TELECOMMUNICATION SWITCHING THEORY AND APPLICATIONS

V SEMISTER

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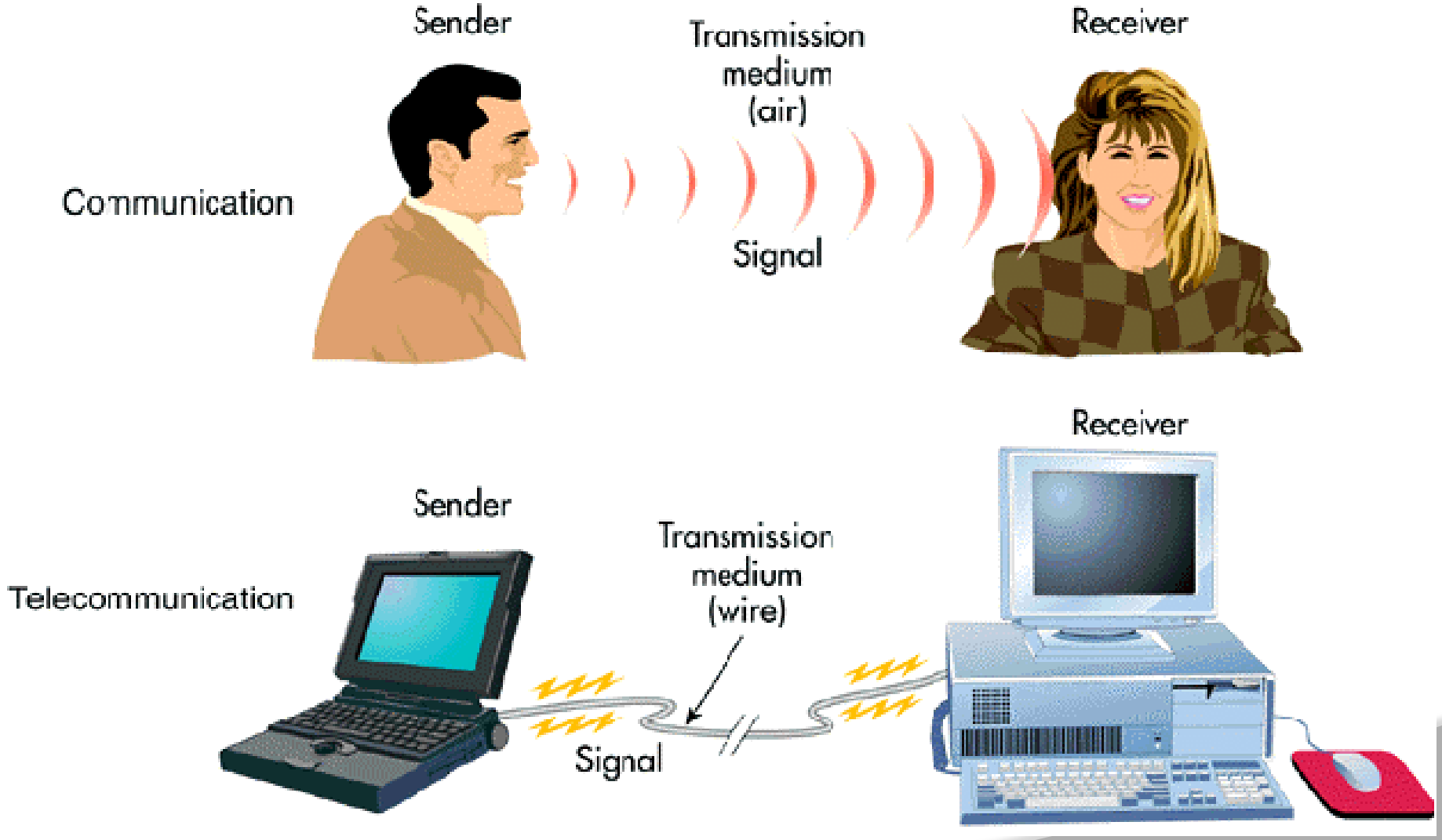
UNIT-I
EVOLUTION OF TELECOMMUNICATIONS

INTRODUCTION

- The exchange of information between two or many individuals is called Communication.
- The word tele is **a Greek word** which means distance.
- Hence, Telecommunication means the exchange of information between two distant places.

Evolution of telecommunications



INTRODUCTION

- **Calling Subscriber:** The one who initiates the call is referred to as the Calling Subscriber .
- **Called Subscriber:** The one for whom the call is destined is the Called Subscriber .

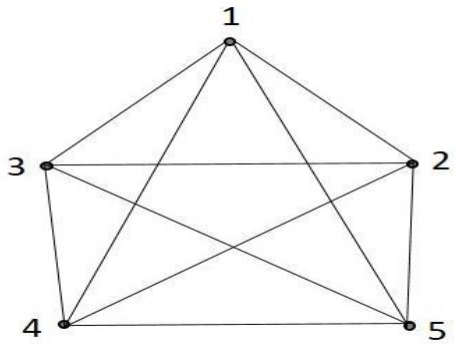
INTRODUCTION

➢**History and Growth** Telegraphy was introduced in 1837 in Great Britain and in 1845 in France.

➢In March 1876, **Alexander Graham Bell** invented and demonstrated his telephone set and the possibility of long distance voice communication .

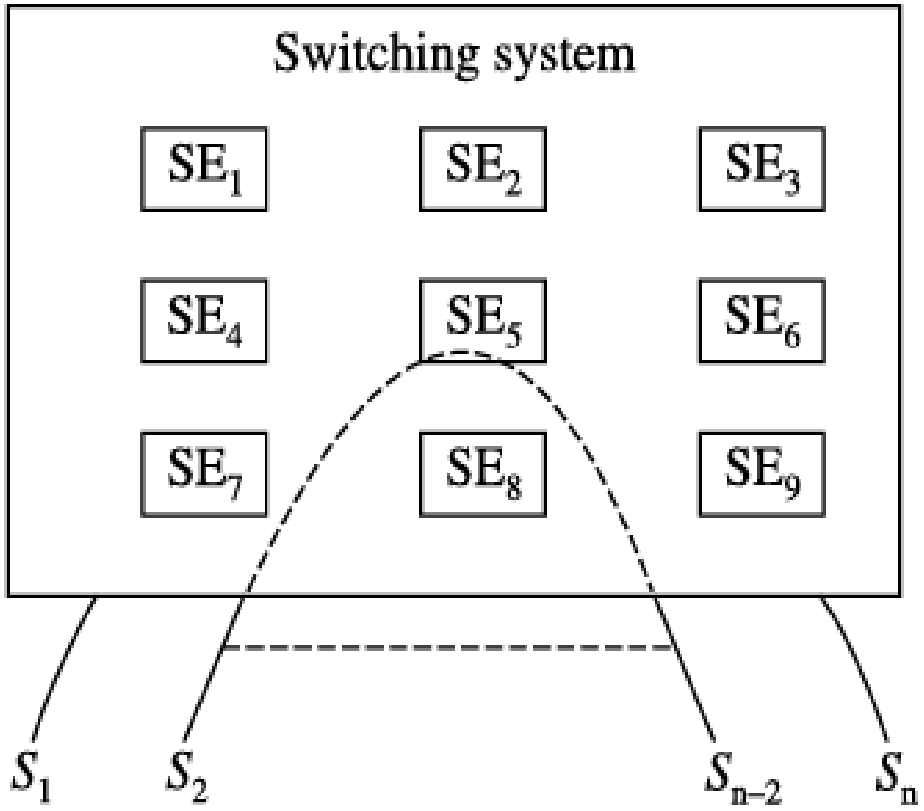
Evolution of telecommunications

Alexander Graham Bell demonstrated the **point-to-point communication**



- The point-to-point connection for establishing communication requires the telephone sets to be linked using wires
- Point-to-point connection, for **n entities, we need n(n-1)/2 links**
- Networks with point-to-point links among all the entities are known as **Fully Connected Networks**

Evolution of telecommunications

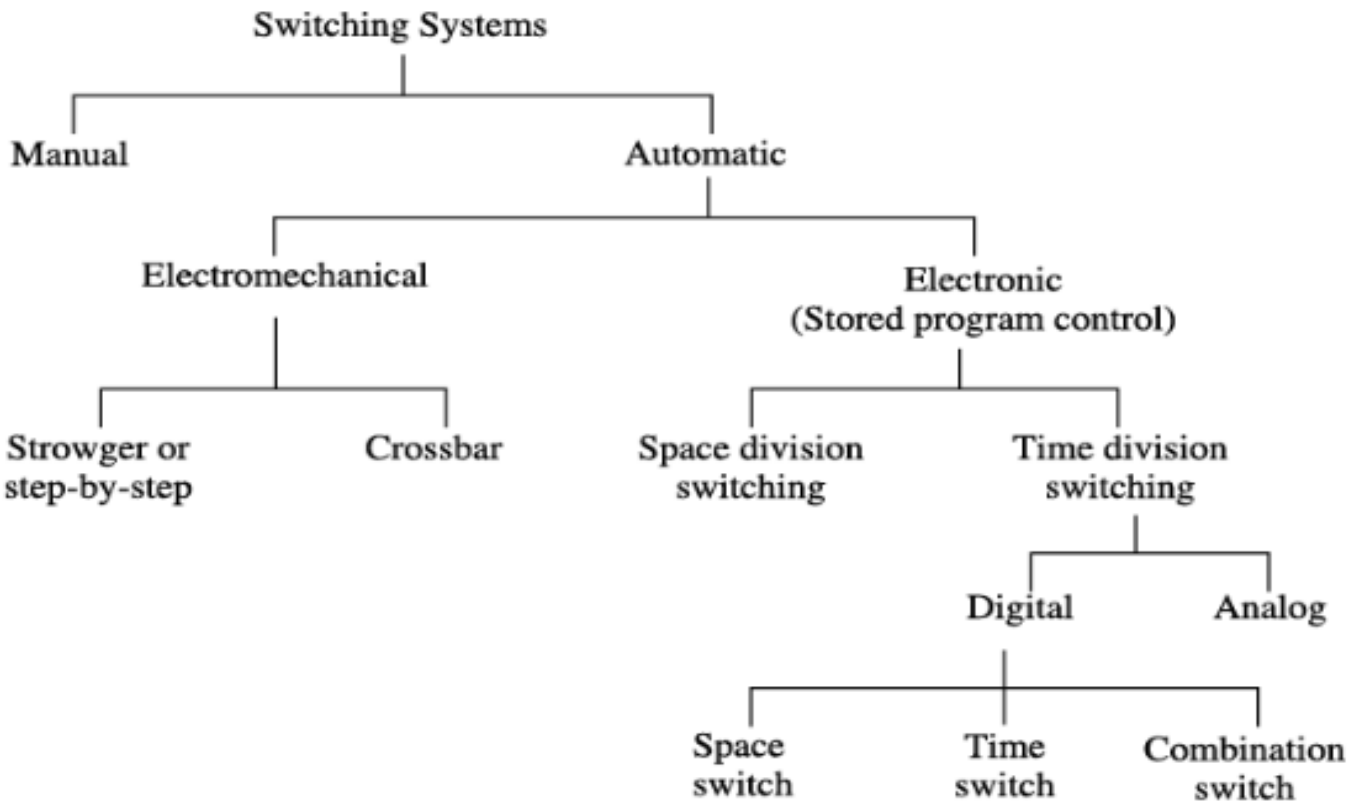


Evolution of telecommunications

Switching Systems

- A switching system is variedly known as a switching office, a switching centre, a telephone exchange, a switching node or simply a switch.
- A switching system contains a number of switching elements.
- When a subscriber wants to communicate with another a connection is established between the two subscribers at the switching system by using one or more switching element.
- The functions performed by a switching system in establishing and releasing connections are known as call processing functions.

Evolution of telecommunications



Classification of switching systems.

Evolution of telecommunications

- Automatic switching systems can be classified as **electromechanical and electronic**.
- Electromechanical switching systems include step-by-step and crossbar systems. The step-by step system is better known as **Strowger switching system** .
- The control functions are disassociated from the switching elements and placed in a separate subsystem called **common control subsystem**.

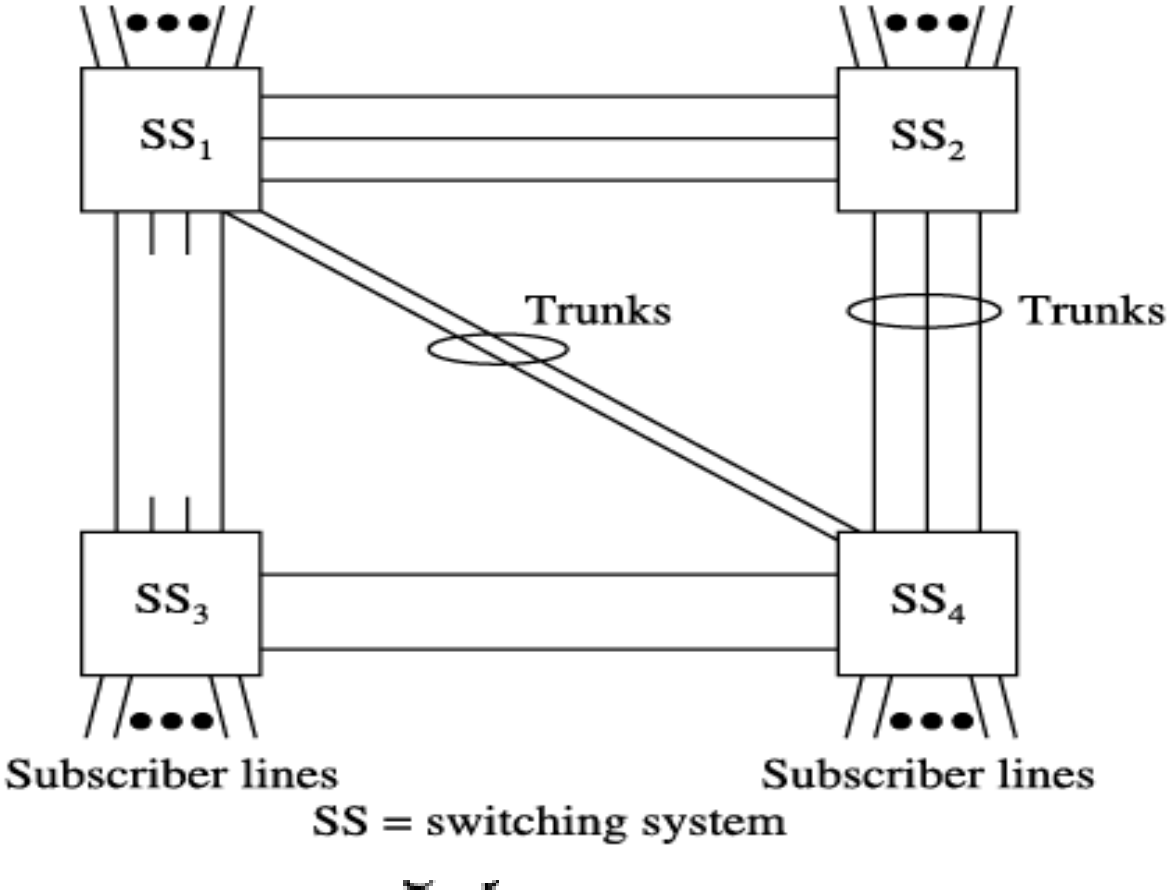
Evolution of telecommunications

- In electronic switching systems, the control functions are performed by a computer or a processor. Hence, these systems are called **stored program control** (SPC).
- The switching scheme used by electronic switching systems may be either **space division switching** or **time division switching.**
- In analog switching, the sampled voltage levels are transmitted as they are, whereas in digital switching. They are binary coded and transmitted.

Evolution of telecommunications

- If the coded values are transferred during the same time interval from input to output, the technique is called **space switching**.
- If the values are stored and transferred to the output at a later time interval, the technique is called **time switching.**
- A time division digital switch may also be designed by using a combination of space and time switching techniques.

Evolution of telecommunications



A switching network.

Evolution of telecommunications

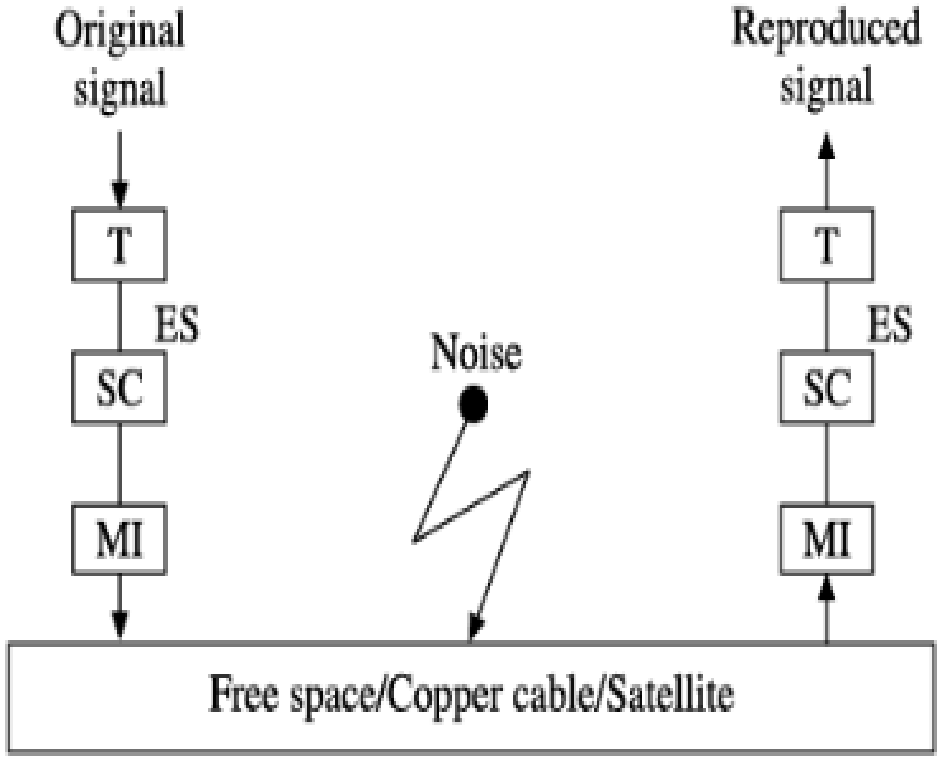
- The links that run between the switching systems are called **trunks**, and those that run to the subscriber premises are known as **subscriber or local lines**.
- The first commercial intercity connection was operationalized between New York and Boston in 1884.
- The first transcontinental trunk connected New York city to San Francisco in 1915
- The first intercontinental connectivity using short wave radio became operational in 1927 between New York and London.

Evolution of telecommunications

- A connection between subscribers attached to switching systems SS2 and SS3 needs to be routed via SS1 or SS4 in a hierarchical structure.
- Ever city has a main or central exchange which is used for routing intercity traffic.
- Exchanges in different localities of the city are connected to the central exchange either directly or via other exchanges.
- The central exchange may also be used to route traffic between two exchanges in the same city. Internationally standardised switching hierarchy.

Evolution of telecommunications

Communication Links

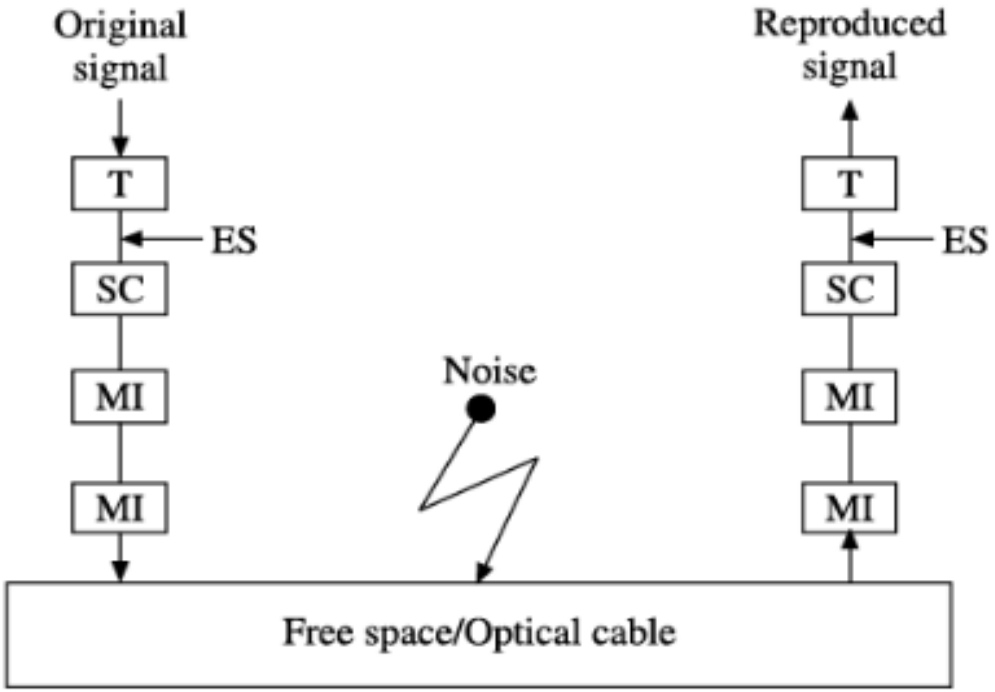


An electrical communication link

EOC = electrical to optical converter; ES = electrical signal; MI = medium interface
OEC = optical to electrical converter; SC = signal conditioner; T = transducer

Evolution of telecommunications

Communication Links



An optical communication link

EOC = electrical to optical converter; ES = electrical signal; MI = medium interface
OEC = optical to electrical converter; SC = signal conditioner; T = transducer

Evolution of telecommunications

Service Specific Networks

- Telegraph networks
- Telex networks
- Telephone networks
- Data networks

Evolution of telecommunications

Telegraph networks

- A telegraph is a communications system in which information is transmitted over a wire.
- The basic components include a source of direct current, a length of wire or cable, and a current-indicating device such as a relay, buzzer, or light bulb.
- The term comes from the Greek words "tele," meaning "at a distance" and "graphy," meaning "to write.

Evolution of telecommunications

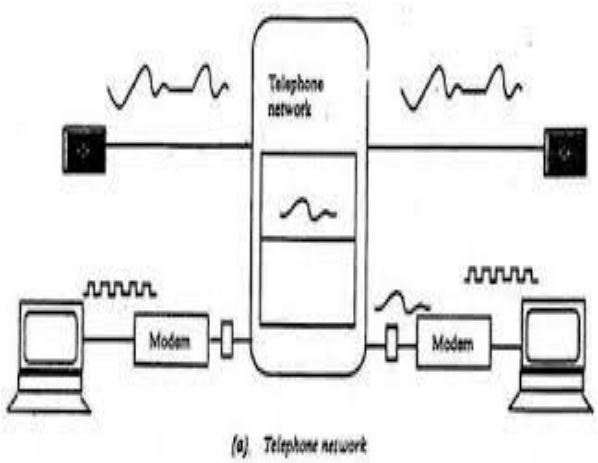
Telex networks

- The **telex** network was a public switched network of teleprinters similar to a telephone network, for the purposes of sending text-based messages. **Telex** was a major method of sending written messages electronically between businesses in the post-World War II period.

Evolution of telecommunications

Telephone networks

- A **telephone network** is a telecommunications **network** used for **telephone** calls between two or more parties.
- A landline **network** where the **telephones** must be directly wired into a single **telephone** exchange.



