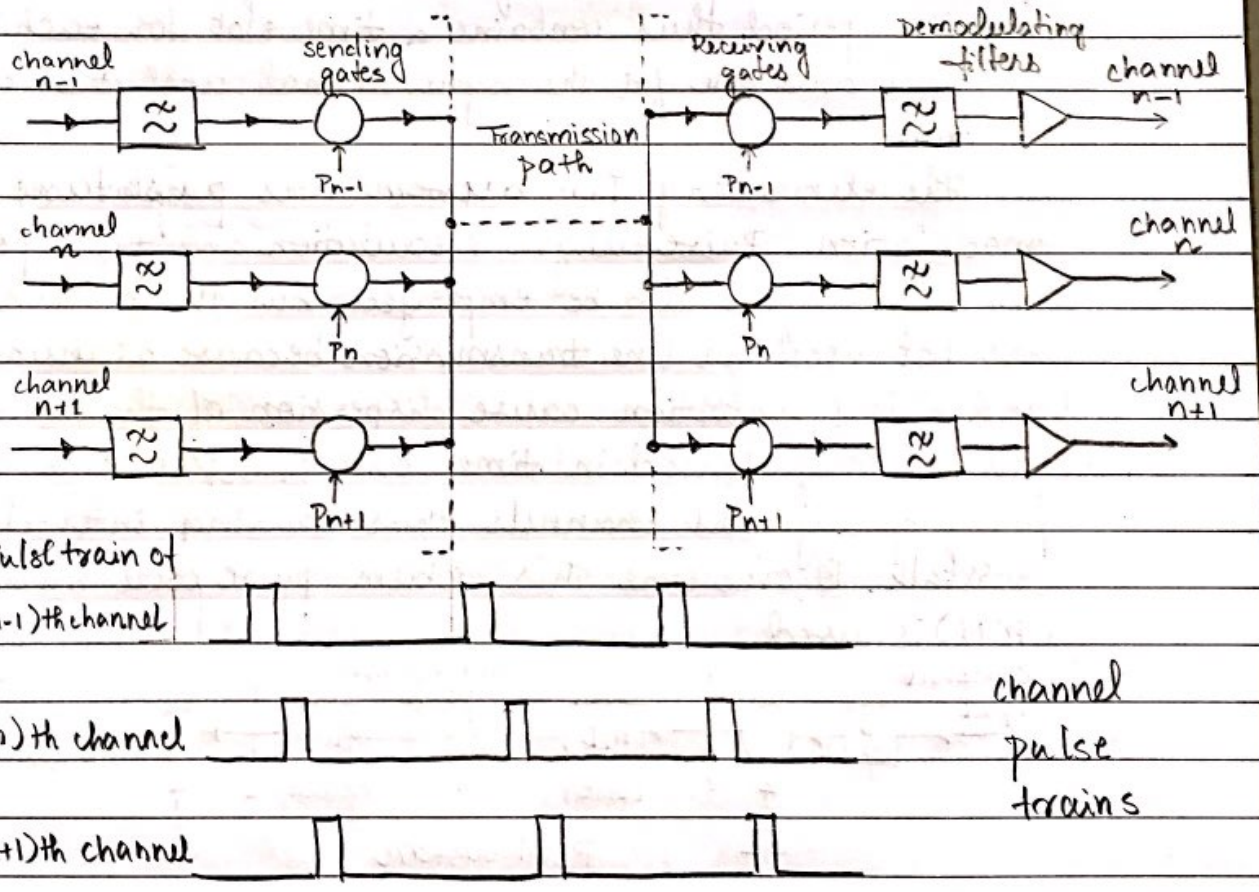
Ex:
- call barring (outgoing or incoming)
- repeat last call
- reminder calls: exchange can be instructed to call the customer at a pre arranged time
- call diversion
- three way calling: to connect a third party to a call that is already in progress
- charge advice: to indicate call duration and charge