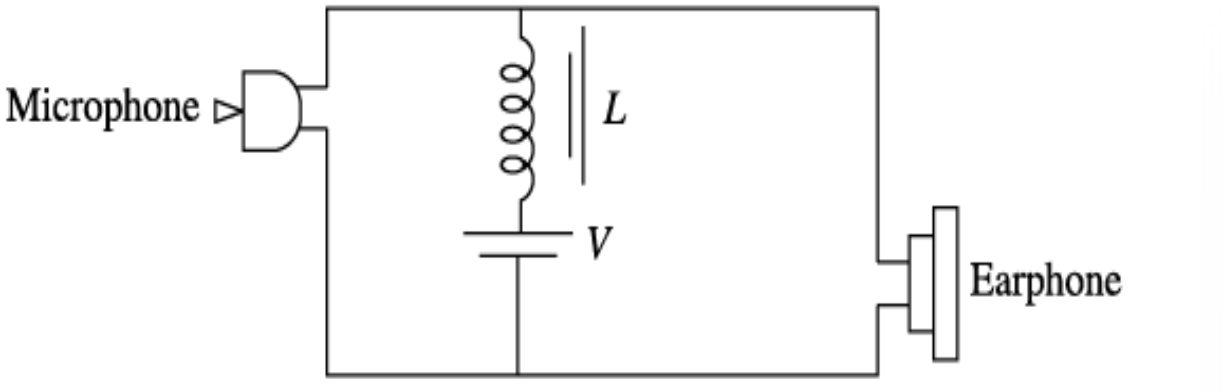
(a) Telephone network

Evolution of telecommunications

Data networks

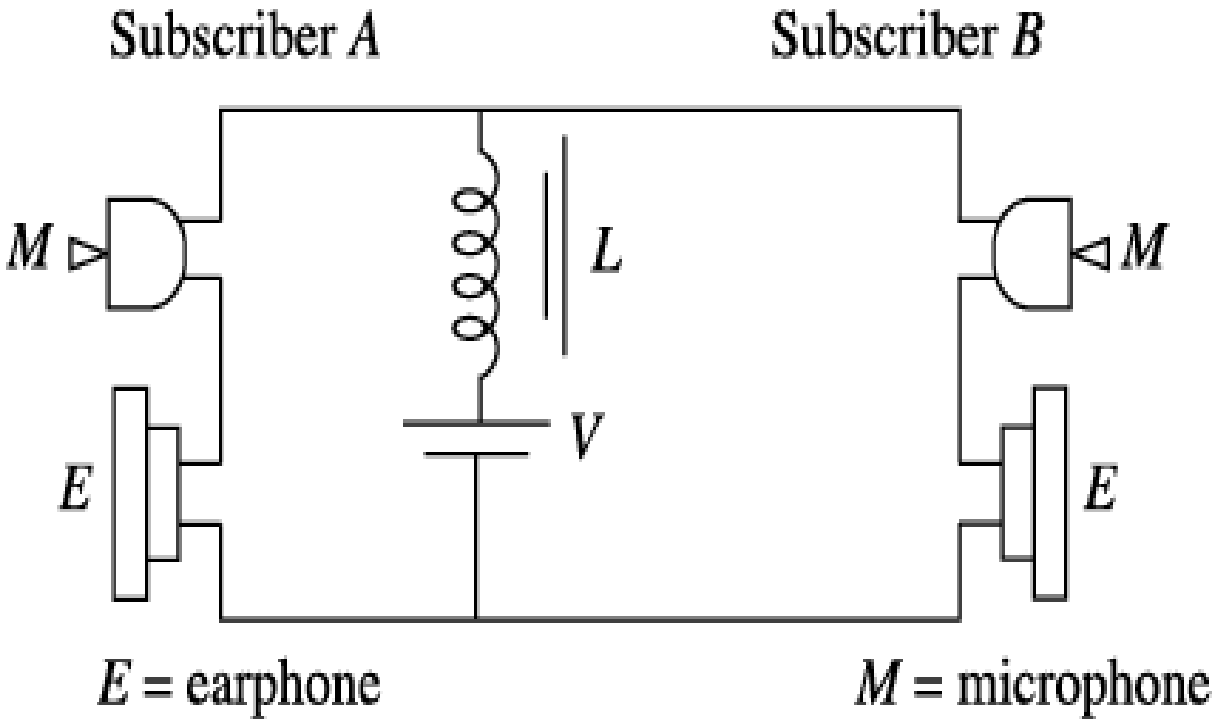
- A **data network** is a system that transfers **data** between **network** access points (nodes) through **data** switching, system control and interconnection transmission lines.
- **Data networks** are primarily designed to transfer **data** from one point to one or more points (multipoint).

Simple telephone communication



- One way communication.
- Also known as Simplex communication .
- Micro phone and Earphones are transducer of the telecommunication system .
- Micro phone converts speech signal into electrical signal, earphone converts electrical signal into audio signal .

Simple telephone communication



Simple telephone communication

- In a normal telephone communication system information is transferred both ways.
- An entity is capable of both receiving and sending although these do not take place simultaneously.
- Such a form of communication where the information transfer takes place both wars but not simultaneously is known as **half-duplex communication.**
- If the information transfer takes place in both directions simultaneously, then it is called **full-duplex communication**.

Major telecommunication networks

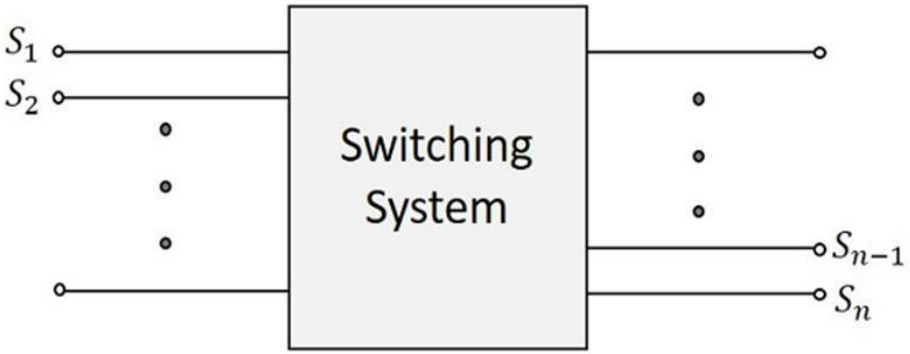
- Wide area networks(WAN)
- Metropolitan area network(MAN)
- Local area networks (LAN)
- Internet area networks (IAN)
- Campus area networks (CAN)
- Virtual private networks(VPN)

Switching Systems

- Network connection cannot be simply made with telephone sets and bunch of wires, but a good system is required to make or break a connection.

- This system is known as the **Switching System or the Switching Office or the Exchange.**

- The switching system, which is also called the **Telephone Exchange**

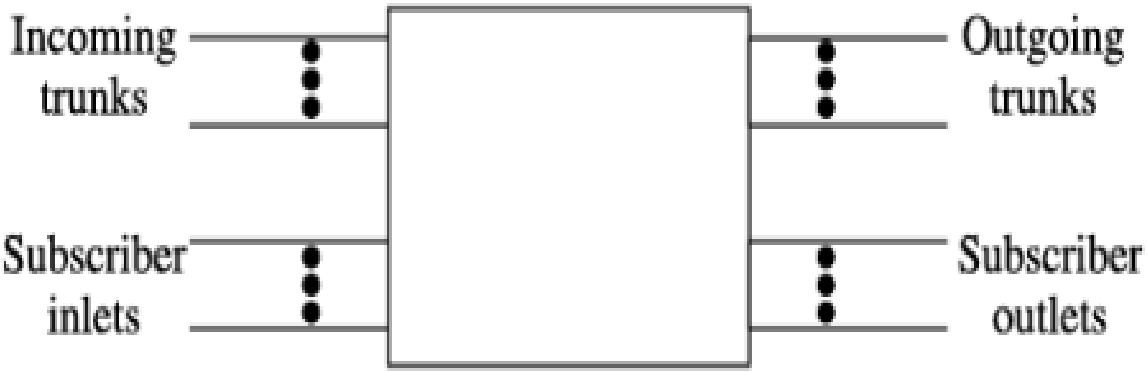


Switching Systems

(a) Model of a switch

- A major component of a switching system or an exchange is the set of input and output circuits called **inlets** and **outlets**, respectively.
- The primary function of a switching system is to establish an electrical path between a given inlet-outlet pair.
- The hardware used for establishing such a connection is called the **switching matrix** or the **switching fabric**.

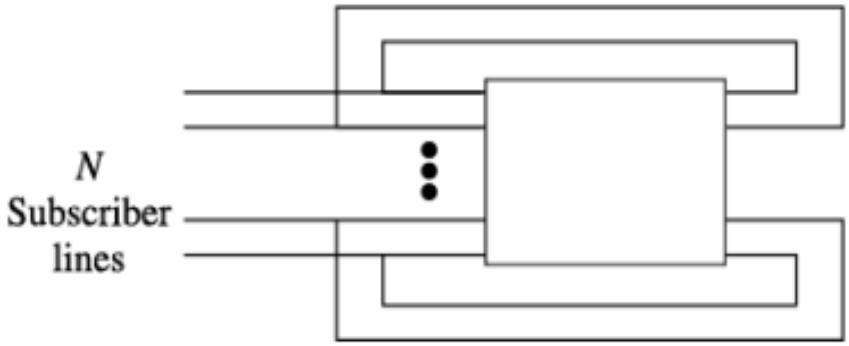
Switching Systems



(b) Inlets/Outlets connections

- When N = M the switch is called a symmetric switch.
- The inlets outlets of a switch may be connected to local subscriber lines or to trunks from/to other exchanges as shown in Figure

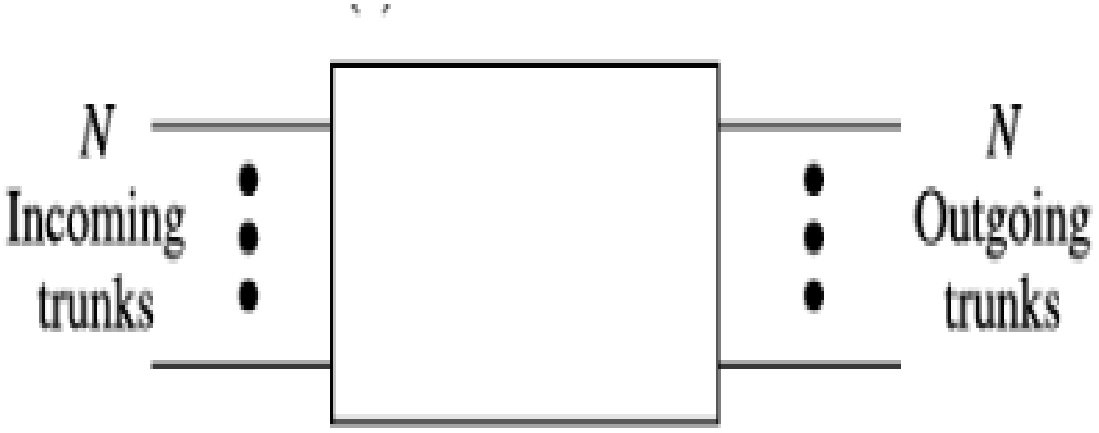
Switching Systems



(c) Folded switch

- The output lines are folded back to the input and hence the switch is called a **folded switch**.
- In a switch, all the inlet outlet connections may be used for inter exchange transmission.
- In such a case, the exchange does not support local subscribers and is called a **transit exchange**.

Switching Systems



(d) Nonfolded switch

Switching Systems

1. Local call connection between two subscribers in the system

2. Outgoing call connection between a subscriber and an outgoing trunk

3. Incoming call connection between an incoming trunk and a local subscriber

4. Transit call connection between an incoming trunk and an outgoing trunk.

Switching Systems

- A folded switch supports Type 1 connections and a non folded switch supports connections of Type 4.

- In a folded switch with N subscribers, there can be a maximum of only N2 simultaneous calls or information interchanges.

- The switch may be designed to provide N/2 simultaneous switching paths, in which case the switch is said to be **Non blocking.**
- **Blocking Switch**
- **Switching capacity**
- **Blocking probability**
- **Fully connectivity or Fully availability**

Switching Systems

- All the switching exchanges are designed to meet an estimated maximum average simultaneous traffic. usually known as **busy hour traffic.**
- The load on a switching resource is measured in terms of the occupancy of the resource. Such a measure is called the **traffic intensity**
- The measure is obviously dimensionless, but is given a unit known as **erlang (E)**.
- Named after the Danish telephone engineer. A.K. Erlang.

Manual Switching

- A microphone requires to be energised in order to produce electrical signals corresponding to the speech waveform.
- In the very early switching systems, the microphone was energised using a battery at the subscriber end. Later, a battery located at the exchange was used.

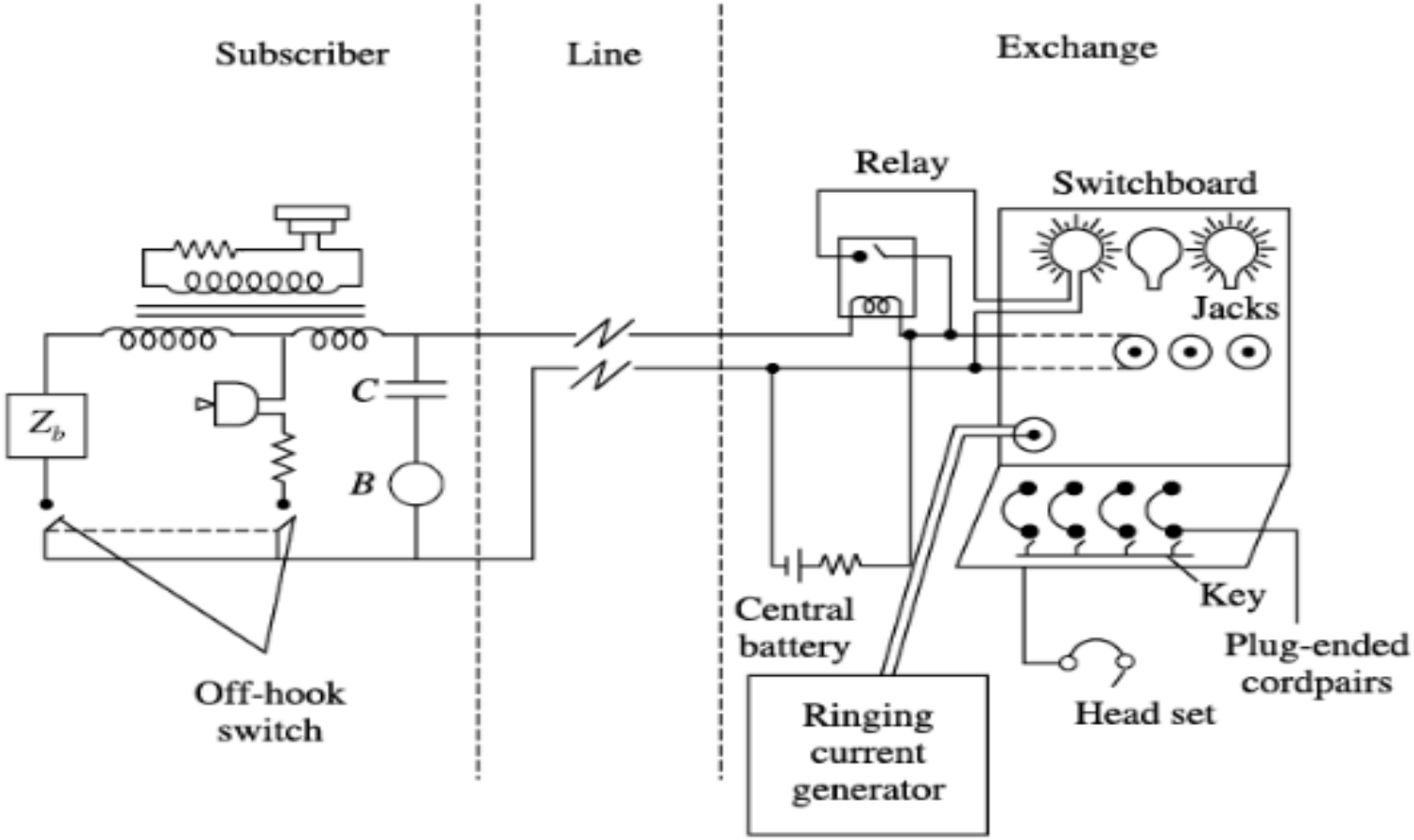
Manual Switching

- With the advent of automatic switching systems, the manual exchanges have almost gone out of use.
- Today, operator assistance is required on a routine basis, only to connect the incoming calls at a private automatic branch exchange (PABX) to the required extension numbers.

Manual Switching

- Accordingly, one may place the exchanges in one of **two categories:**
  - ✓ Local battery (LB) exchanges
  - ✓ Central battery (CB) exchanges.
- In the LB systems, dry cells were used in subscriber sets to power the microphone.
- LB subscriber sets were provided with a magneto generator.
- In this case, a subscriber needed to rotate a handle to generate the required alternating current to operate indicators at the exchange.
- The necessity to replace dry cells frequently and the cumbersome procedure of rotating the magneto generator led to the development of CB exchanges.

Manual Switching



Manned central battery exchange.

Manual Switching

- The system consists of one or more switchboards manned by operators.
- The subscriber lines are terminated on jacks mounted on the switchboard.
- There is one jack for every subscriber line.
- Associated with each jack is a light indicator to draw the attention of the operator.

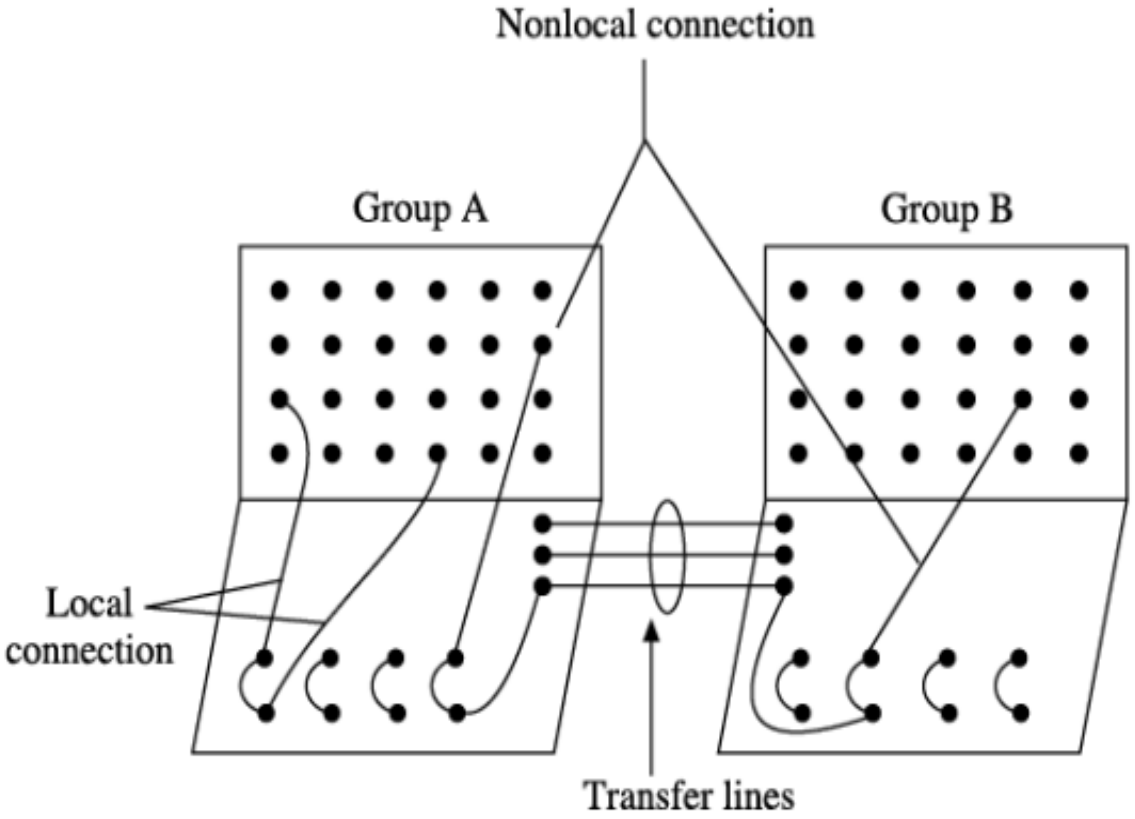
Manual Switching

- When a subscriber lifts the hand set, the off-hook switch is closed, causing a current to flow through the handset and the lamp relay coil.
- The lamp relay operates and the indicator corresponding to the subscriber lights up.
- The operator establishes contact with the subscriber by connecting the head set to the subscriber line via the head set key and a plug-ended cord pair.

Manual Switching

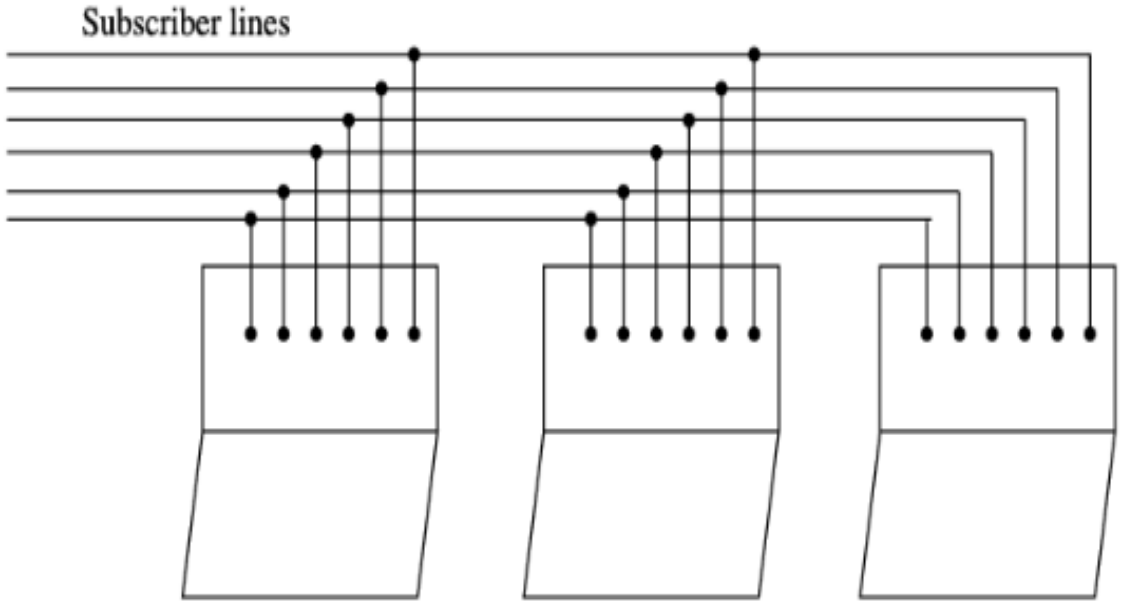
- If there are 200 subscribers terminated on a switchboard, there can be a maximum of loo simultaneous calls.
- In order to support all these calls, the switchboard must contain 100 plug- ended cord pairs.
- But a single operator may not be able to handle 100 calls simultaneously.
- it is, however, rare that all the subscribers would like to talk simultaneously.
- Assuming that only 20 subscribers (10 calls) will use the system simultaneously, the switchboard needs to be provided with only 10 plug-ended cord pairs.

Manual Switching



Single termination boards with transfer jacks.

Manual Switching



Multitermination boards.

Manual Switching

- When the number of subscribers increases, multiple switchboards and operators are required to handle the traffic.

- In this case, the subscriber switchboards at the exchange may be of two types:
  - ✓ Single termination switchboards
  - ✓ Multi termination switchboards.

Strowger switching system

- Strowger switching system was the first automatic switching system developed by Almon B. Strowger in 1889.
- Annoyed at the amount of business he was losing everyday.
- Strowger decided to make a switching system that would replace the human operator.
- The switch developed by him is named after him.
- Functionally, the system is classified as step-by-step switching system since the connections are established in a step-by-step process. .

Strowger switching system

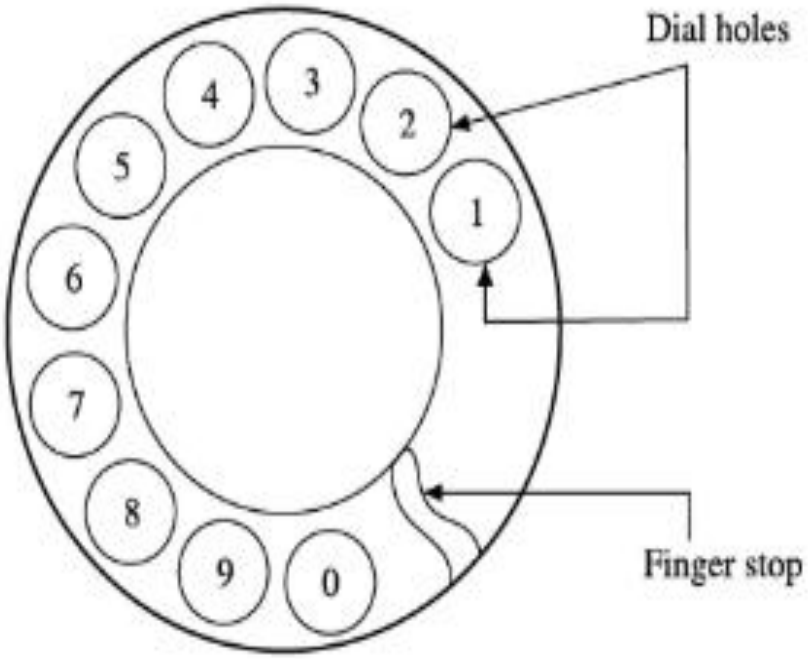
- In a manual exchange. the subscriber needs to communicate with the operator and a common language becomes an important factor.
- In multilingual areas this aspect may pose problems. On the other hand, the operation of an automatic exchange is language independent.
- A greater degree of privacy is obtained in automatic exchanges as no operator is normally involved in setting up and monitoring a call.
- Establishment and release of calls are faster in automatic exchanges.
- In an automatic exchange, the time required to establish and release a call remains more or less of the same order irrespective of the load on the system or the time of the day.

Strowger switching system

ROTARY DIAL TELEPHONE

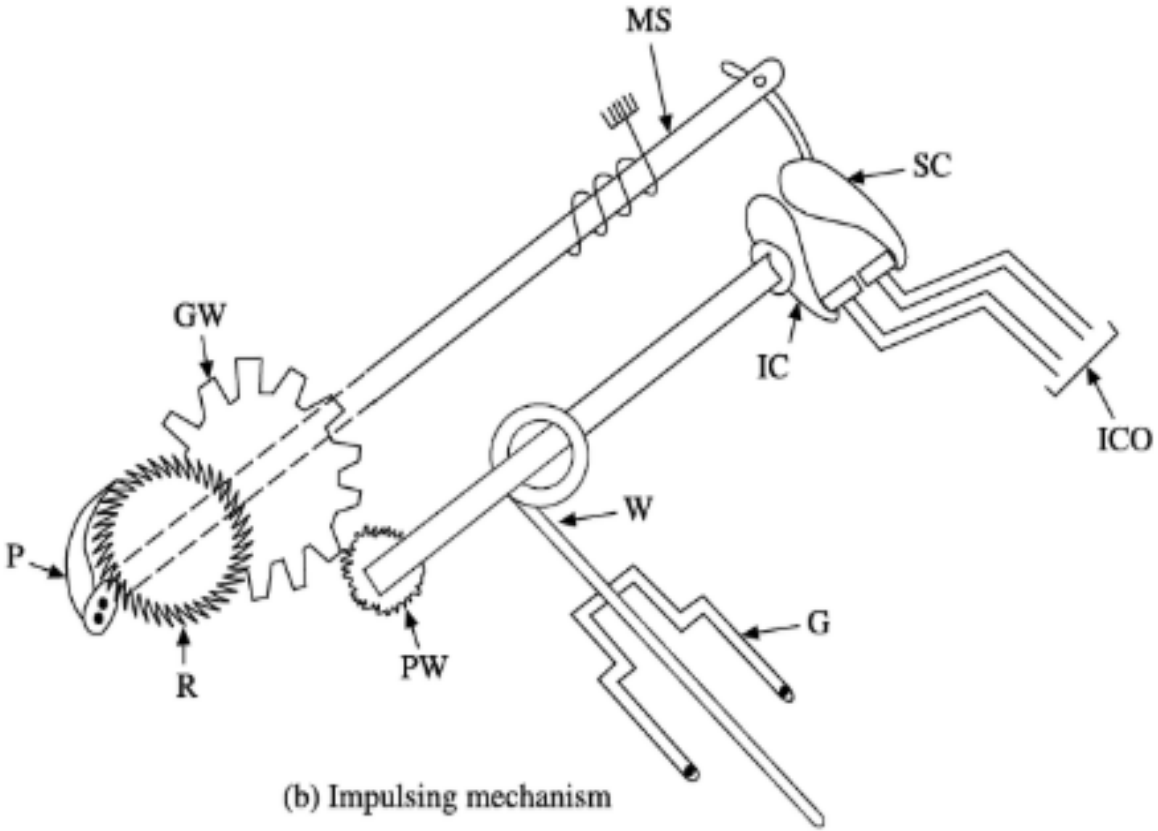
- A rotary dial telephone uses the following for implementing pulse dialling:
  - ✓ Finger plate
  - ✓ Shaft, gear and pinion wheel
  - ✓ Pawl and ratchet mechanism
  - ✓ Impulsing cam and suppressor cam or a trigger mechanism
  - ✓ Impulsing contact
  - ✓ Centrifugal governor and worm gear
  - ✓ Transmitter. receiver and bell by-pass circuits.

Strowger switching system



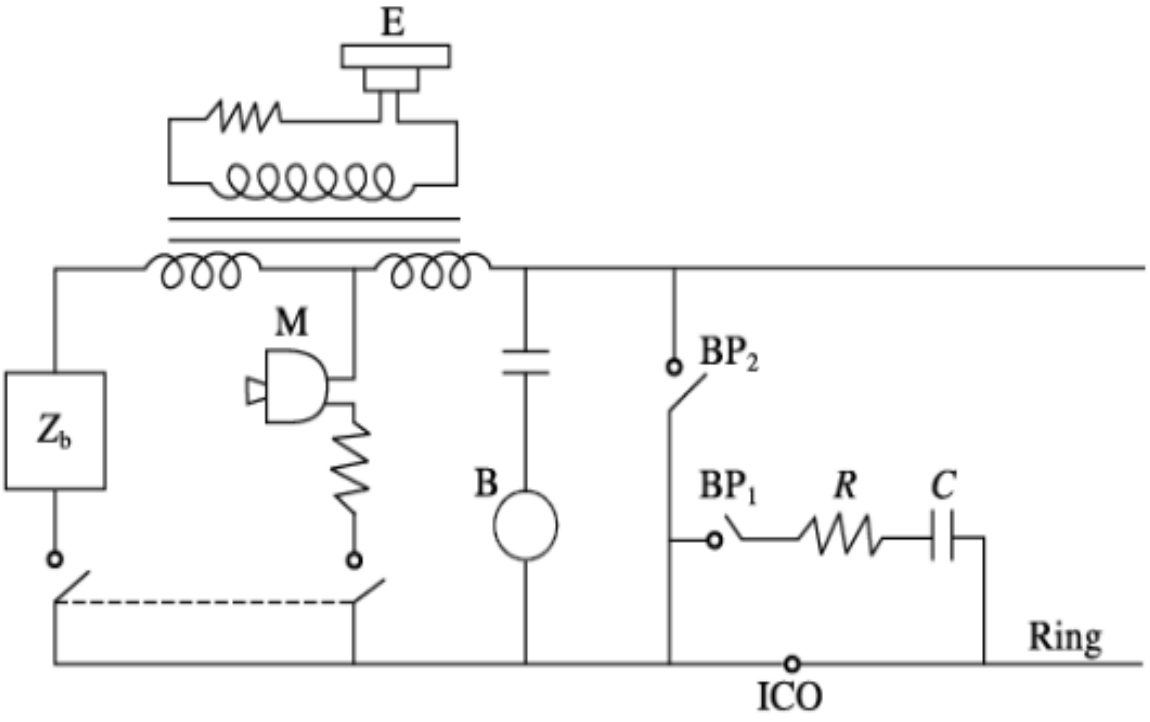
(a) Finger plate arrangement

Strowger switching system



(b) Impulsing mechanism

Strowger switching system



B = bell BP_1, BP_2 = by-pass switches ICO = impulsing contact

Strowger switching system

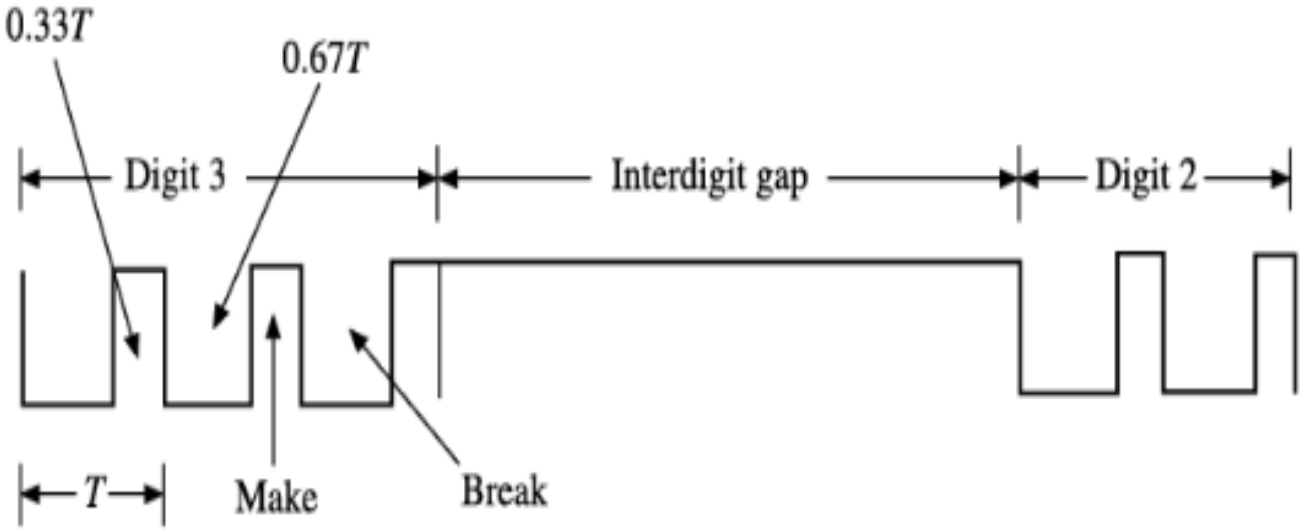


Figure 2.1 Pulse dialling.

Strowger switching system

In introducing dial pulsing mechanism in the telephone set, the following points have to be considered:

1. Since the pulses are produced by make and break of the subscriber loop, there is likelihood of sparking inside the telephone instrument.

2. The transmitter, receiver and the bell circuits of the telephone set may be damaged if the dialing pulses are passed through them.
3. The dialing habits of the users vary widely and hence all timing aspects should be independent of user action.

Signaling Tones

A number of signaling functions are involved in establishing, maintaining and releasing a telephone conversation.

- Dial Tone
- Ring Tone
- Busy Tone
- Number Unobtainable Tone
- Routing Tone or Call-in-Progress Tone

Signaling Tones

- Respond to the calling subscriber that system is ready to receive the identification of the called party.
- Inform the calling subscriber that the call is being established.
- Ring the bell of the called party.
- Inform the calling subscriber, if the called party is busy.
- Inform the calling subscriber, if the called party line is unobtainable for some reason.

Signaling Tones

- Function 1 above is fulfilled by sending a dial tone to the calling subscriber.
- This tone indicates that the exchange is ready to accept dialed digits from the subscriber.
- The subscriber should start dialing only after hearing the dial tone,otherwise,initial dial pulses may be missed by the exchange.

Signaling Tones

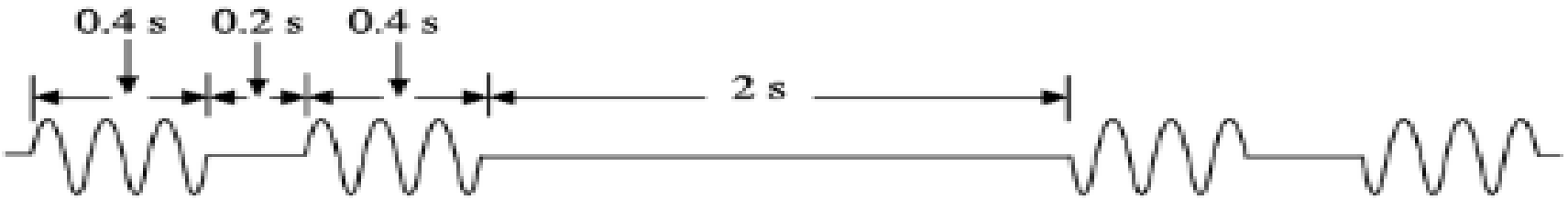
- which may result in the call landing on a wrong number.
- Most often, the dial tone is sent out by the exchange even before the handset is brought near the ear.

33 or 50 or 400 Hz continuous

(a) Dial tone

Signaling Tones

- When the called party line is obtained, the exchange control equipment sends out the ringing current to the telephone set of the called party.
- This ringing current has the familiar double-ring pattern, simultaneously.
- The control equipment sends out a ringing tone to the calling subscriber.



(b) Ringing tone

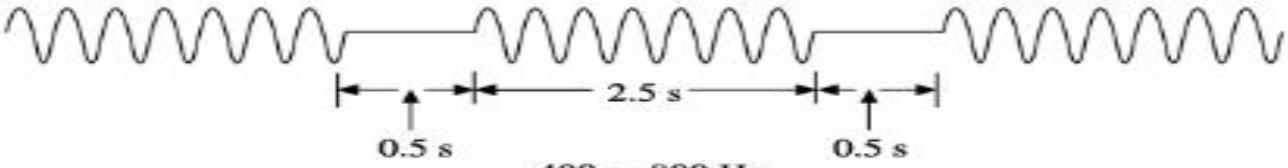
Signaling Tones

400 Hz

(c) Busy tone

400 Hz continuous

(d) Number unobtainable tone



400 or 800 Hz

(e) Call-in-progress tone

STROWGER SWITCHING COMPONENTS

In Strowger exchanges, two electromechanical devices form the basic building blocks for the switching system:

- Uni selector
- Two-motion selector

STROWGER SWITCHING COMPONENTS

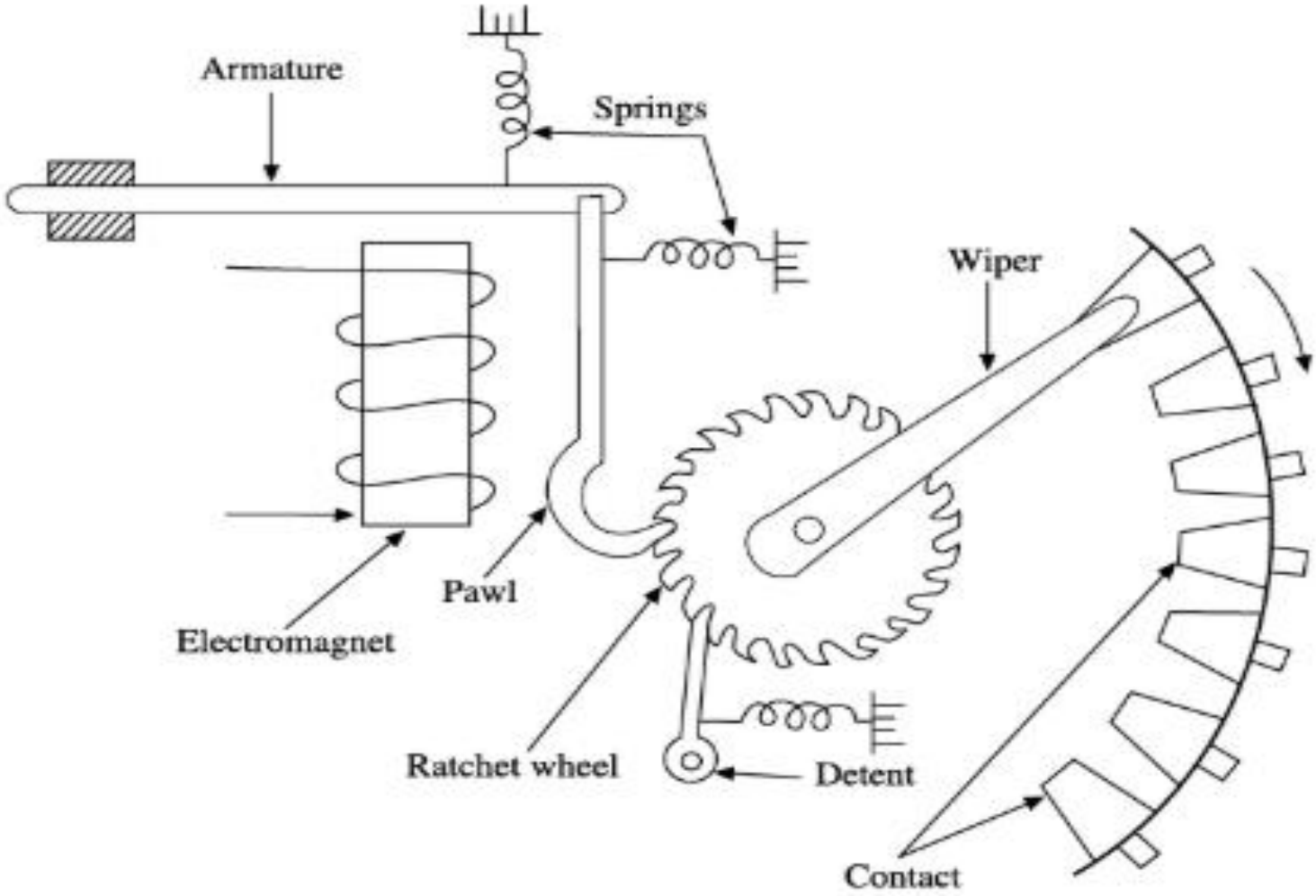
Uni selector

- These devices are called selectors as they enable selection of suitable switching paths for establishing connections amongst subscribers.

- Uniselectors have a mechanism to span across a bank of contacts that lie in a horizontal plane and to select a free contact that can be used to establish a connection.

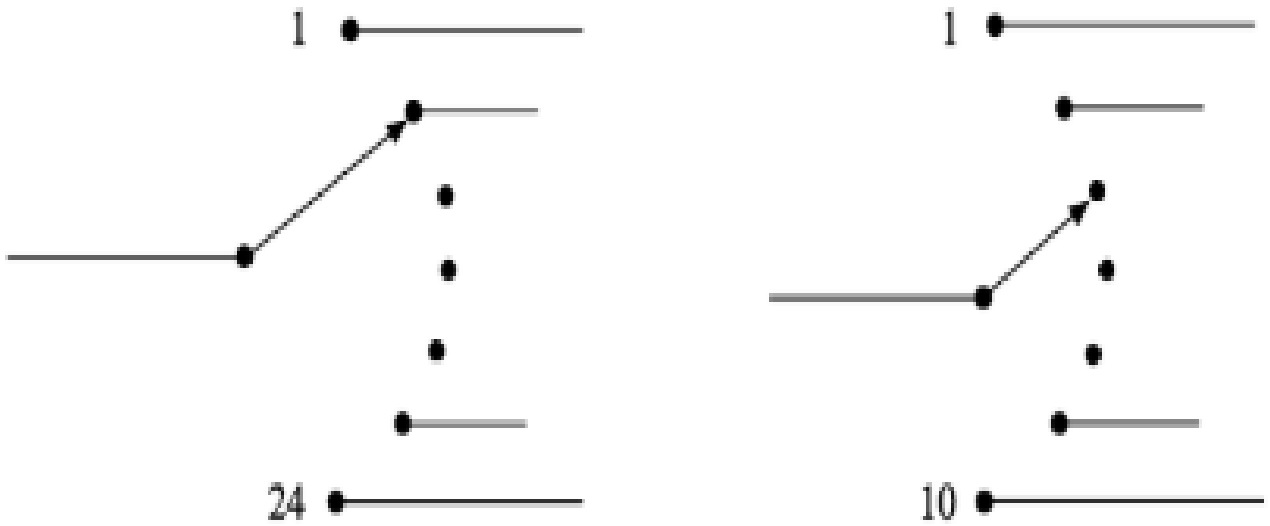
- Two- motion selectors have the ability to move both in the vertical and horizontal directions to select a free contact. Uniselectors and two-motion selectors are constructed using electro-mechanical rotary switches which in turn are built using among others, an electromagnet, an armature and a rachet wheel.

STROWGER SWITCHING COMPONENTS



(a) Drive mechanism of a rotary switch

STROWGER SWITCHING COMPONENTS



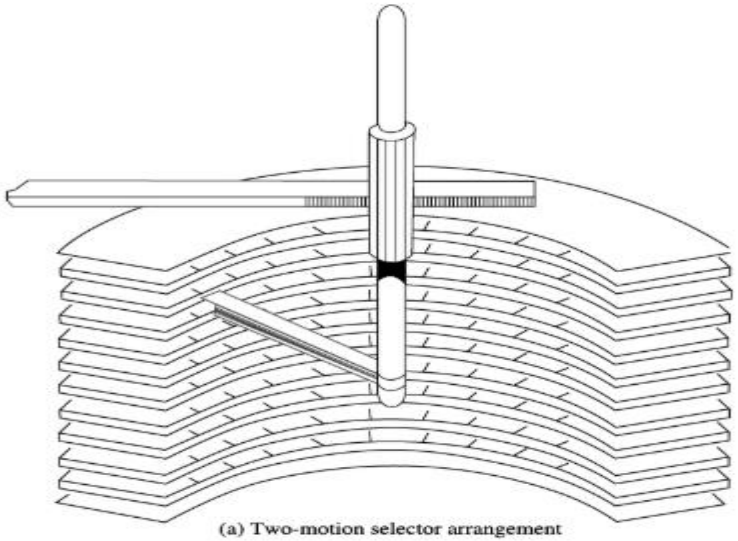
(b) Schematic representation of uniselectors

STROWGER SWITCHING COMPONENTS

The proper functioning of a uniselector is dependent on a number of factors:

- Energizing current level
- Inertia of the moving system
- Friction between wipers and bank contacts
- Friction in drive assembly
- Tension in restoring springs
- Adjustment of interrupter contact.

STROWGER SWITCHING COMPONENTS



(a) Two-motion selector arrangement

(b) Schematic representation

STROWGER SWITCHING COMPONENTS

- The vertical and horizontal motions in a two-motion selector may be effected directly by using two impulse trains from subscriber dialing.
- The first impulse train corresponding to the first digit operates the vertical magnet, and the second impulse train drives the horizontal rotary switch.
- In such a case, it follows that the bank contacts are so numbered as to correspond to the digits necessary to reach each contact.
- It may be noted that the lowest vertical level commences with 11 and ends with 10, while the tenth level commences with 01 and ends with 00.
- This is so because digit zero produces 10 pulses when dialed.

Step by Step Switching

- A step-by-step switching system may be constructed using uniselectors or two-motion selectors or a combination of both. As already stated, the wiper contacts of these selectors move in direct response to dial pulses.

- They may also be made to move through interrupter mechanism which may be activated by other signals like off-hook from the subscriber telephone.

- The wiper steps forward by one contact at a time and moves by as many contacts (takes as many steps) as the number of dial pulses received or as required to satisfy certain signalling conditions.

Step by Step Switching

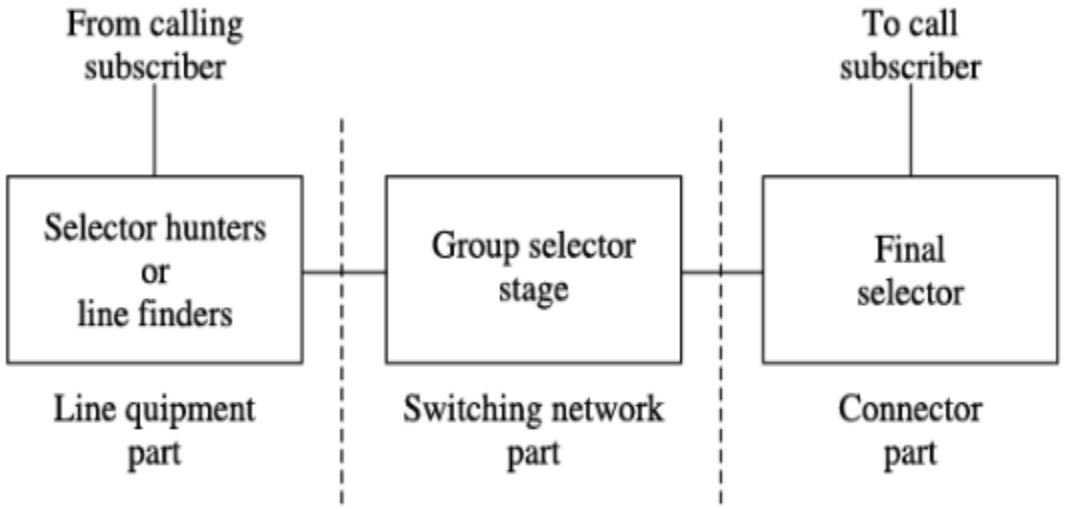
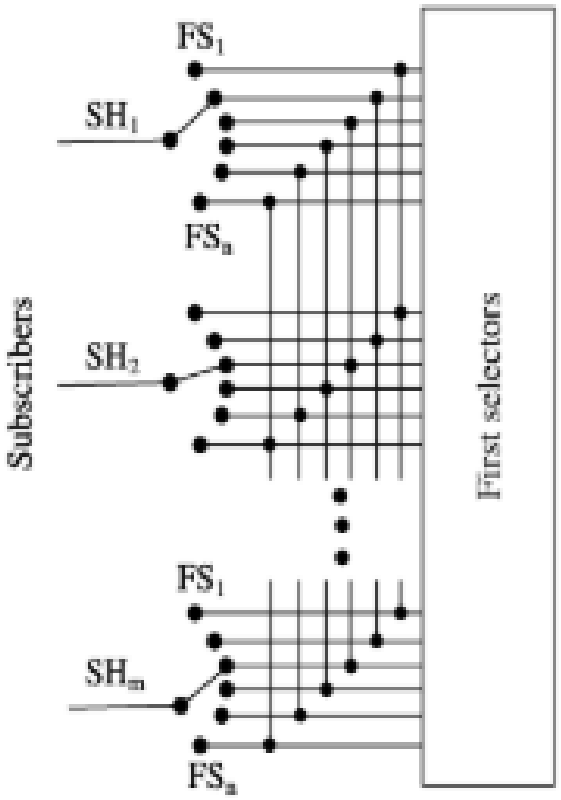


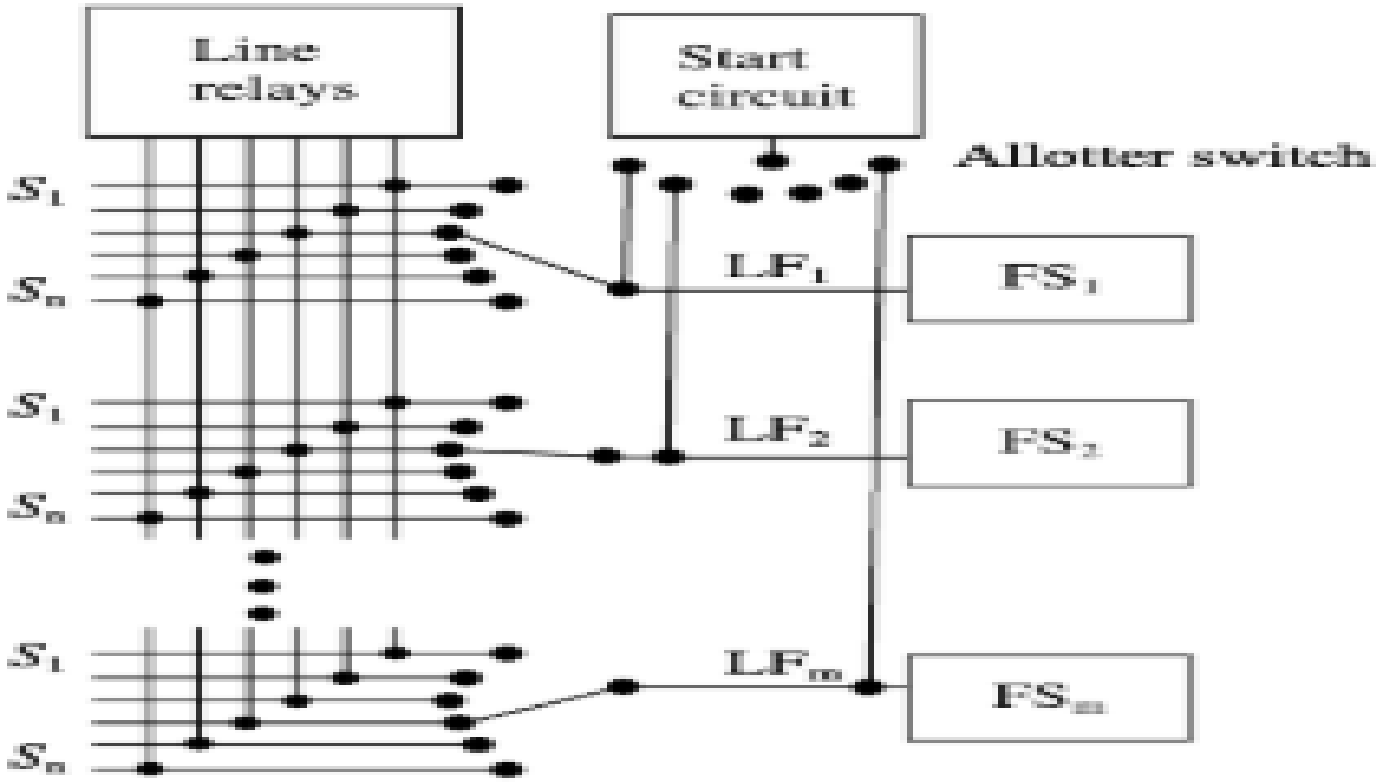
Figure 2.7 Configuration of a step-by-step switching system.