★ **TDM Transmission:**

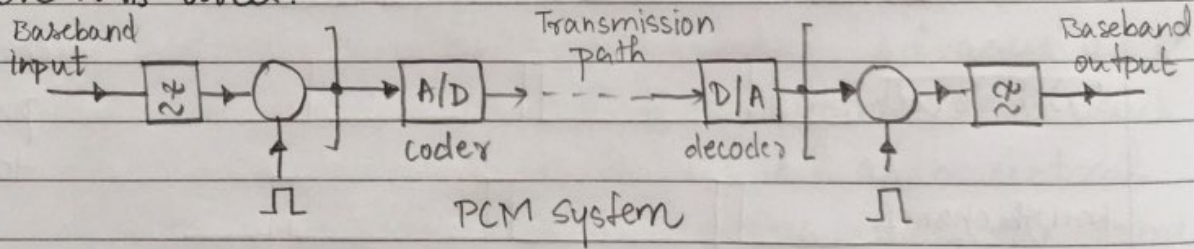


Each baseband channel is connected to the transmission path by a sampling gate which is opened for short intervals by means of a train of pulses. Pulses with same frequency but staggered in time are applied to the sending gates of the other channels. Thus the common transmission path

receives interleaved trains of pulses modulated by the signals of different channels. At the receiving terminal gates are opened by pulses coincident with those received from the transmission path for its allotted intervals.

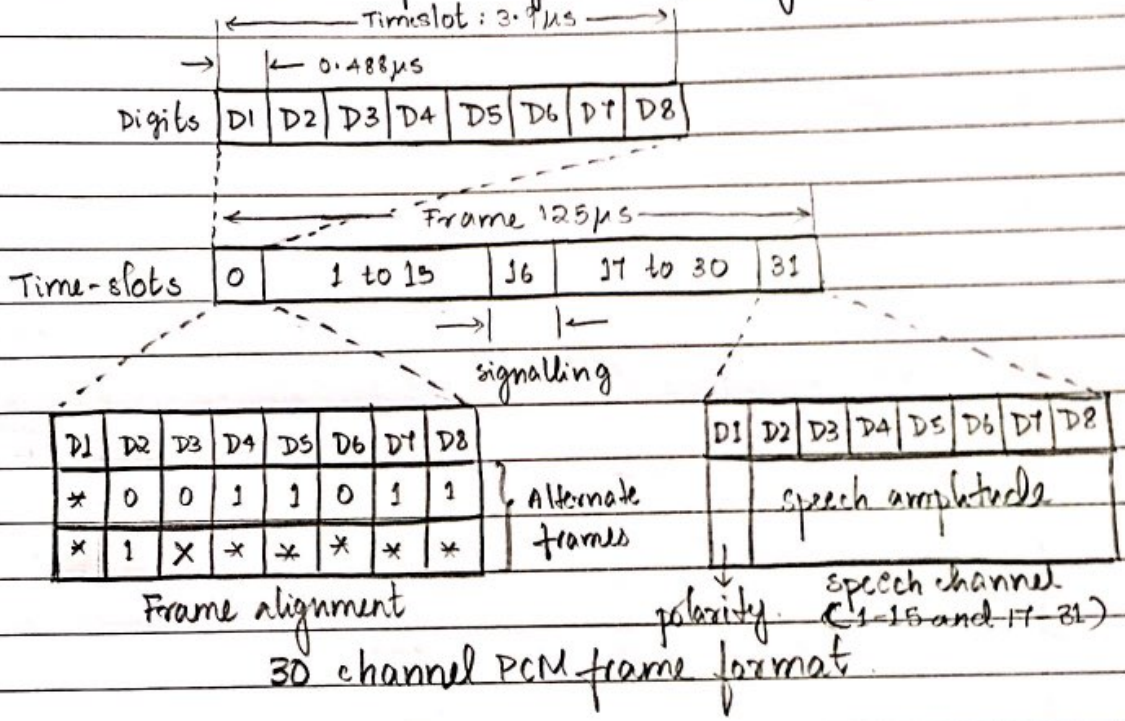
The pulse generator at the receiving terminal must be synchronized with that at the sending terminal. A distinctive synchronizing pulse signal is therefore sent in each repetition period in addition to the channel pulses. The complete waveform transmitted during each repetion period thus contains a time slot for each channel and one for the sync signal and it is called a frame.

The elementary TDM system uses pulse amplitude modulation. Pulse-length modulation and pulse position modulation can also be employed but these methods are not used for line transmission because attenuation and delay distortion cause dispersion of the transmitted pulses. They spread in time and interfere with the pulses of adjacent channels thus causing inter-channel crosstalk. To overcome this problem pulse code modulation (PCM) is used.