Step by Step Switching



(a) Selector hunter based access

Step by Step Switching



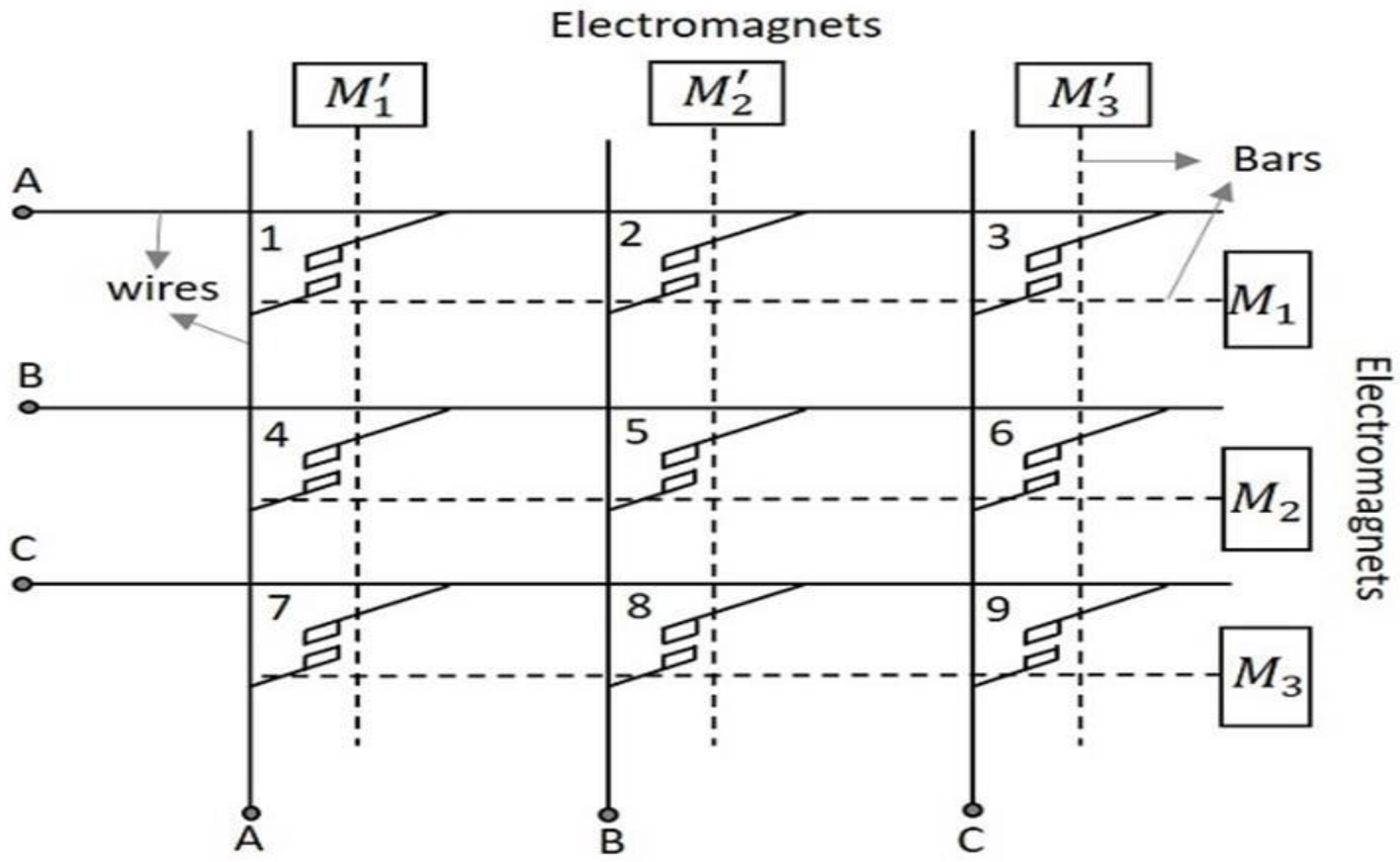
(b) Line finder based access

Crossbar switching

The Features of Crossbar Switches

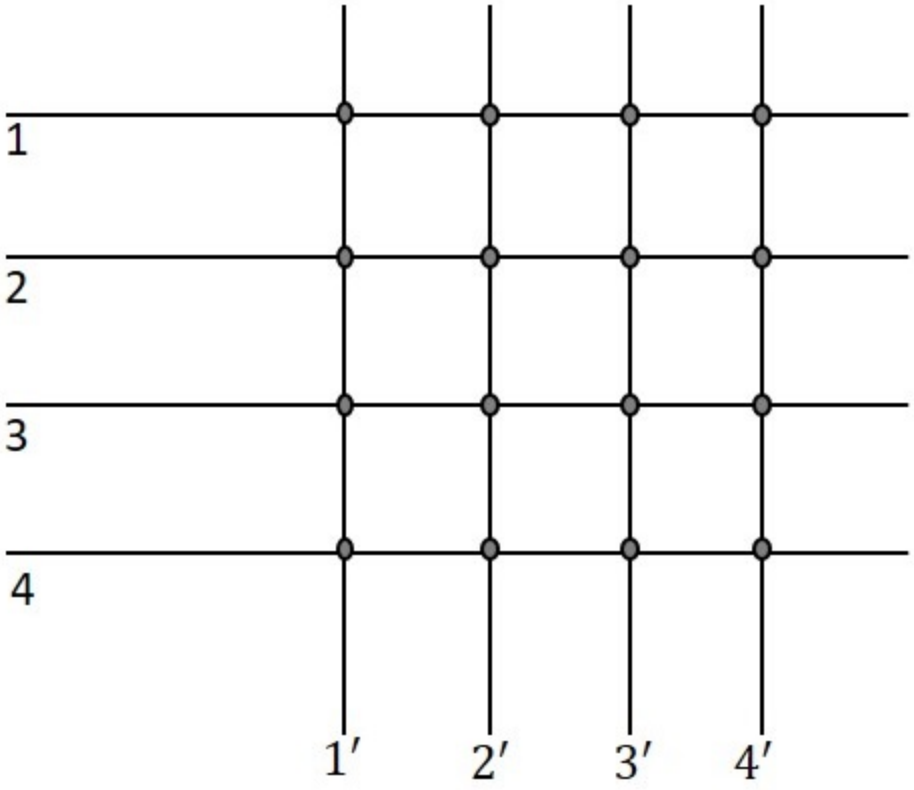
- While processing a call, the common control system helps in the sharing of resources.
- The specific route functions of call processing are hardwired because of the Wire logic computers.
- The flexible system design helps in the appropriate ratio selection is allowed for a specific switch.
- Fewer moving parts ease the maintenance of Crossbar switching systems

Crossbar switching

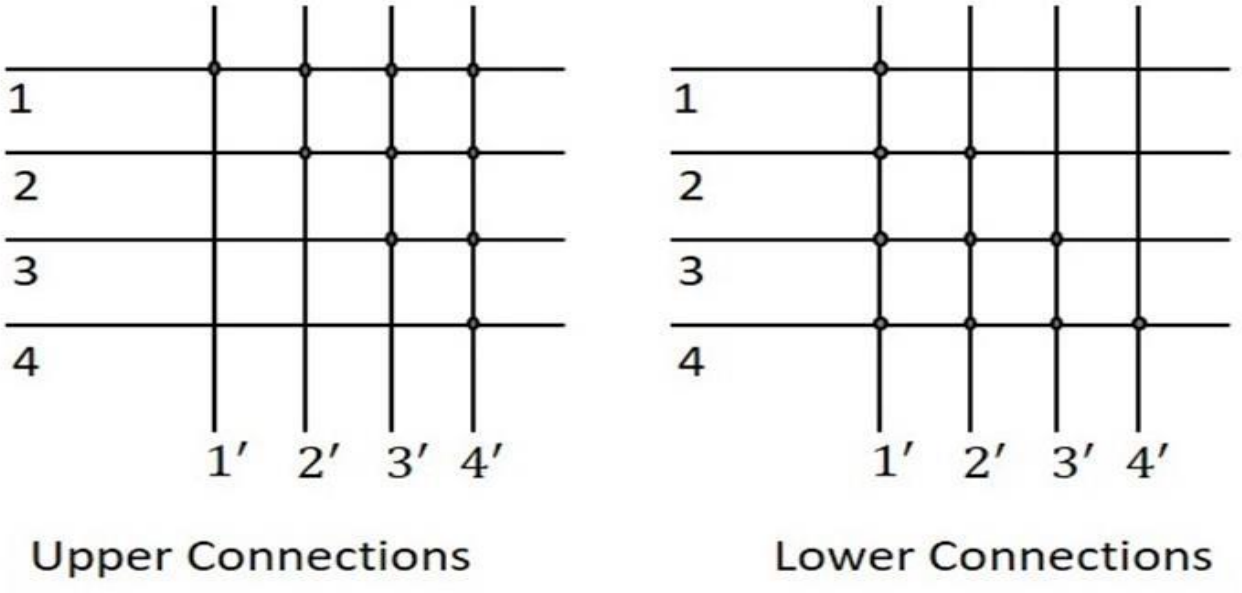


3 X 3 Crossbar Switching

Non-Blocking Crossbar configuration



Diagonal Cross point Matrix



The diagonal points are also considered, the total number of Cross points will be

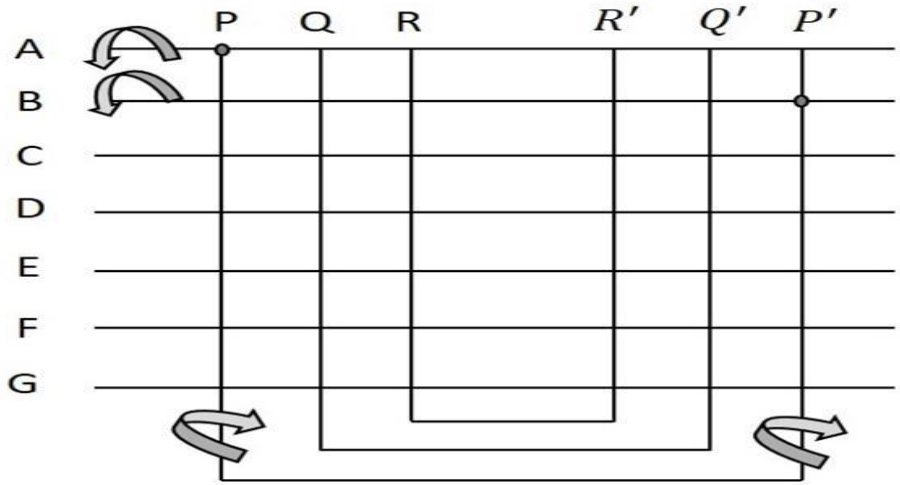
$$N\ (N{+}1)/2$$

If the diagonal points are not considered, then the total number of Cross points will be,

$$N\ (N{-}1)/2$$

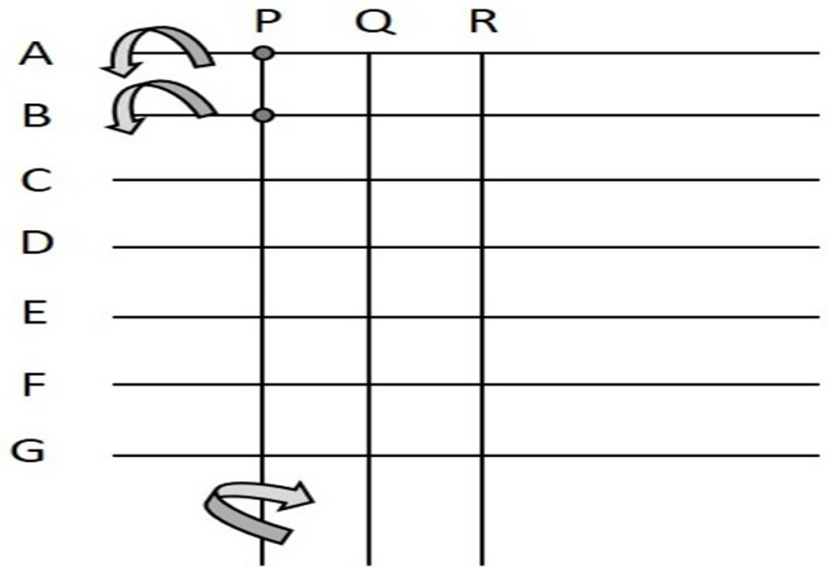
Crossbar Switch Configurations

Blocking Crossbar Switches



- Hence, the steps associated with the establishment of connection follows a sequence:
- Energize horizontal bar A
- Energize free vertical bar P
- De-energize horizontal bar A
- Energize horizontal bar B
- Energize free vertical bar P’ (associated with P)
- De-energize horizontal bar B

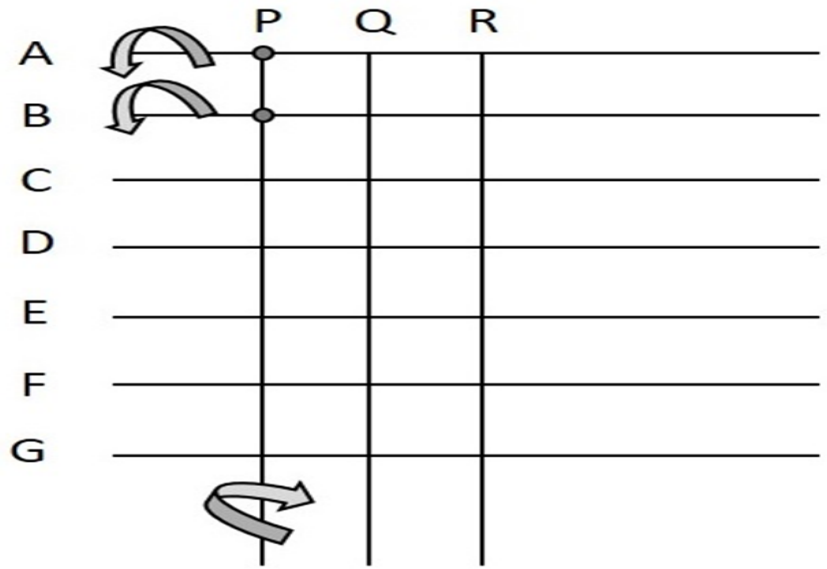
Crossbar Switch Configurations



Hence, the establishment of connection follows a sequence:

- Energize horizontal bars A and B
- Energize free vertical bar P
- De-energize horizontal bars A and B

Crossbar Switch Configurations



Hence, the establishment of connection follows a sequence:

- Energize horizontal bars A and B
- Energize free vertical bar P
- De-energize horizontal bars A and B

Electronic Space Division Switching

- Stored Program Control
- Centralized SPC
- Distributed SPC
- Software Architecture
- Application Software
- Enhanced Services
- Two-Stage Networks
- Three-Stage Networks
- N-Stage Networks

Electronic Space Division Switching

- Efforts to improve the speed of control and signaling Late 1940s and early 1950s.
- Use of vacuum tubes, transistors, gas diodes, magnetic drums and cathode ray tubes.
- Arrival of modern electronic digital computers.
- The registers and translators of common control systems can be replaced by a single digital computer.

Stored Program Control

Stored Program Control (SPC)

- Carrying out the exchange control functions through programs stored in the memory of a computer.
- Consequence
  - ✓ Full-scale automation of exchange functions
  - ✓ Introduction of a variety of new services

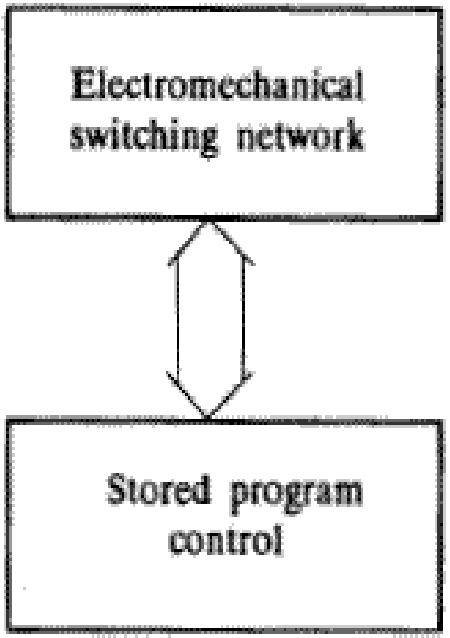
Stored Program Control

- New features possible for SPC
  - ✓Common Channel Signaling (CCS)
  - ✓Centralized maintenance
  - ✓Automatic fault diagnosis
  - ✓Interactive human-machine interface
- Special Requirements of SPC
  - ✓ Operating without interruption
  - ✓ Fault tolerant hardware and software

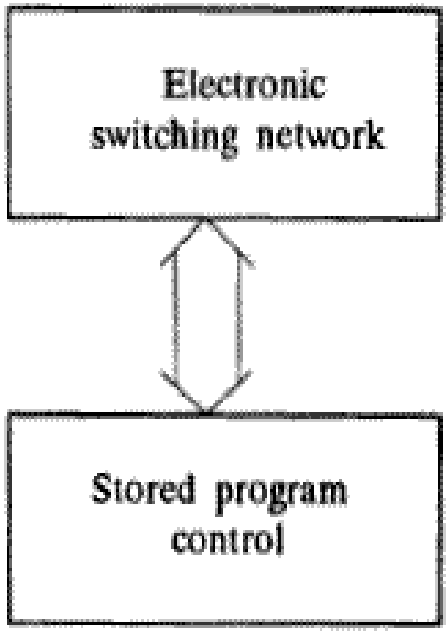
Stored Program Control

- Two types of SPC switching system
  - ✓ Electromechanical Switching SPC+Electromechanical switching network
  - ✓ Electronic Switching SPC+Electronic switching network

Stored Program Control



(a) Electromechanical switching



(b) Electronic switching

Stored Program Control

- Organization of SPC
  - ✓ Centralized SPC Broadly used in early SPC switching systems.
  - ✓ Distributed SPC Gaining popularity in modern switching systems.

Centralized SPC

➢Concept

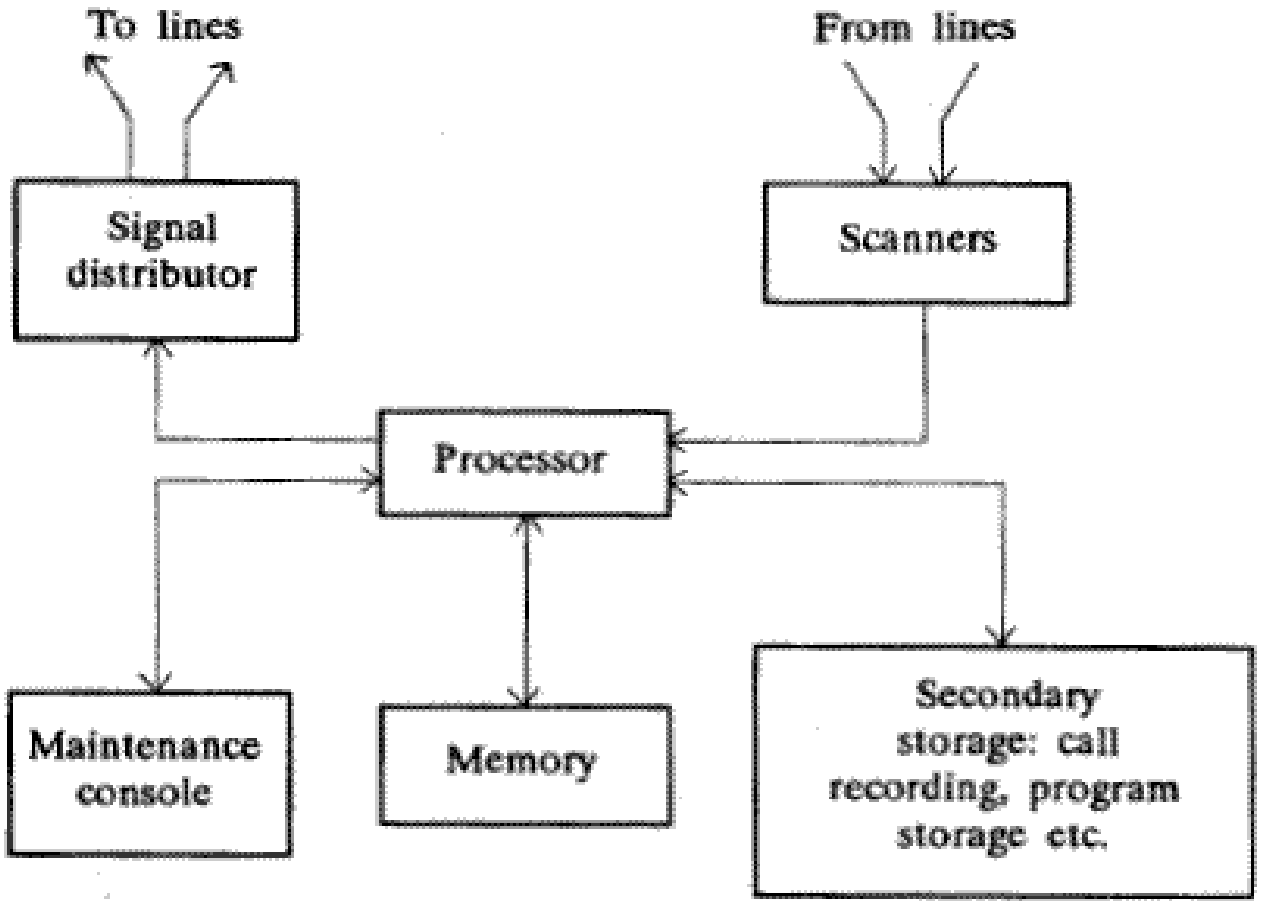
- All the control equipment is replaced by a single powerful processor.