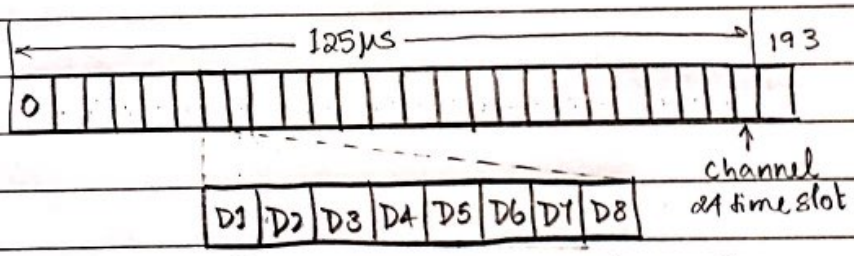


In pulse codemodulation each analog sample is applied to an analog to digital (A/D) converter which produces a group of pulses that represents its voltage in a binary code. At the receiving end, a digital to analog (D/A) converter performs the inverse process.

Telephone channels are combined by time division multiplexing to form an assembly of 24 or 30 channels. This is known as the primary multiplex group.



30 channel PCM frame format



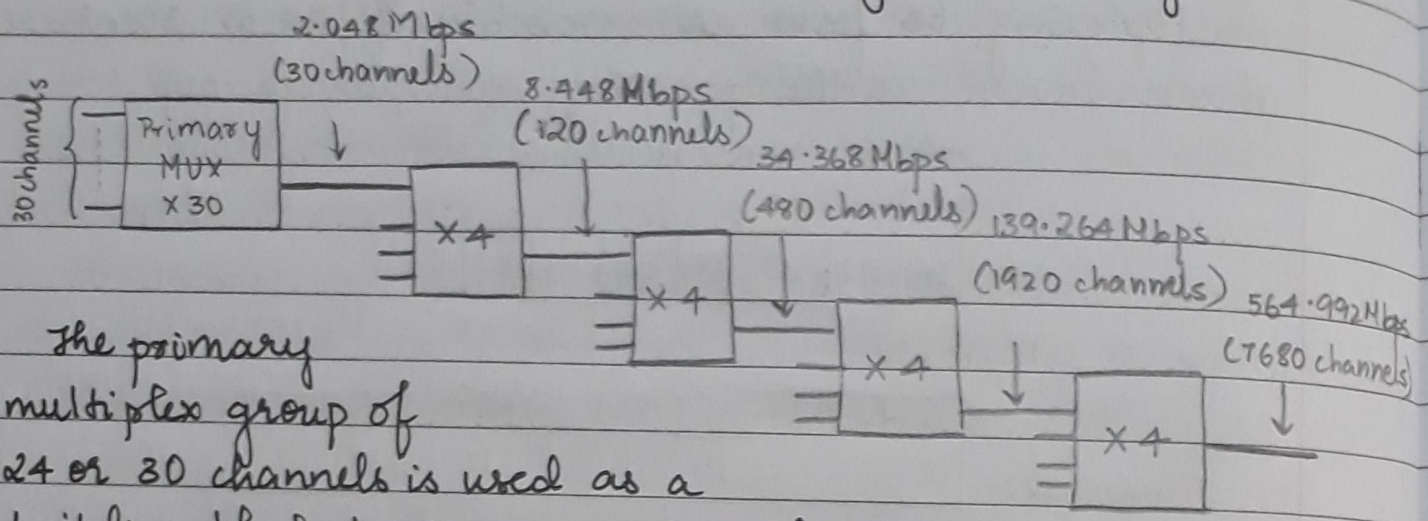
24 channel PCM frame format

The length of the frame is 125 µs, corresponding to the sampling interval. It contains one speech sample from each channel, together with additional digits used for synchronization and signalling. Two frame structures are widely used

- the European 30-channel system
- the DS1 24-channel system: North America and Japan.

Both systems employ 8 bit coding, however the 30 channel system uses A law companding and the 24 channel system uses µ law companding.

* **PDH Transmission**: (Plesiochronous Digital Hierarchy)



The primary multiplex group of 24 or 30 channels is used as a building block for larger numbers of channels in higher-order multiplex systems. At each level in the hierarchy, several bit streams known as tributaries are combined by a multiplexer. The output from a multiplexer may serve as a tributary to a multiplexer at the next level in the hierarchy or it may be sent directly over a line or radio link.

The inputs to a digital MUX will not generally be exactly synchronous. Although they have the same nominal bit rate, they commonly originate from different crystal oscillators and can vary within the clock tolerance. They are said to be 'plesiochronous' (PDH), the first generation of higher-order digital multiplex systems.

The introduction of integrated digital networks has resulted in the transmission systems being fully synchronised and this has led to the emergence of a new synchronous digital hierarchy (SDH).

If the inputs to a multiplexer are synchronous, i.e., they have the same bit rate and are in phase, they can be interleaved by taking a bit or a group of bits from each in turn. This can be done by a switch that samples each input under the control of the multiplex clock. There are two main methods of interleaving digital signals:

- bit interleaving: one bit is taken from each tributary in turn.
- word interleaving: group of bits is taken from each tributary in turn.

If there are N input signals, each with a rate of f_t bps then the combined rate will be Nf_t bps and each element of the combined signal will have a duration equal to 1/N of an input digit.

In word interleaving groups of bits are taken from each tributary in turn and this involves the use of storage at each input to hold the bits waiting to be sampled. since bit interleaving is simpler it was chosen for the PDH and word interleaving was chosen for the SDH.

There are three standards of PDH

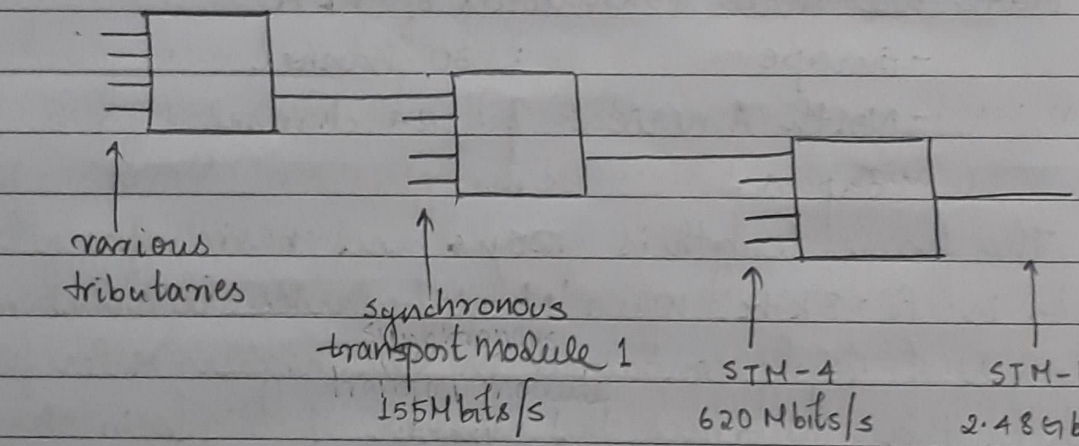
- Europe : 30 channel
- North America } : 24 channel
- Japan. }

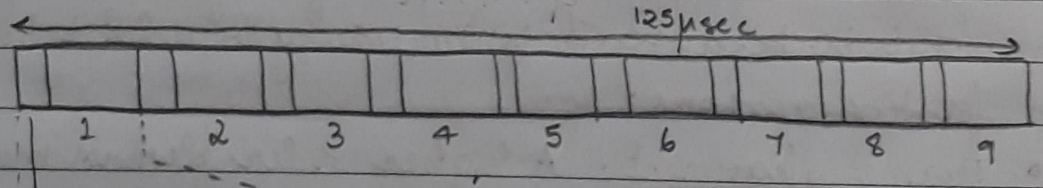
The frame length is 125μs and basic channel sampling rate is $f_s = 8$ kHz. When 'N' tributaries are combined the number of digits contained in the higher-order frame is greater than N times the number of digits in the tributary frame. This is because it is necessary to add extra 'overhead' digits for two reasons:

- Frame alignment: A higher order demux must recognise the start of each frame in order to route subsequent received digits to the correct outgoing tributaries. A unique code is sent as a frame alignment word (FAW) which is recognised by the demultiplexer and used to maintain its operation in synchronism with the incoming signal.
- Justification: This process is to enable the multiplexer and demultiplexer to maintain correct operation although the input signals of the tributaries entering the multiplexer may drift relative to each other. If an input tributary is slow, a

dummy digit is added to maintain the correct output digit rate. And if the input tributary speeds up no justification digit is added. These justification digits must be removed by the demultiplexer in order to send the correct sequence of signal digits to the output tributary. Further additional digits are added to the frame for the multiplexer to signal to the demultiplexer whether a justification digit has been added for each tributary.