➢ Configuration of centralized SPC

•Typical organization

• Redundant configuration

Centralized SPC



Distributed SPC

- Concept of distributed SPC
  - The control functions are shared by many processors within the exchanges.
- Background
  - Low cost processors
- Advantages
  - Better Availability
  - Better Reliability
- Decomposition of Control Functions
  - Vertical decomposition
  - Horizontal decomposition

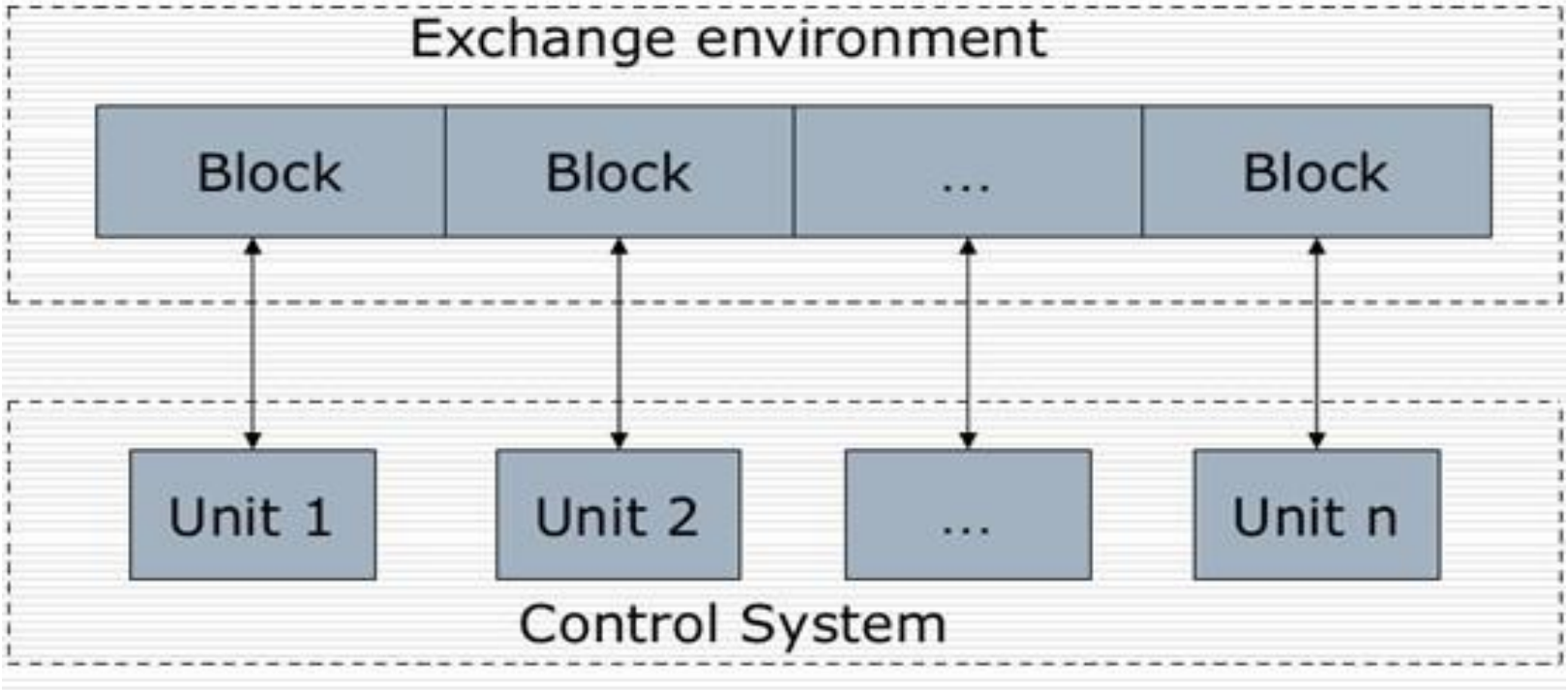
Distributed SPC

❑Vertical decomposition

The exchange environment is divided into several blocks

- ✓ Each block is assigned to a processor.
- ✓ A processor performs all control functions related to the corresponding block.
- ✓ The processor in each block may be duplicated for redundancy purposes.
- ✓ Obviously, the control system consists of a number of control units.
- ✓ The modular structure is flexible for system expanding.

Distributed SPC



Distributed SPC

❑Horizontal decomposition

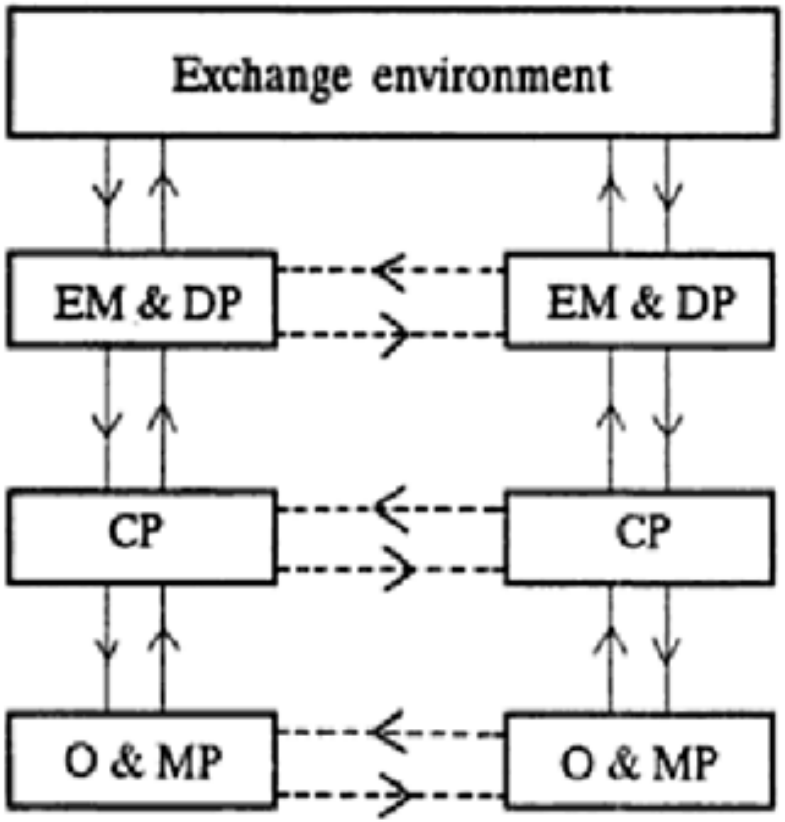
✓The control functions are divided into groups, e.g. event monitoring, call processing, and O&M functions.

✓ Each processor performs only one or some of the exchange control functions.

✓ A chain of processors are used to perform the entire control of the exchange.

✓ The entire chain may be duplicated to provide redundancy.

Distributed SPC



CP = call processor EM&DP = event monitoring and distribution processor O&MP = operation and maintenance processor

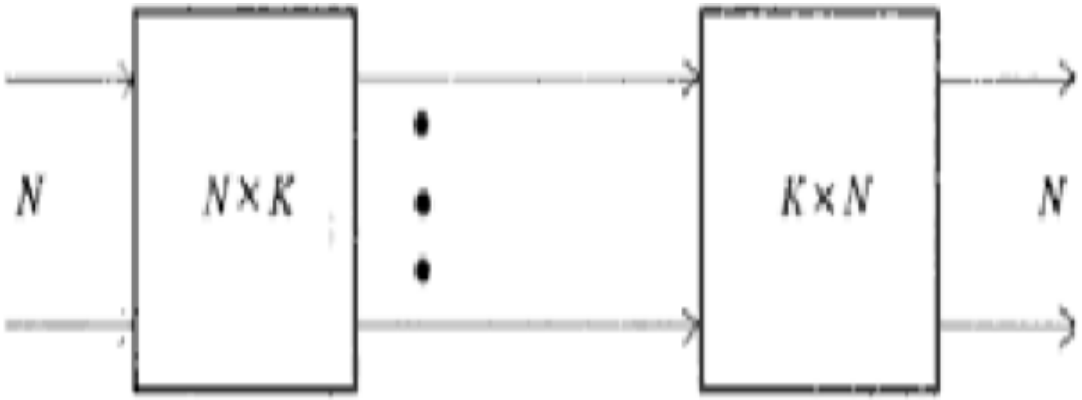
Enhanced Services

- Categories of enhanced services
  - ✓ Services associated with the calling subscriber and designed to reduce the time spent on dialing and the number of dialing errors.
  - ✓ Services associated with the called subscriber and designed to increase the call completion rate.
  - ✓ Services involving more than two parties.
  - ✓ Miscellaneous services.

Two-Stage Networks

- Theorem
  - ✓For any single stage network, there exists an equivalent multistage network.
- Simple Two-stage NxN network
  - ✓ A NxN single stage network with a switching capacity of K connections can be realized by a two-stage network of NxK and KxN.

Two-Stage Networks



- First Stage: Any of the N inlets can be connected to any of the K outputs. NK switching elements.
- Second Stage: Any of the K inputs can be connected to any of the N outlets. NK switching elements.
- There are K alternative paths for any inlet/outlet pair connection.

Two-Stage Networks

- Full connectivity/full availability
- Any of the N inlets can be connected to any of the N outlets.
- Example
- Assume 10% of the subscribers to be active on average.
- Set K to be N/16. The number of switching elements is S=N 2/8.
- For N=1024, we have K=64, S=131072. Note: Feasibility & Flexibility

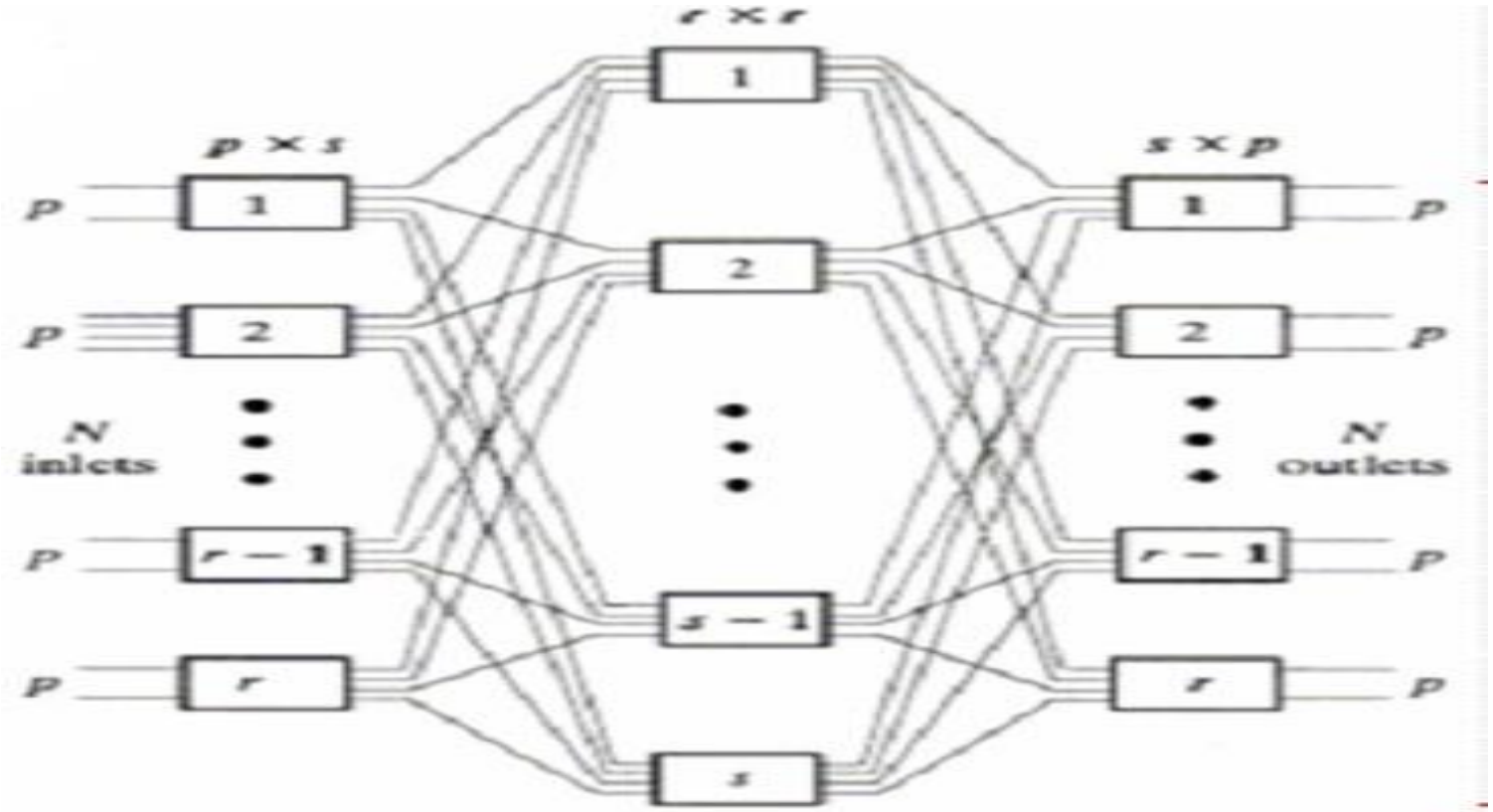
Two-Stage Networks

- Single stage vs. Multistage networks
  - ✓Inlet to outlet connection
  - ✓Quality of link Utility of cross-points
  - ✓Establishment of a specific connection
  - ✓ Cross-point & path
  - ✓Redundancy Number of cross-points
  - ✓Capacitive loading problem
  - ✓Blocking feature
  - ✓Call establishing time

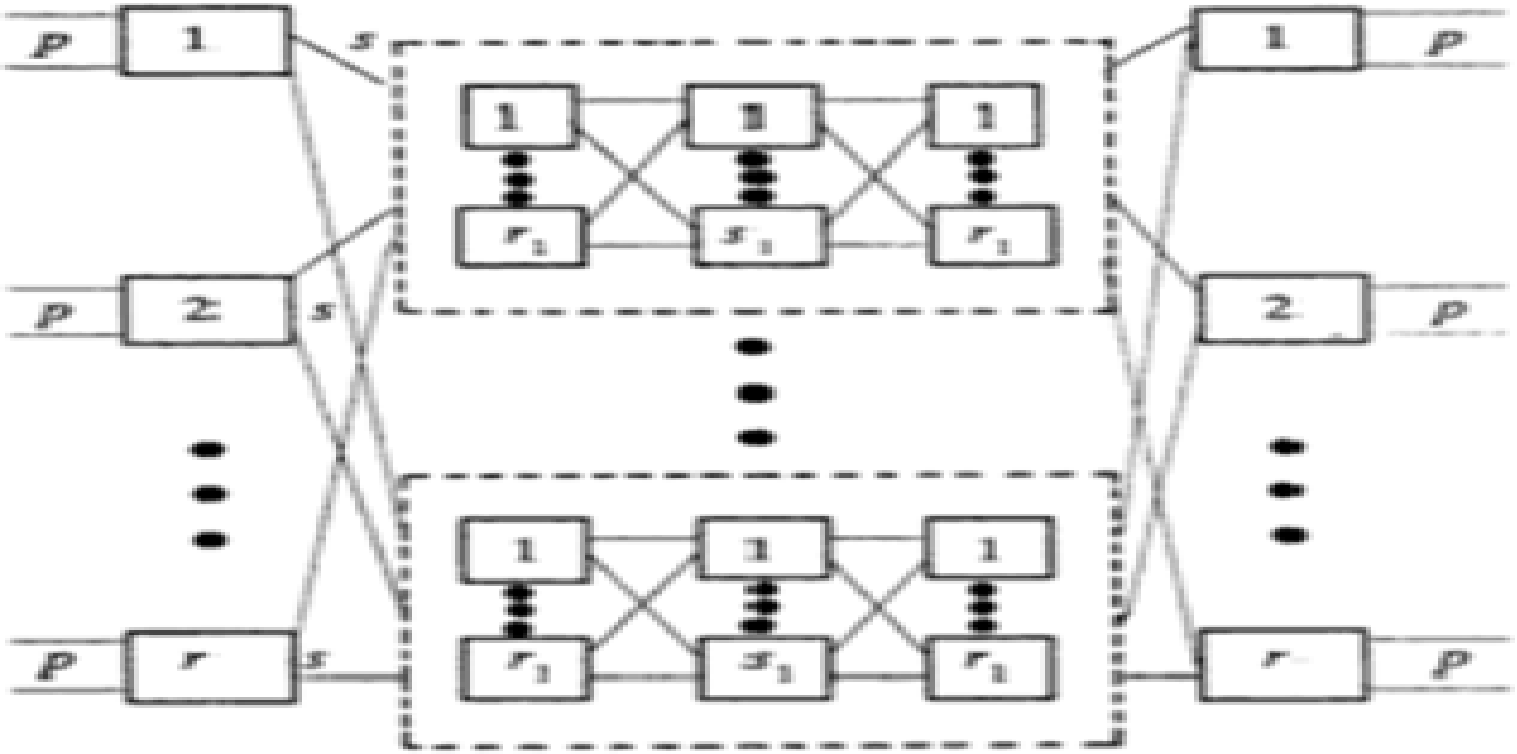
Three-Stage networks

- General structure of an NxN threestage blocking network
  - ✓Stage 1: p x s switching matrices
  - ✓Stage 2: r x r switching matrices
  - ✓Stage 3: s x p switching matrices
  - ✓N=pxr, s is changable
  - ✓Compared with a two-stage network, there are s alternative paths between a pair of inlet and outlet.

Three-Stage networks



n-stage networks



n-stage networks

- Further reduction in the number of switching elements are possible by using even higher number of stages than three.

- Construction of multi-stage networks By replacing the middle blocks with three-stage network blocks continually, any number of stages can be obtained.

UNIT-II
TIME DIVISION SWITCHING

Time Division Switching

❑Features of PAM/PCM signal

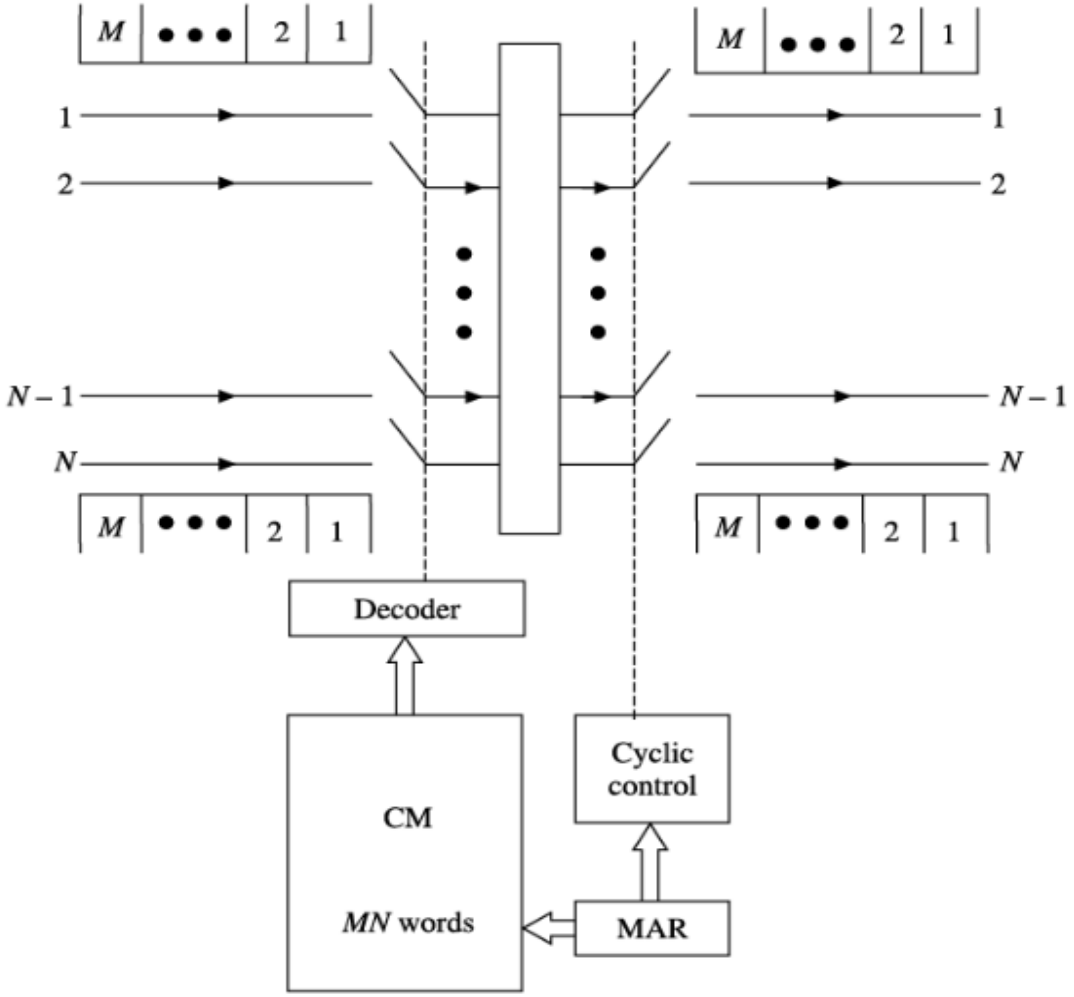
✓ Discrete in time domain

✓Transmission of PAM/PCM signal Multiplexing

✓ Periodical time slots

❑For PAM/PCM signals, it is possible for a number of active speech circuits to share a single switching element, and therefore reduce the number of switching elements significantly.

Time Multiplexed space switching



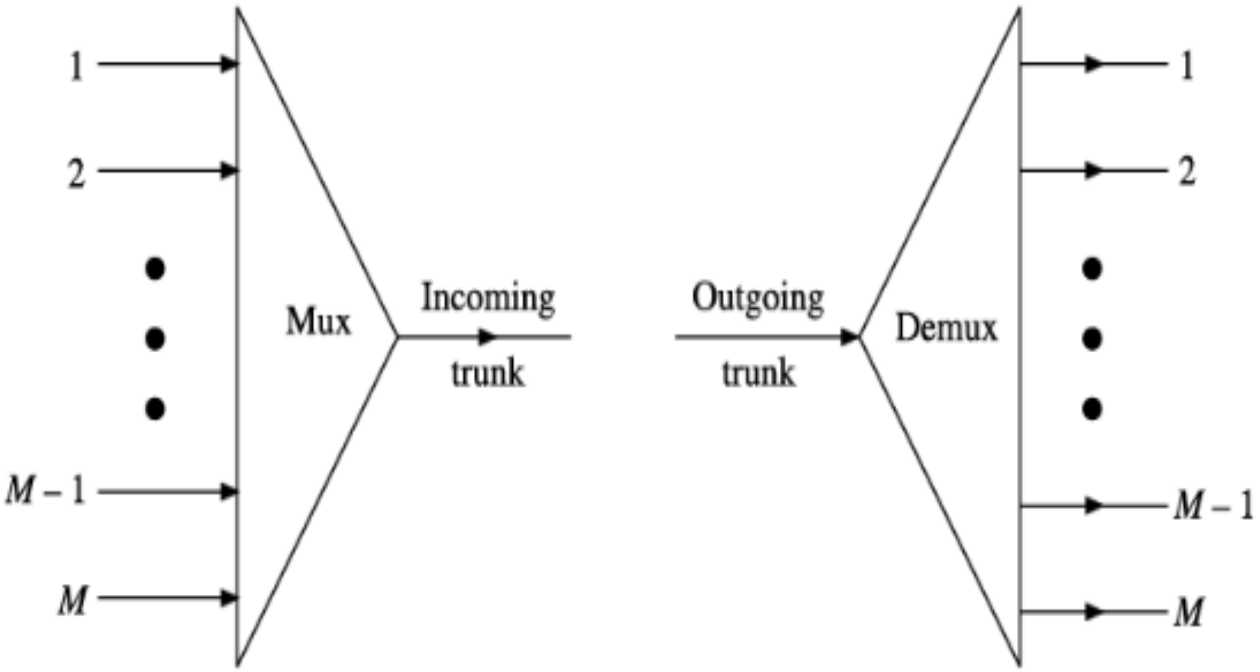
Time Multiplexed space switching

- Time division switches where an inlet or an outlet corresponded to a single subscriber line with one speech sample appearing every 125 us on the line.
- Such switches are used in local exchanges.
- The inlets and outlets are trunks which carry time division multiplexed data streams.

Time Division Switching

- They are N incoming trunks and N outgoing trunks, each carrying a time division multiplexed stream of M samples per frame.
- Each frame is of 125-jis time duration.
- In one frame time, a total of MV speech samples have to be switched.
- One sample duration, 125M microseconds, is usually referred to as a time slot

Time Multiplexed space switching



Source multiplexing and destination demultiplexing.

Time Multiplexed space switching

- Sources and incoming trunks time slots.
- Outgoing trunk time slots and the destinations.
- Time slots of incoming and outgoing trunks.

Time Multiplexed Time Switching

- Time multiplexed time switches permit time slot interchange (TSI) of sample values.
- In TSI, a speech sample input during one time slot may be sent to the output during a different time slot.
- Such an operation necessarily implies a delay between the reception and the transmission of a sample.

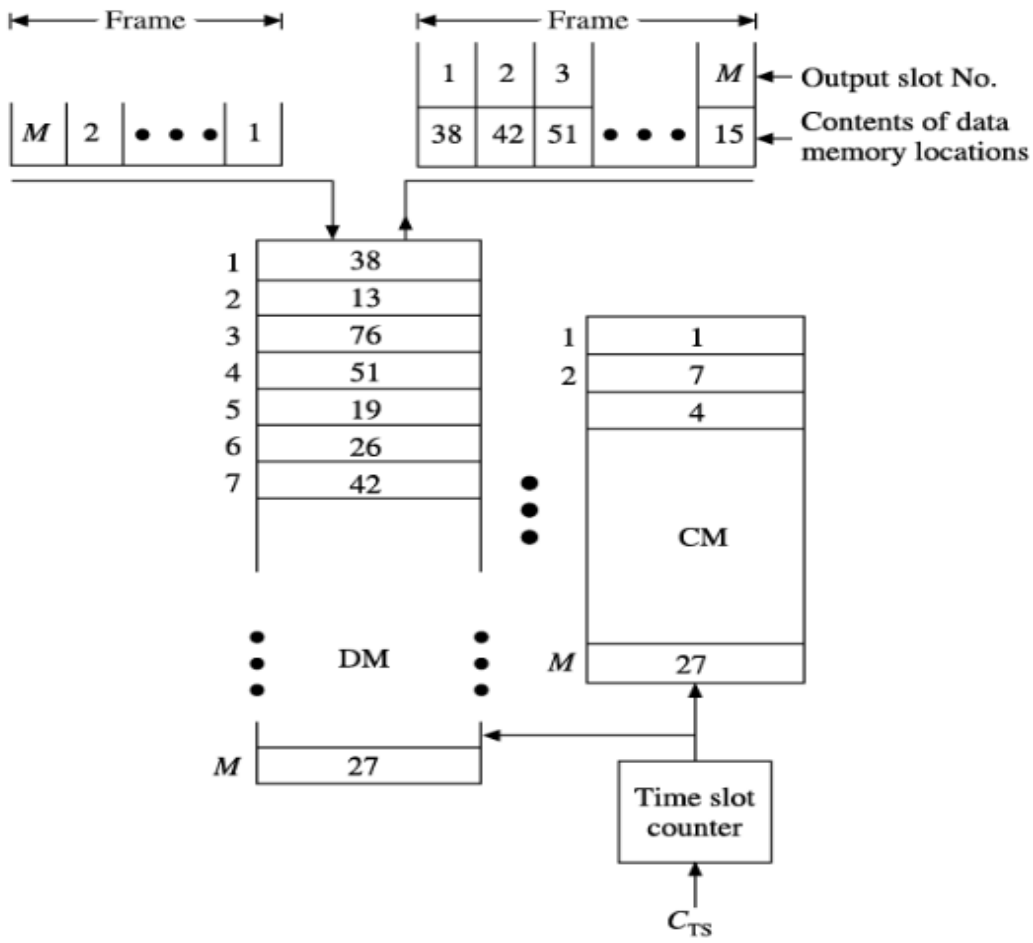
Time Multiplexed Time Switching

- The time slot duration tTS is given by

$$t_{TS} = \frac{125}{M}$$

- The time slot clock runs at the time slot rate i.e at the rate of one pulse ever' 125M microseconds.
- The time slot counter is incremented by one at the end of each time slot.
- The contents of the counter provides location addresses for the data memory and the control memory Data memory and control memory accesses take place simultaneously in the beginning of the time slot.
- The contents of the control memory are used as the address of the data memory and the data read out to the output trunk

Time Multiplexed Time Switching



CM = control memory DTS = time slot clock DM = data memory

(a) Principle of time slot interchange

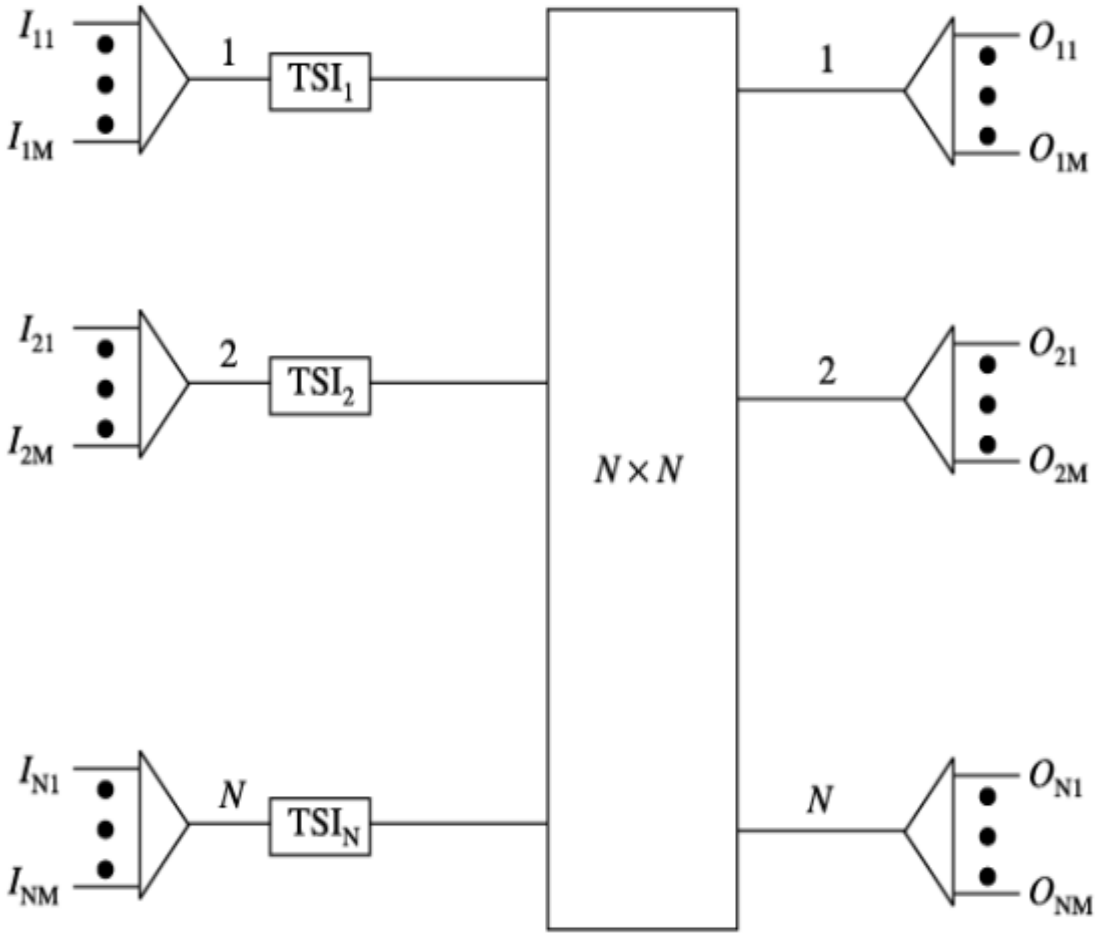
Combination switch

- Time slot interchange switches are not capable of switching sample values across the trunks without the help of some space switching matrices.

- a combination of the time and space switches leads to configurations that achieve both time slot interchange and sample switching across trunks.

- A two-stage combination switch may be organised with time switch as the first stage and the space switch as the second stage or vice versa.
- Accordingly the two switch configurations are known by the nomenclature time-space (TS) or space-time (ST) switches respectively.

Combination switch



Two-stage TS switch.

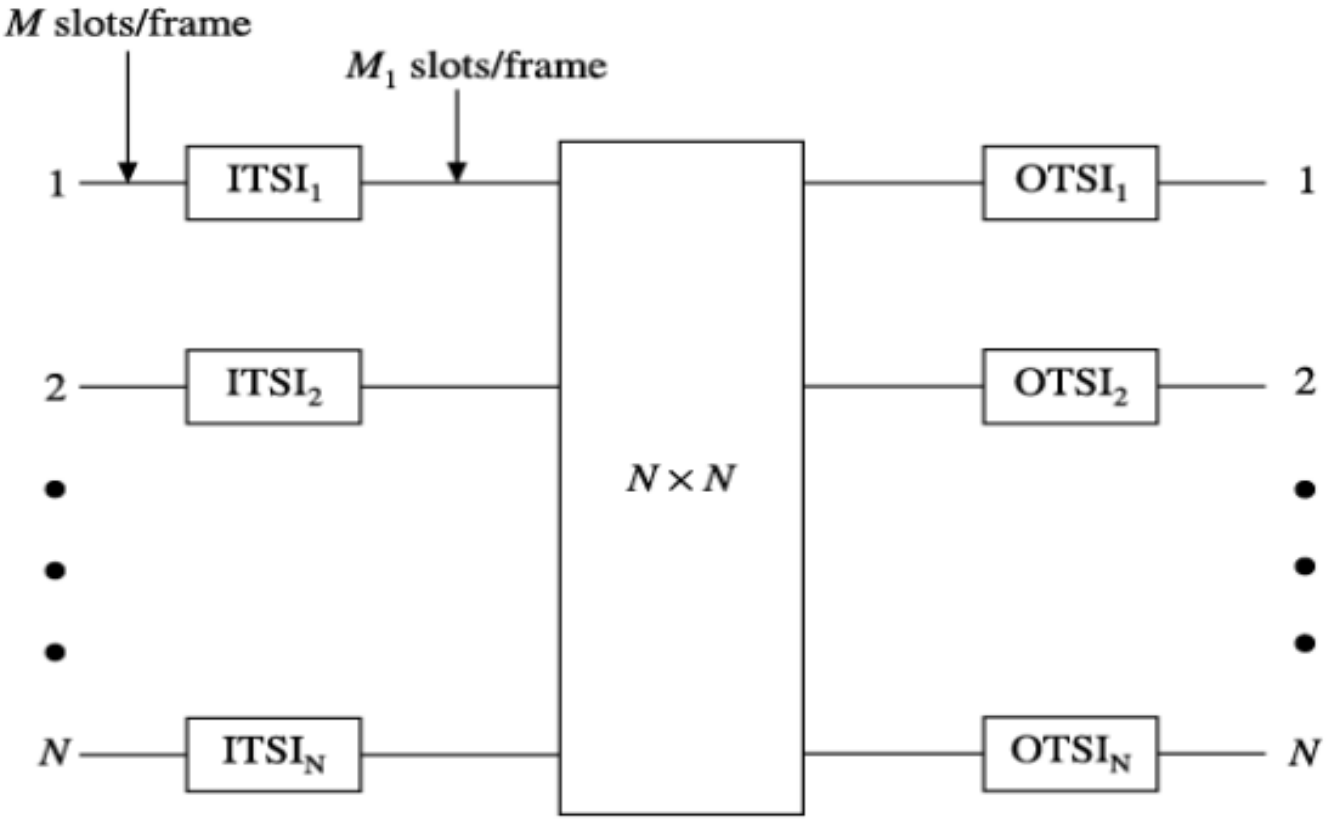
Three stage combination switching

Three-stage time and space combination switches are more flexible than their two-stage counterparts

The most common three-stage configurations are:

- Those which place time stages on either side of a space stage giving rise to TS configuration
- Those which place space stages on either side of a time stage giving rise to STS configuration

Three stage combination switching



n-stage combination switching

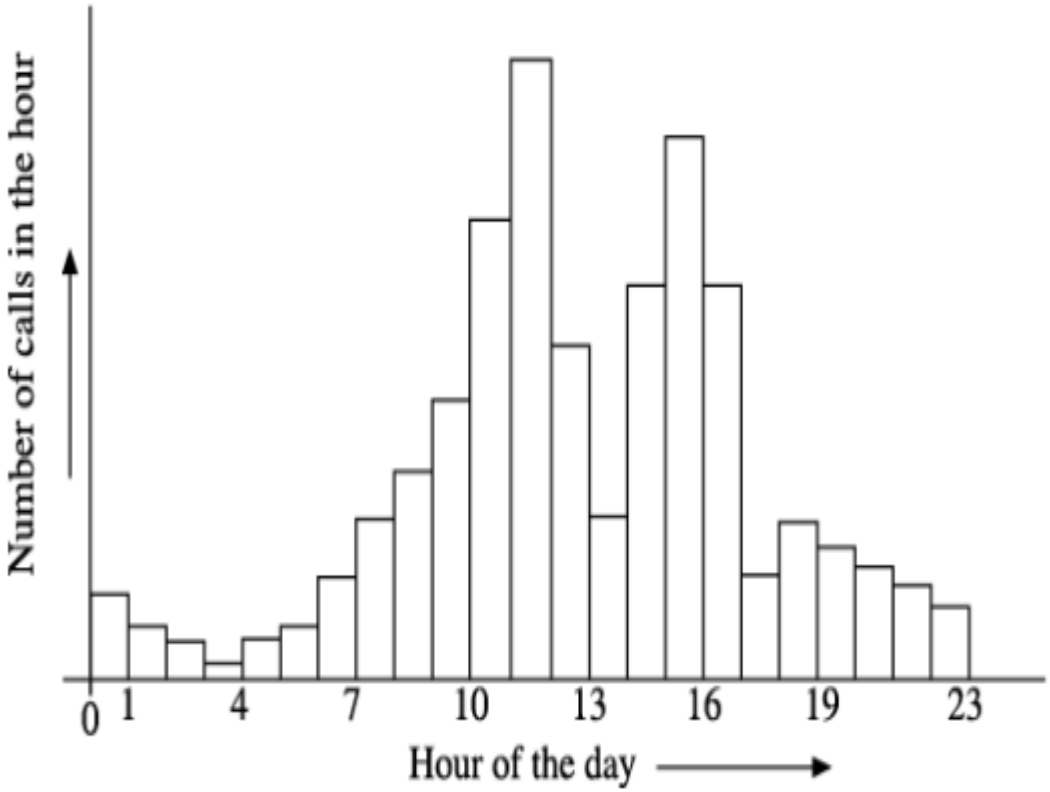
- Very large time division switches, supporting 40,000 lines or more. Can be economically designed by using more than three stages of time and space combination switching.
- This N-stage switching where N is greater than three.
- N-stage combination networks may also be designed to provide better flexibility and less blockage.
- Basically two approaches are seen in designing N-stage switches

  - ✓ Expanding a TST switch with additional space stages
  - ✓ Modular design using a number of time-space (TS) modules.

Network traffic load and parameters

- There is a large peak around mid-forenoon and mid-afternoon signifying busy office activities.
- The afternoon peak is however slightly smaller.
- The load is low during the lunch-hour period. i.e. 12.00—14.00 hours.
- The period 17.00—18.00 hours is characterised by low traffic signifying that the people are on the move from offices to their residences.

Network traffic load and parameters



Typical telephone traffic pattern on a working day.

Network traffic load and parameters

- **Busy Hour**: Continuous 1-hour period laying wholly in the time interval concerned, for which the traffic volume or the number of call attempts is greatest.

- **Peak Busy Hour**: The busy hour each day: it usually varies from day to day. or over a number of days.

- **Time Consistent Busy Hour**: The 1-hour period starting at the same time each day for which the average traffic volume or the number of call attempts is greatest over the days under consideration.

Grade of service

- In loss systems. the traffic carried by the network is generally lower than the actual traffic offered to the network by the subscribers.
- The overload traffic is rejected and hence is not carried by the network.
- The amount of traffic rejected by the network is an index of the quality of the service offered by the network.
- This is termed grade of service (GOS) and is defined as the ratio of lost traffic to offered traffic Offered traffic is the product of the average number of calls generated by the users and the average holding time per call.

Grade of service

- GOS is given by

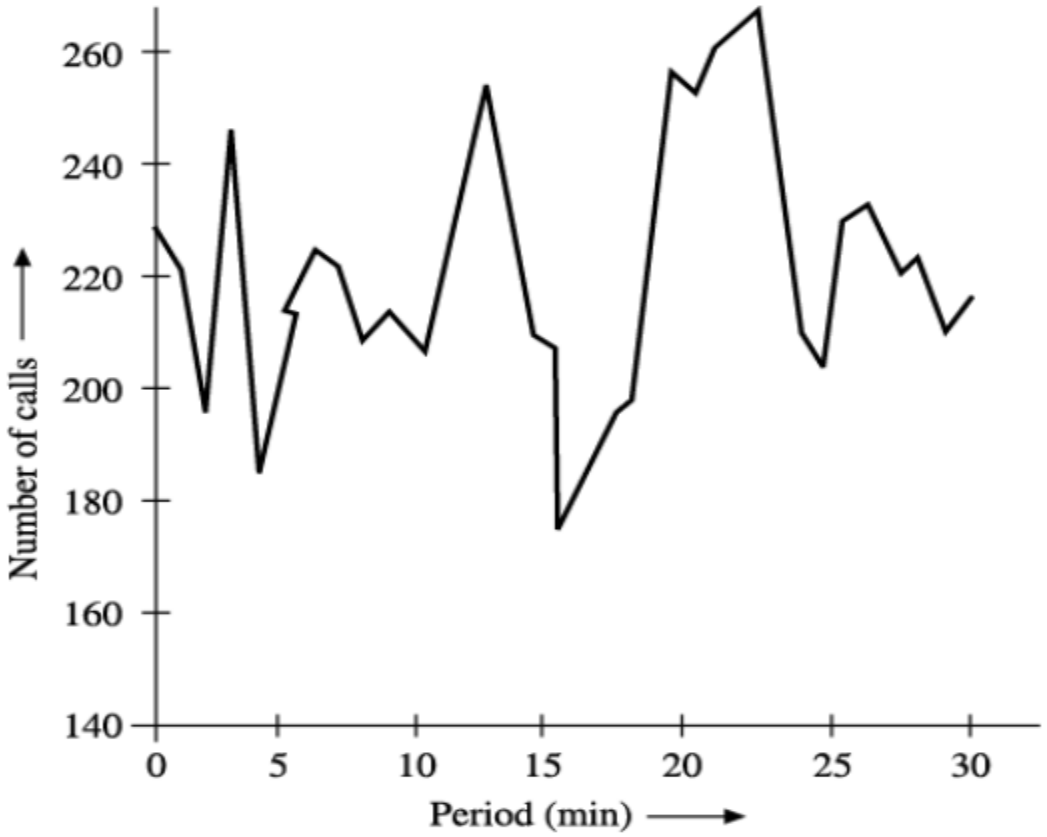
$$\text{GOS} = \frac{A - A_0}{A}$$

where

A = offered traffic
A_0 = carried traffic
$A - A_0$ = lost traffic

The smaller the value of grade of service, the better is the service. The recommended value for GOS ill India is 0.002 which means that two calls in every 1000 calls or one call in every 500 calls may be lost. Every common subsystem in a network has an associated GOS value.

Modeling switching systems



Typical fluctuations in the number of telephone calls.

Modeling switching systems

- A telecommunication network carries traffic generated by a large number of individual subscribers connected to the network.

- The call generation by the subscribers and therefore the behaviour of the network or the switching systems in it can be described as a random process.

Modeling switching systems

- Subscribers generate calls in a random manner.
- A random process or a stochastic process is one in which one or more quantities vary with time in such a way that the instantaneous values of the quantities are not determinable precisely but are predictable with certain probability.

Modeling switching systems

Similarly, the time index of the random variables can be discrete or continuous.

Accordingly. we have four different types of stochastic processes:

1. Continuous time continuous state

2. Continuous time discrete state

3. Discrete time continuous state

4. Discrete time discrete state.

Incoming traffic and service time characterization

- Whenever a subscriber originates a call, he adds one to the number of calls arriving at the network and has no way by which lie can reduce the number of calls that have already arrived.
- We are thus in need of a model that describes an originating process.
- Interestingly, this process can be treated as a special case of the B-D process in which the death rate is equal to zero.
- In other words. there is no death occurring in the process.
- Such a process is known as a renewal process.

Blocking models and loss estimates

- The behaviour of loss systems is studied by using blocking models and that of the delay systems by using queuing models.
- it is apparent that we are concerned with three aspects while dealing with the analysis of the telecommunication systems:

  1. Modelling the system
  2. Traffic arrival model
  3. Service time distribution

Blocking models and loss estimates

- In loss systems. the overflow traffic is rejected.
- In other words the overflow traffic experiences blocking from the network.
- There are three ways in which overflow traffic may be handled
  - ✓ The traffic rejected by one set of resources may be cleared by another set of resources in the network.
  - ✓ The traffic may return to the same resource after sometime.

Blocking models and loss estimates

Some part of the initial information from the subscriber may be lost. But the resources are allocated soon enough so that the loss is unnoticeable by the subscriber or within acceptable limits.

Corresponding to the above three cases, we consider three models of loss systems:

1. Lost calls cleared (LCC)
2. Lost calls returned (LCR)
3. Lost calls held (LCH)

Delay systems

- A class of telecommunication networks. such as data networks, places the call or message arrivals in a queue in the absence of resources, and services them as and when resources become available.
- Servicing is not taken tip until the resource becomes available.
- Such systems are known as delay systems which are also called **lost call delayed** (LCD) systems.

Delay systems

- Delay systems are analysed using queuing theory which is sometimes known as waiting line theory.

- Although the foundations of queuing theory were laid by early tele traffic researchers, the theory is nowadays used for the analysis of a wide variety of applications outside telecommunications.

Delay systems

- Examples of delay systems in telecommunications include the following:

  . Message switching

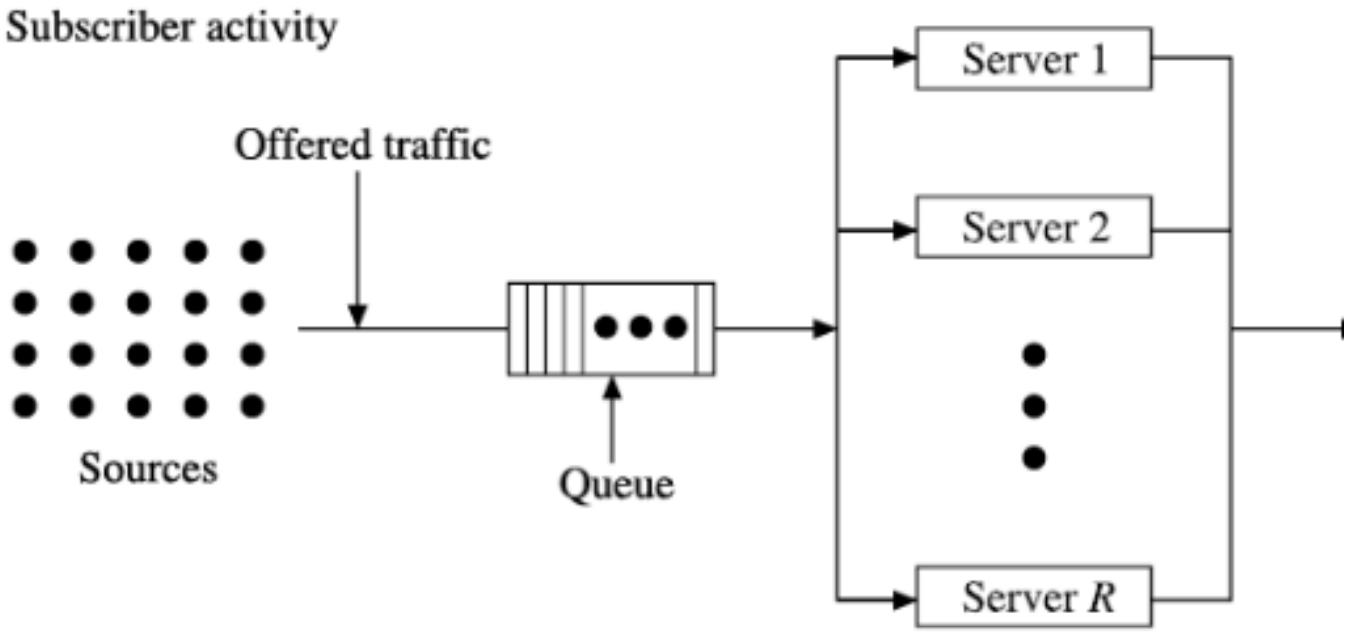
  . Packet switchin2

  . Digit receiver access

  . Automatic call distribution

  . Call processing

Delay systems



Elements of a queuing system.