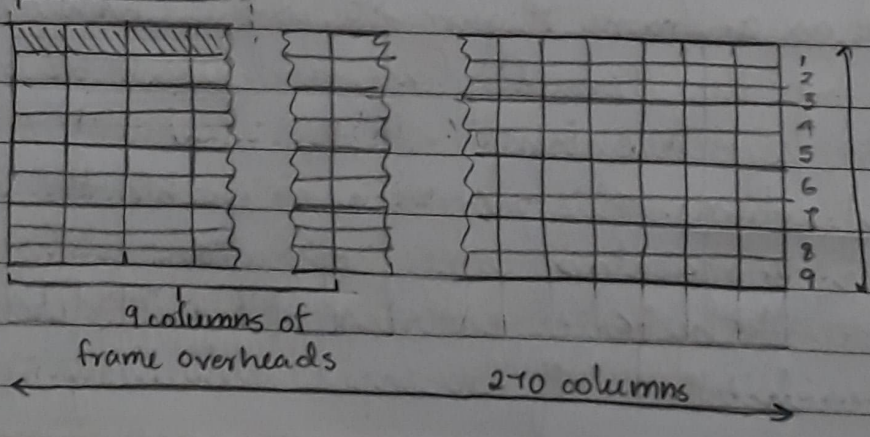
* SDH Transmission: (Synchronous Digital Hierarchy)
SONET: (Synchronous Optic Network)





Frame alignment word

Each box = 1 byte
i.e., 64 kbps capacity



The basic SDH signal called the synchronous transport module at level 1 (STM-1) has nine segments with overhead bytes at the start of each. The remaining bytes contain a mixture of traffic and overheads depending on the type of traffic carried. The total length is 2430 bytes with each overhead using nine bytes. Thus the overall bit rate is 155520 kbps ≃ 155Mbps.

This frame is usually represented as nine rows and 270 columns of 8 bit bytes. The first nine columns are for section overheads (SOH) such as frame alignment, error monitoring and data. The remaining 261 colums comprise the payload into which a variety of signals can be mapped.

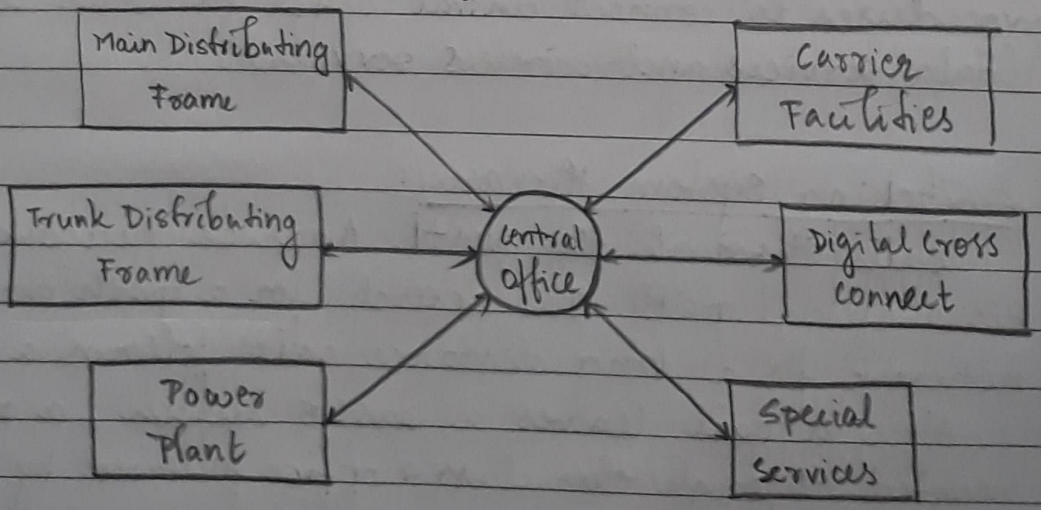
Each tributary to the multiplex has its own payload area known as a tributary unit (TU). Each column contains 9 bytes (one from each row) with each byte having 64 kbps capacity.

Three columns (27 bytes) can hold a 1.5 Mbps PCM signal with 24 channels and some overheads.

Four columns (32 bytes) can hold a 2Mbps PCM signal with 32 time slots.

DIGITAL SWITCHING SYSTEMS:

* Basic central Office Linkages:



- Main Distributing Frame: (MDF)

Location where all lines and other related links are cross-connected to a central office switch, also refered to as the "line side" of a switch.

- Trunk Distributing Frame: (TDF)

Location where all trunks and other related links are cross-connected to a central office switch, also referred to as the "trunk side" of a switch.

- Power Plant: /

A combination of power converters, battery systems and emergency power sources which supply the basic direct current power and protected alternating current power to a CO switch or a group of switches.