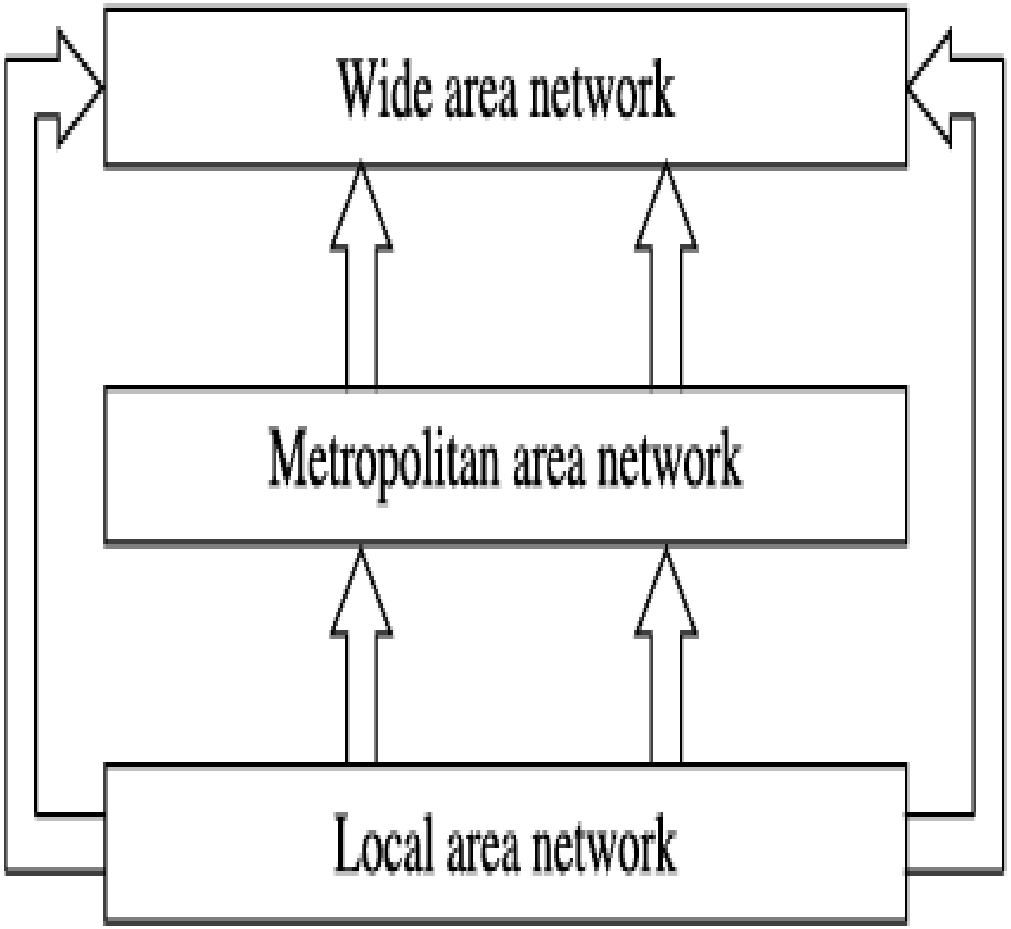
UNIT-III
DATA NETWORKS

DATA NETWORKS

Data networks are classified according to their geographical coverage:

- Wide area networks (WANs)
- Metropolitan area networks (LANs
- Local area networks (LANs)

DATA NETWORKS



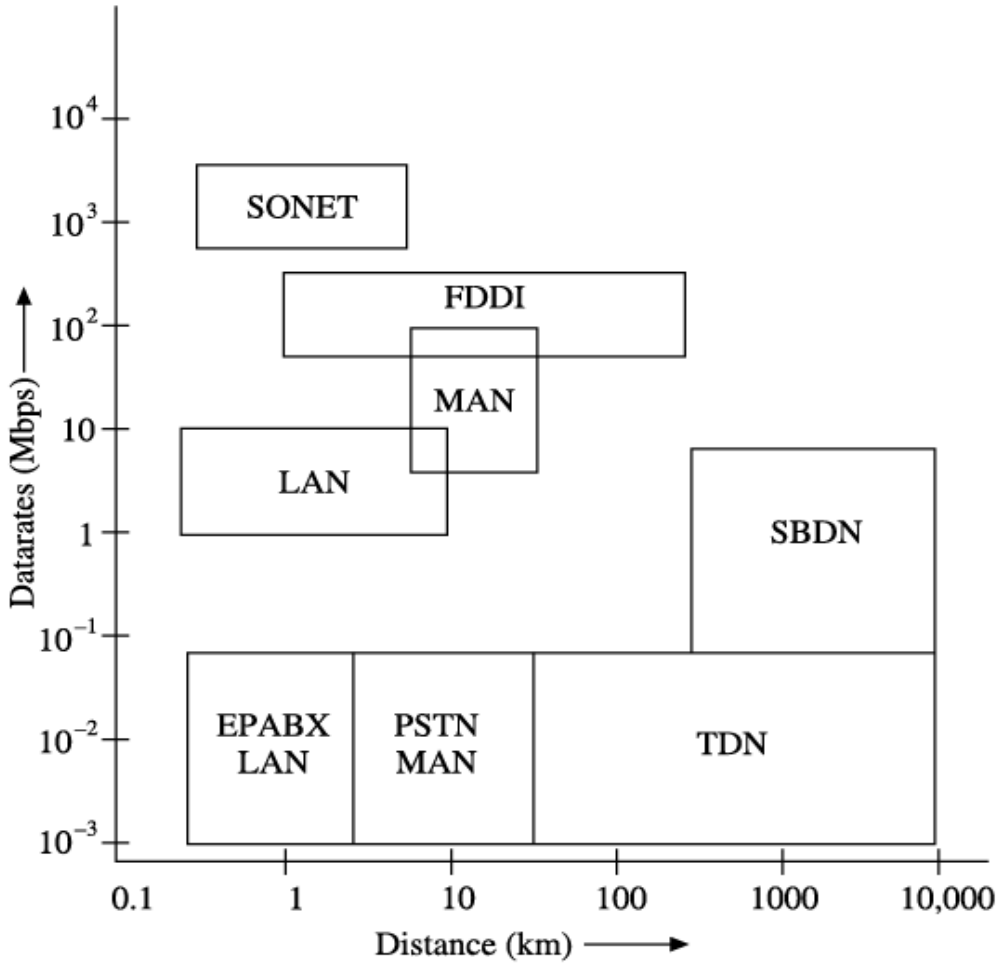
DATA NETWORKS

- LANs. MANs and WNs are generally interconnected in a hierarchical manner to form a global network
- LANs are often connected directly to WANs particularly in places where MANs are not installed or have not developed well.
- Apart from the different geographical coverage's, the range of data rates supported on these networks also differs widely.

DATA TRANSMISSION IN PSTNS

- Public switched telephone networks and electronic PABXs are designed to carry analog voice signals.
- LANs can be designed around PABXs, and MANs around PSTNs.
- In these cases, the data rates are usually limited to a maximum of 64 kbps.
- Terrestrial data networks and the integrated services digital networks however, support data rates of 1.544 or 2.048 Mbps.

DATA TRANSMISSION IN PSTNS

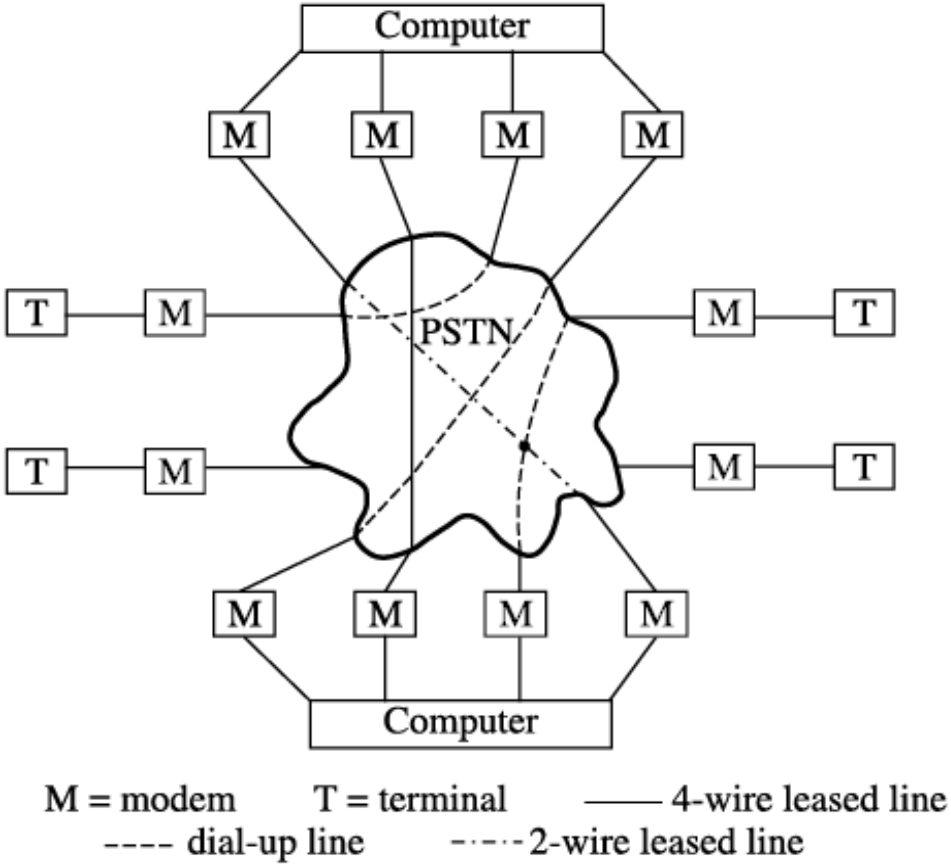


Geographical coverage and speeds of data networks

DATA TRANSMISSION IN PSTNS

- Transmission of digital data signals over PSTN networks demands that the digital signals be converted to analog form at the transmitting end and vice versa at the receiving end.
- A modulator translates the data pulses into voice band analog signals at the transmitting end.
- At the receiving end, the analog signals are demodulated to recover the digital Information.
- A combined modulator demodulator unit is called a modem.

DATA TRANSMISSION IN PSTNS



Data communication using PSTN

Data Rates in PSTNs

- A voice channel in a PSTN is band limited with a nominal bandwidth of 3.1 kHz.
- A first-cut estimate of this can be obtained from Nyquist theorem which applies to noiseless channels and states

$$R = 2H \log_2 V \text{ bps}$$

where

R = maximum data rate

H = bandwidth of the channel

V = number of discrete levels in the signal

Data Rates in PSTNs

$$R_b = H \log_2\left(1 + \frac{S}{N}\right)$$

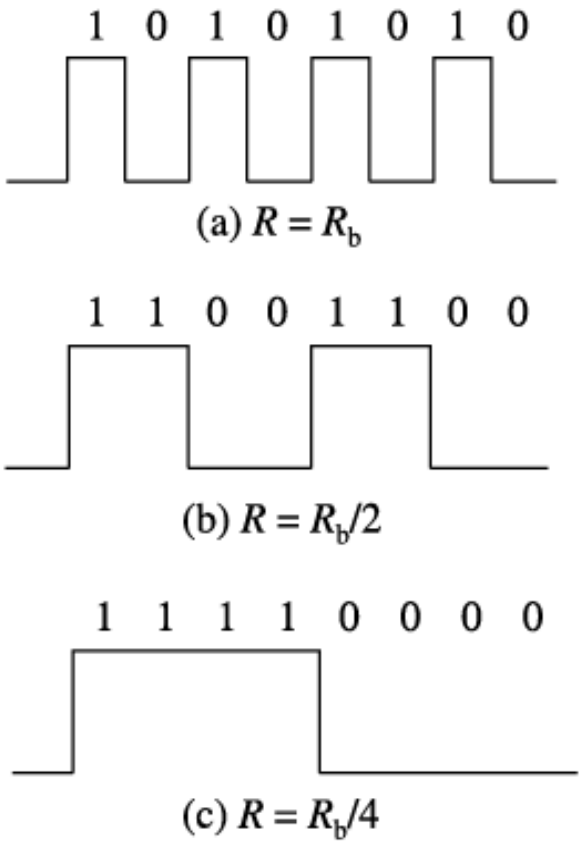
where

R_b = the maximum bit rate obtainable

H = bandwidth of the channel

S/N = signal-to-noise ratio

Data Rates in PSTNs



Baud rates and bit rates

Modems

- Amplitude, frequency and phase modulation are all used in the design of modems.
- In amplitude modulation, zeros and ones are represented by two different voltage levels.
- A signal waveform s(t), called baseband signal, is generated from the digital data.
- This is then multiplied by a sinusoidal carrier, say cos (2tfot), to generate a modulated signal

Modems

$$m(t) = s(t) \cos(2\pi f_0 t) \tag{10.3}$$

At the receiver end, the modulated signal is again multiplied by $\cos(2\pi f_0 t)$, yielding a received signal

$$r(t) = s(t) \cos^2(2\pi f_0 t)$$

$$= \frac{s(t)}{2} + \frac{s(t)}{2} \cos(2\pi(2f_0)t) \tag{10.4}$$

Modems

- While the message sample rate is the baud rate, the bit rate is four times the baud rate in this example.
- This technique of varying the amplitude of sinusoidal carrier using the voltage levels of the baseband signal is known as amplitude shift keying (ASK) .
- If the carrier is sinusoidal and the baseband voltage level is used to vary the frequency or phase of the carrier, the modulation is known as frequency shift keying (FSK) or phase shift keying (PSK) respectively.

Switching techniques for data transmission

- They are basically designed to carry voice traffic and there are some significant differences in the nature of voice and data traffic.
- Voice traffic is generally continuous (except for the silence periods in normal speech), whereas data traffic is bursty in nature.
- In contrast, voice traffic needs low bandwidth (3.4 kHz) for long durations.

Switching techniques for data transmission

Voice traffic	Data traffic
Continuous	Bursty
Low bandwidth for long duration	High bandwidth for short duration
Typical line utilisation 85–95%	Typical line utilisation 5–15%
Half duplex	Half or full duplex
Real time	Nonreal time or near real time
Loss acceptable	Loss unacceptable
Error tolerable	Error unacceptable

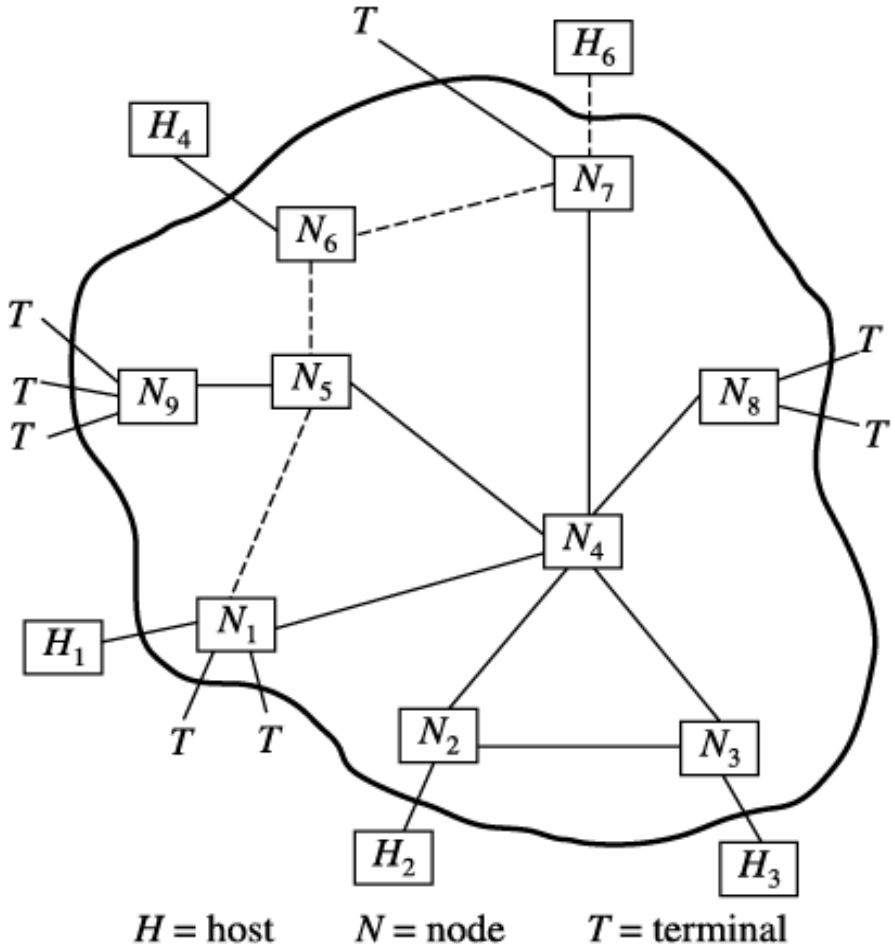
Switching techniques for data transmission

- The recognition of the diverse characteristics of voice and data traffic has led to the development of a switching technique other than the one used for voice transmission.
- This technique is better suited for transmitting data traffic.
- Hence, two switching techniques are prevalent for data transmission:
  - **Circuit switching**
  - **Store and forward (S&F) switching.**

Circuit switching

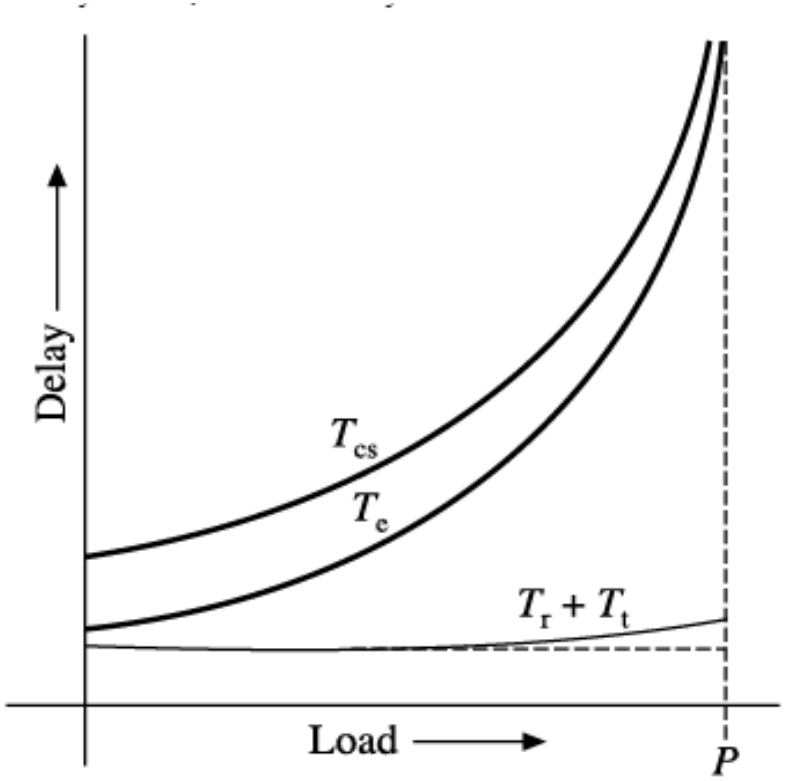
- In circuit switching, an electrical path is established between the source and the destination before any data transfer takes place.
- The electrical path may be realised by physical wires or coaxial cables or radio or satellite links.
- It remains dedicated to the communicating pair for the entire duration of the transmission irrespective of either data is actually transferred or not.
- The connection is released only when specifically signalled so by either of the communicating entities

Circuit switching



Circuit switching Network

Circuit switching



T_{cs} = total circuit switching delay T_e = connection establishment time
T_r = connection release time T_t = data transmission time

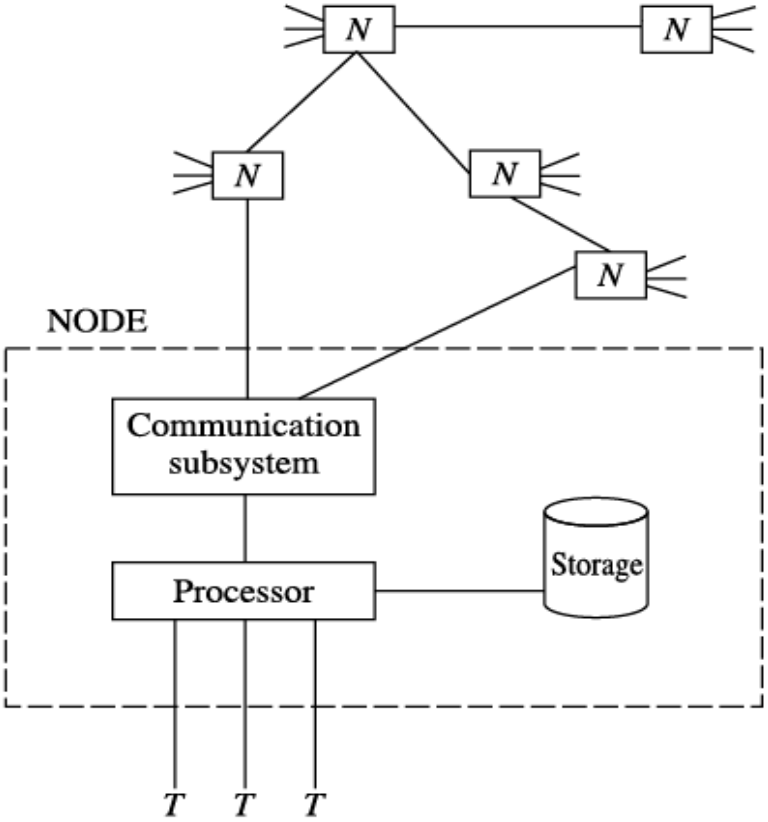
Circuit switching

- Circuit switching has certain disadvantages for transmitting data traffic.
- The path set up time which is typically of the order of 20—3 0 s or more turns out to be an excessive overhead for busty computer traffic which typically lasts for a few seconds or less.
- The entire line quality is affected if there is one bad link in the circuit In fact, this is a typical problem faced in many PSTN circuit switched connections.

Store and forward switching

- A store and forward (S&F) network configuration is In S&F switching.
- The switching nodes have the ability to store user messages and forward the same towards the destination as and when the links become available.
- For this purpose, each node is equipped with a processor and some buffer storage.
- No end-to-end link is set up prior to data transmission.

Store and forward switching



Store and forward switching

- The network moves the user information from node to node.
- One such movement is called a hop.
- Since the communication links are used one at a time between any two nodes, line speeds can be utilized efficiently.
- S&F switching may be classified as:
  - Message switching
  - Packet switching

Store and forward switching

- Receive the full user message and store the same.
- Check the message for data transmission errors and perform error recover if required.
- Determine the destination address from the user message.
- Choose an appropriate link towards destination based on certain routing criterion.
- Forward the message to the next node on the chosen link.

Data communication architecture

- Data communication among computers involves a number of functions such as physical transmission of bits, error control, and routing and session establishment.
- In order to efficiently implement these functions, vendors of computer systems evolved their own architectures.
- Examples of vendor specific architectures are System Network Architecture (SNA) of IBM and Digital Network Architecture (DNA) of Digital Equipment Corporation (DEC).

Data communication architecture

An architecture which is used as a standard by all the vendors is required.

The heterogeneity covers the following aspects:

1. Systems of different vendors
2. Systems under different managements
3. Systems of different complexities
4. Systems of different technologies.

Data communication architecture

- ARPANET: The network project supported by Advanced Research Projects Agency of the Department of Defence, United States, was one of the pioneering efforts in interconnection heterogeneous systems.
- The efforts put in and the experience gained in the project significantly contributed the emergence of a world standard architecture for computer communication, largely pursued and set out by International Standardisation Organisation (ISO).

ISO-OSI reference model

System:

A system is one or more autonomous computers and their associated software, peripherals and users, which are capable of information processing and or transfer .

Subsystem:

A logically independent smaller unit of a system A succession of subsystem make up a system.

ISO-OSI reference model

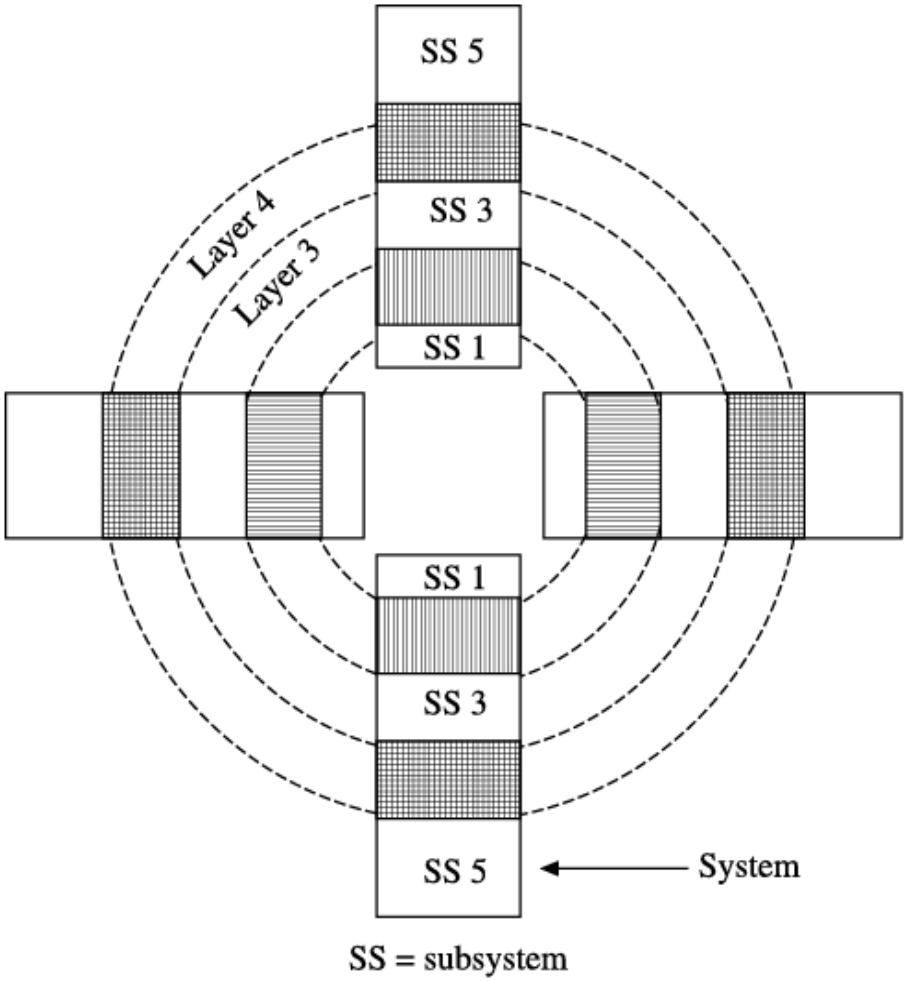
Layer:

- A layer is composed of subsystems of the same rank of all the interconnected systems.
- The subsystems and the layers are numbered starting with one at the bottom level.