- Carrier Facilities:

Facilities that provide carrier or multiplex transmission mode between central offices and with other parts of the telephony network.

- Digital x-connect:

Digital cross-connect provides automatic assignments and cross connection of trunks to digital switching systems. (small switching system for trunks)

- Special services:

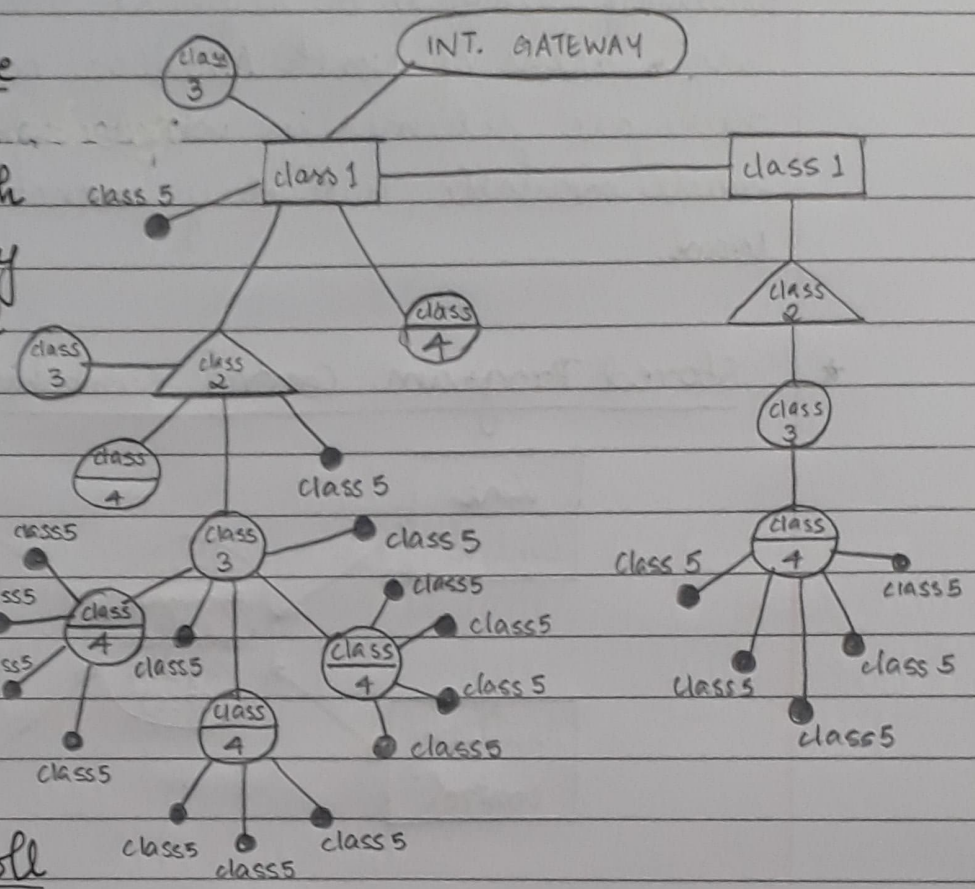
Those services which require special interfaces or procedures to connect central office facilities to a customer (data services and wireless services).

* Switching System Hierarcy:

calls through the North America network follow a hierarchical path. The search for a path through the network for a long distance call follows a hierarcy.

After a call leaves a class 5 switch, a path is hunted through the class 4 office followed by class 3,

class 2 and class 1. In addition there are international gateway offices which a central office calls to complete international destination calls through cables, satellite or microwaves.



class 5 : End office local exchange

It interfaces with subscribers directly and connects to toll centers via trunks.

class 4: Tandem and toll office

The tandem offices primarily switch trunk traffic between class 5 offices.

class 3: Primary Toll center : The class 3 toll center can be directly served by class 4 or class 5 offices depending upon the trunk deployment. class 3 offices have the capacities of storing, modifying, prefixing, translating or code converting received digits as well as finding the most efficient routing to higher-level toll offices.

class 2: sectional toll center: It functions as a toll center and can home into class 1 offices.

class 1 : Regional toll center: It functions as a toll center and can home into international gateway offices.

International gateway: These offices have direct access to international gateway offices in other countries.

The advantage of the hierarchical network is that it provides an efficient way of searching for a path through the network. The disadvantage is that if the primary sectional or regional toll center goes down, then large areas of North America can become inaccessible. There are schemes in which some alternate routes are made available, but they cannot carry the full service load.