Entity:

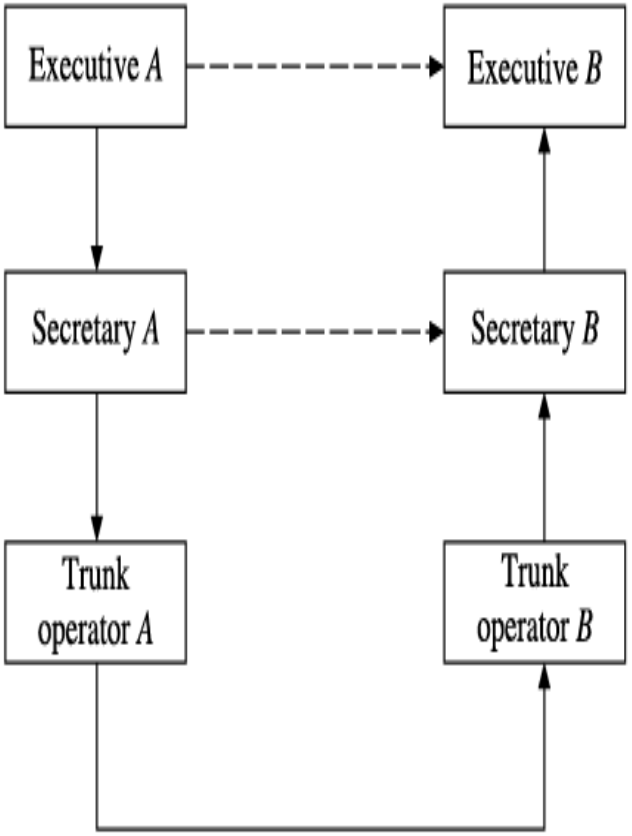
- The functions in a laver are performed by hardware subsystems and or software packages.
- These are known as entities.
- ISO-OSI architecture is a layered one.
- Layering is a natural choice for communication architectures

ISO-OSI reference model



Systems, subsystems and layers in ISO-OSI model.

ISO-OSI reference model

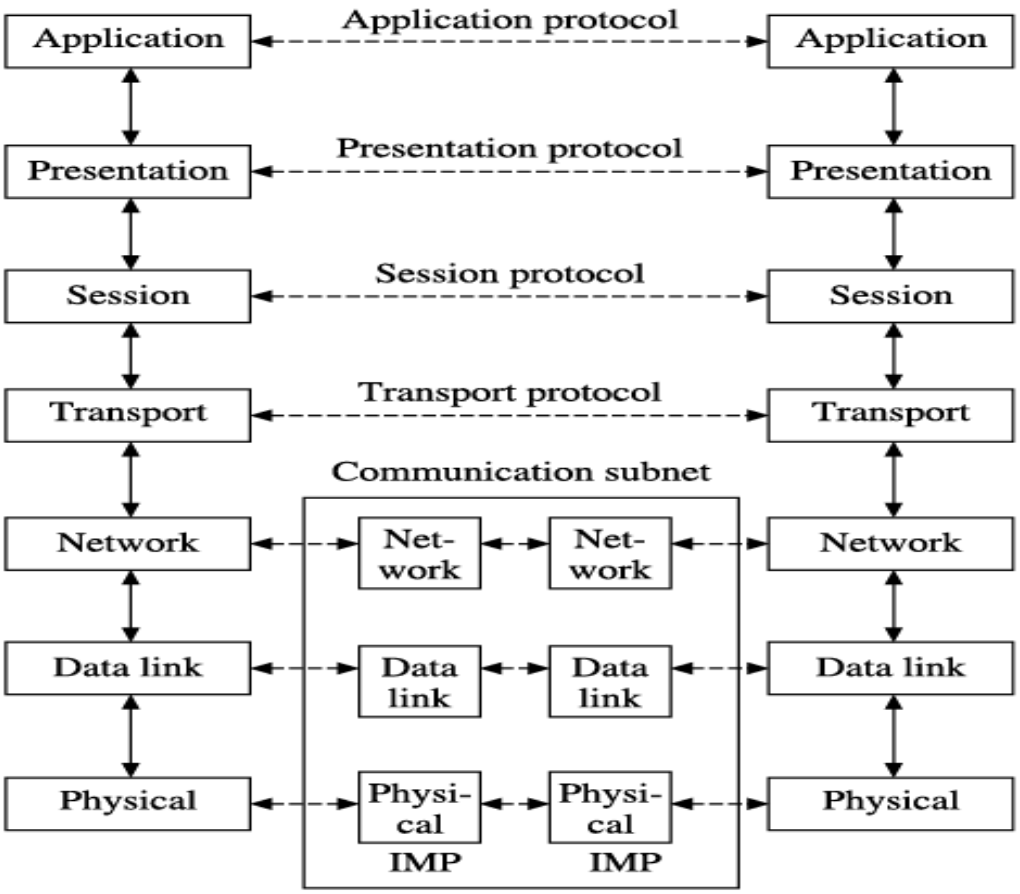


A three-layer structure for a trunk call connection.

ISO-OSI reference model

- A three-layer structure is used in this communication process.
- The conversation between an upper and lower laver is strictly business like.
- There is generally a little private conversation between the trunk operators and the two secretaries on account of their familiarity.
- A layer obtains services from its immediate lower layer and provides services to its immediate upper layer.
- There are fairly well defined functions to be performed by each layer.
- It is immaterial as to how the functions of each laver are implemented.

ISO-OSI reference model



ISO-OSI reference model

The important principles are:

- Create layers to handle Functions which are manifestly different in the process performed or technology involved.
- Collect similar functions into the same layer and create a boundary at a point where the number of interactions across the boundary are minimised.
- Create a layer of easily localised functions so that the layer could be totally redesigned and its protocols changed in a major way to take advantage of new advances in architectures.

Link to link layers

- ✓ The first three layers, viz. physical, data link and network layers, form the link-to-link layers of OSI reference model.
- ✓ They obtain services from the immediate lower layer and provide services to the immediate upper laver.
- ✓ OSI services may be placed under two broad categories:

  - ➢ Connection oriented services
  - ➢ Connectionless services.

Link to link layers

Connection oriented services

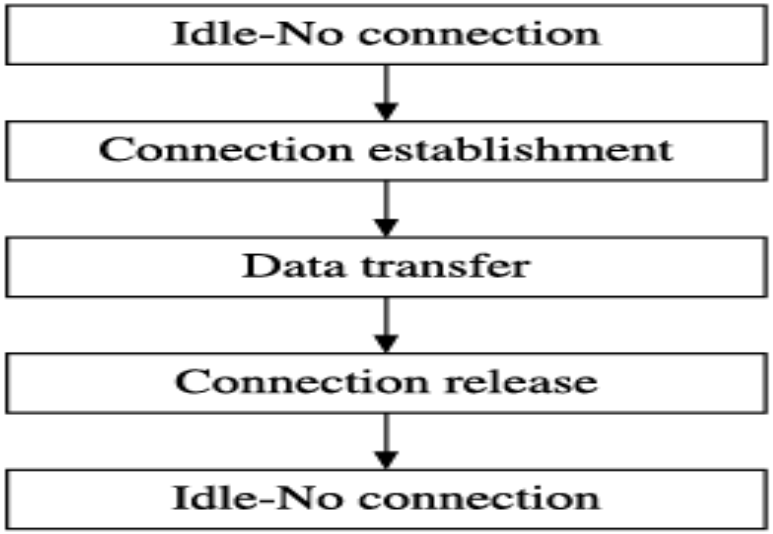
- A connection is first established between the sender and the receiver before data transfer can commence.
- The connection may be virtual (logical) or physical, depending upon the network capabilities and facilities.
- The essence of a connection oriented service is that a connection acts like a tube or a pipe delivering.
- The data to the receiver strictly in the same order in which the data was put into the connection by the sender. Connection oriented service is modelled after the telephone system.

Link to link layers

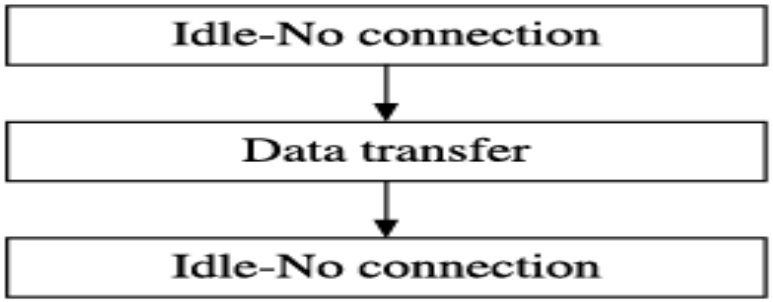
Connectionless service

- It is modelled after the postal system.
- Each submission by the sender is treat independently of others and is sell-contained with the full address of the destination and the source indication which may be the full address too.
- it is possible that the fast one is delayed and the second one arrives first. Datagram service and the virtual circuit service

Link to link layers



(a) Connection oriented service



(b) Connectionless service

Physical layer

- It is essential that the OSI architecture permits the usage of a realistic variety of physical media and control procedures.
- Keeping this in mind, the lowest layer of the architecture has been identified as the physical laver
- This laver performs functions associated with the activation and deactivation of physical connections.

Data link layer

- Special techniques are required to ensure error free transmission of data.
- The data link laver deals with error detection and automatic recover procedures required when a message is lost or corrupted.
- For this purpose, a user of this layer, ie. the network layer, is required to break up the data to be transmitted into frames which are then numbered and transmitted sequentially.

Data link layer

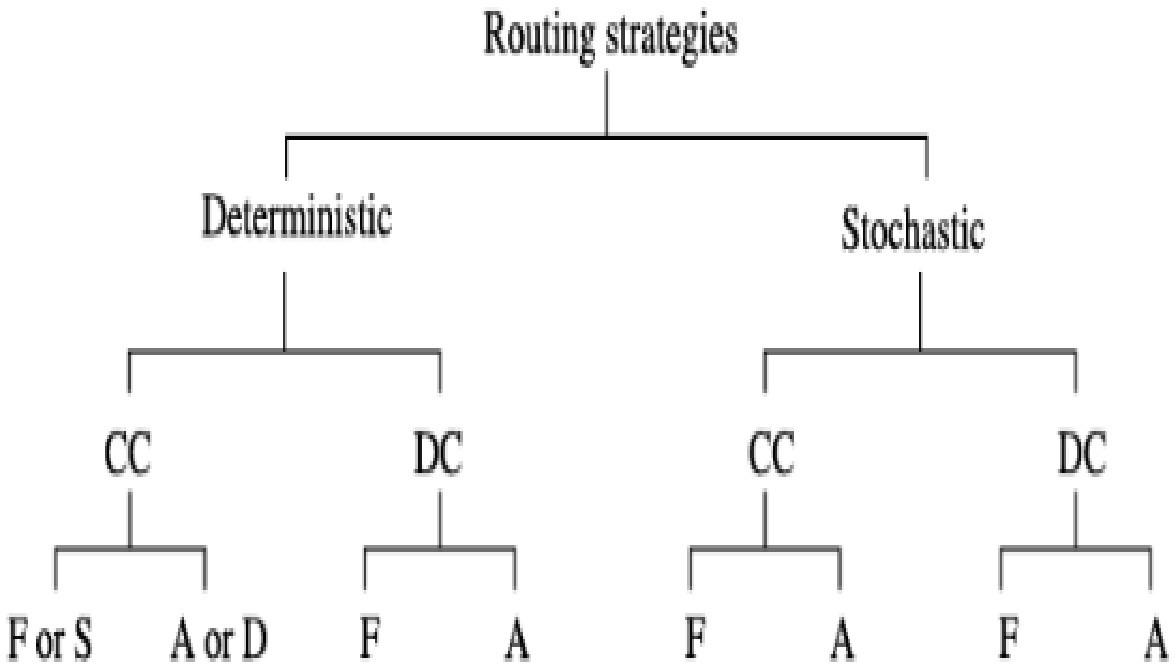
There are three error control mechanisms that are commonly used:

1. Echo checking
2. Forward error correction (FEC)
3. Automatic repeat request (ARQ).

Network Layer

- The highest link-to-link layer in the OSI model is the network layer.
- Although this layer functions on a link-to-link basis, it is concerned with transmission of packets from the source node to the destination node.
- The network laver makes invisible to the transport laver, the details of the underlying communication media and the different characteristics of the transmission and network technologies.

Network Layer



CC = centralised control DC = distributed control F = fixed

S = static A = adaptive D = dynamic

Network Layer

A number of measures may be used in assessing the performance of a routing algorithm:

1. Minimum delay
2. Minimum number of intermediate nodes or hops
3. Processing complexity
4 Signalling capacity required on the network
5. The rate of adaption in the case of adaptive algorithms
6. Fairness to all types of traffic
7. Robustness: the ability to reach the destination even when parts of the network fail

END-TO-END LAYERS

- Many data networks were operational before the OSI model was designed.
- These networks were well thought out up to the network laver, but little had been done about the transport layer and above.
- As a consequence, the design of the bottom three layers of OSI vas highly the flounced by pre-OSI developments.

Transport Layer

- Transport layer is the first end-to-end layer in the OSI architecture.
- It is responsible for matching user message characteristics and service requirements with that of the network capabilities.
- In a packet switched network, the transport entity breaks up a long user message into packets to match the network capabilities.
- The packets are reassembled at the destination transport subsystem to reconstruct the user message.

Transport Layer

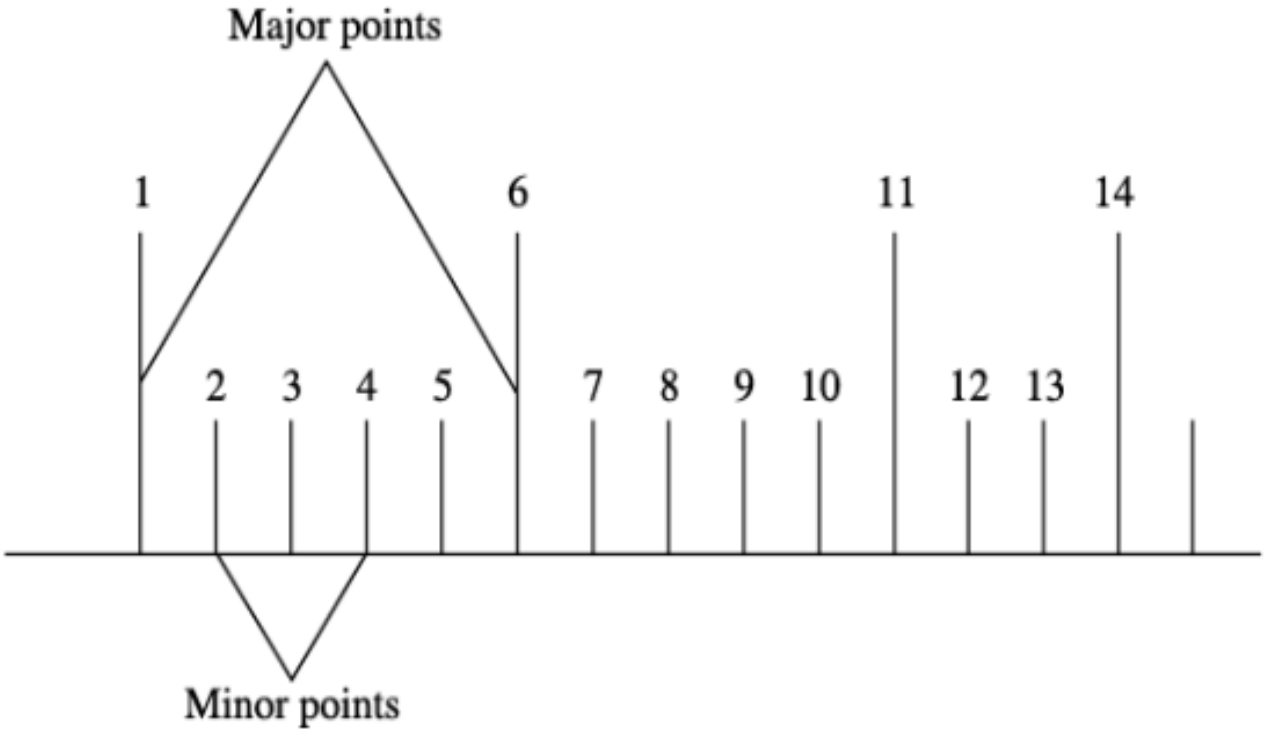
Some QOS parameters that are of direct interest to the users are:

1. Transit delay
2. Residual error rate
3. Protection
4. Transfer failure probability
5. Priority
6. Throughput.

Session Layer

- The main function of the session layer is to organise different sessions between cooperating entities and perform all related functions like synchronisation, failure management, control, etc. for the successful execution of a session.
- Online search of databases, remote job entry, remote login to a time sharing system and file transfer between two systems are all examples of sessions.
- The session layer may also offer a director s service.

Session Layer



Presentation layer

- The purpose of the presentation laver is to represent information to the communicating application entities in a way that preserves the meaning.
- Syntax differences are resolved by encoding application data into a standard abstract notation that is valid throughout the network.

Presentation layer

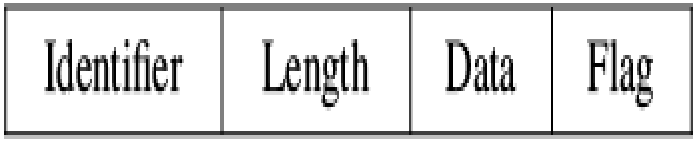


Figure 10.26 ASN.1 transfer syntax.

1. Universal
2. Application
3. Private
4. Context specific.

SATELLITE BASED DATA NETWORKS

- Satellite network topology and confutations modulation schemes and bandwidth utilisation; these are aspects related to the physical layer functions of the reference model.
- Being a common communication resource accessible by all or a group of earth stations simultaneously. media access becomes a nontrivial function in the data link layer.
- Satellite communication being broadcast in nature, routing becomes a trivia function;

SATELLITE BASED DATA NETWORKS

- In the simplest form of ALOHA, often called ‘pure ALOHA to distinguish from other forms of ALOHA protocols
- A station or terminal starts transmission as soon as it is ready. In this case, anyone of the following three things may happen
- There may be an on-going transmission already in the channel and the new transmission may collide with the existing one, thereby affecting both transmissions.

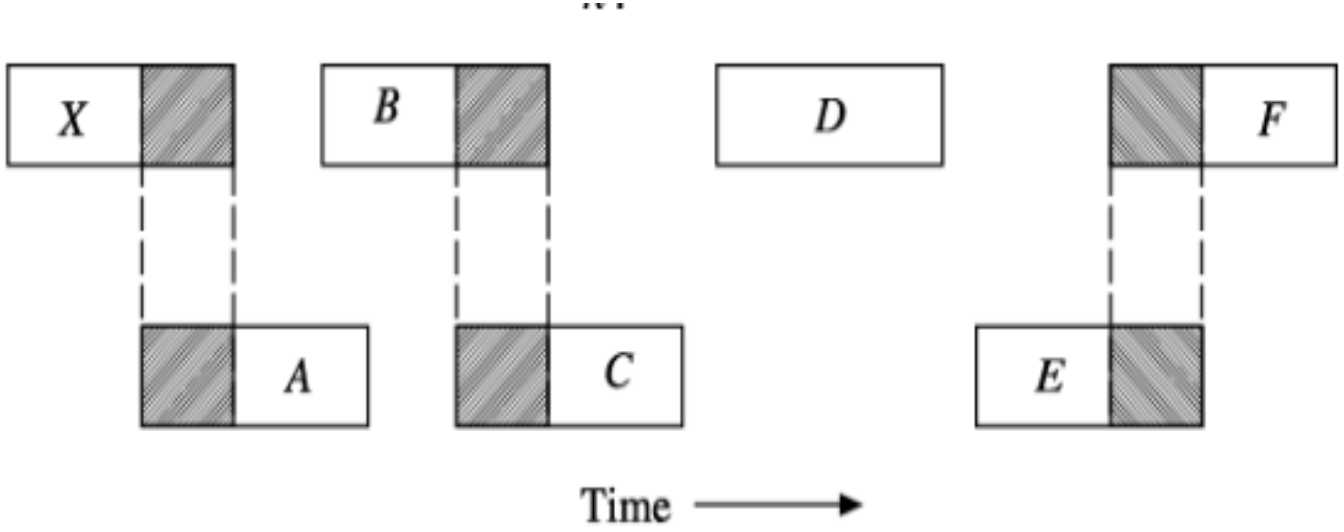


Figure 10.30 Collision in pure ALOHA access.

where

LAN

A local area network (LAN) typifies a distributed environment and finds applications in a number of areas.

Some examples are:

1. Office automation
2. Factory automation
3. Distributed computing
4. Fire and security systems
5. Process control
6. Document distribution.

LAN

The advantages offered by the LANs are:

- Unlike a large centralised system, a LAN may evolve with time. It may be put into operation with a small investment, and more systems may be added as the need arises.

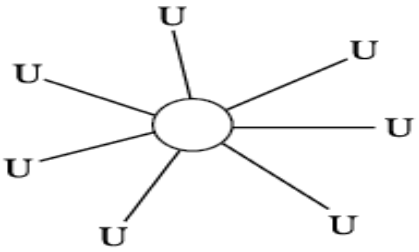
- Since LAN is a set of multiple interconnected systems, it offers a good back up capability in the event of one or two systems failing in the network. This, in turn, enhances the reliability and availability of the systems to users.

LAN

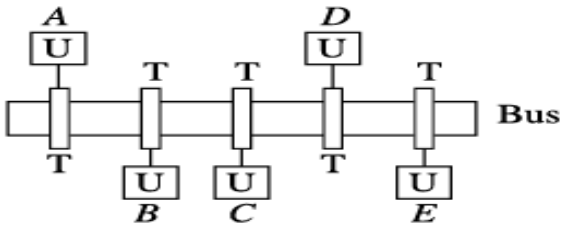
The advantages offered by the LANs are:

- LAN provides a resource-sharing environment. Expensive peripherals, hosts and databases may be shared by all the LAN users.
- A LAN adhering to a certain standard permits multivendor systems to be connected to it. Thus, a user is not committed to a single vendor.
- In LAN, the systems are generally so chosen as to meet most of the user

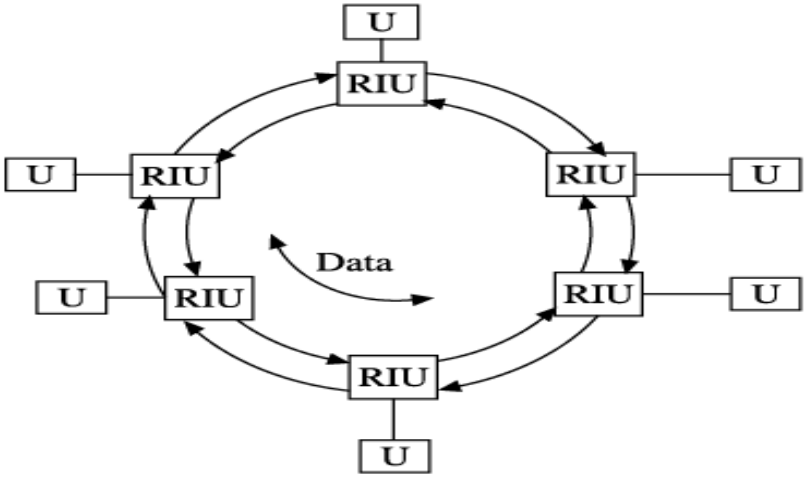
LAN



(a) Star topology



(b) Bus topology



RIU = ring interface unit

(c) Ring topology

LAN

As a result, only three combinations of access techniques and topologies are popularly used:

1. Multiple access bus

2. Token passing ring or token ring

3. Token passing bus or token bus.

Metropolitan area network

- A metropolitan area network (MAN) usually covers a geographical area spanning a distance of 5—50 km.
- In functionality MANs support services that require guaranteed bandwidth and bounded delay performance
- In addition to data services that do not pose such restrictions.
- Additional services may include voice and video: depending on the available bandwidth.

Metropolitan area network

- MANs may operate at speeds of 1 Mbps and above although a more common range is 50—150 kbps.
- Network structures to MAN are similar to the ones used in LANs: star, bus and ring. In this sense.
- The LANs may be considered as an extension of LANs

Fiber optic networks

Optical fibre networks are characterised by

- High speed operation (typically loo Mbps or more)
- Ability to span large distances (100—200 km)
- Ability to support a moderate number of stations; typically 10 to a few hundred stations are supported with a maximum limit around 1000.

Fiber optic networks

- These characteristics make the fibre optic networks suitable for high speed LASs and MANs with a limited number of stations.
- Fibre networks may be configured around a star. ring or bus structure.
- The number of stations that can be supported in a star or a bus structure is relatively low compared to that in a ring configuration.
- Optical fibres are inherently unidirectional and this influences the way in which the network structures are realised.

Fiber optic networks

- The passive hub is usually a silica cylinder. The incoming fibres are fused to one end of the cylinder and the outgoing fibres to the other end.
- The light emitted by the transmitters (LEDs) of the stations diffuses inside the passive hub illuminating all the receivers (,photodiodes).
- The incoming energy is divided among all the outgoing lines.

Data network standards

- Three major international bodies have been signficantly contributing to the data network The bodies, their major area of concentration, and the standard series identifiers are.

Body	Main thrust areas	Series
ISO	OSI reference model; end-to-end layers (4–7)	7xxx 8xxx 9xxx 10xxx
CCITT	Link-to-link layers (1–3) of wide area networks: PSTN, PDN and ISDN; electronic messaging and directory services	V series X series I series
IEEE	Link-to-link layers (1–3) of local and metropolitan area networks	802.x

Data network standards

- Standards laid down by ISO and CCITT have international legal standing, whereas IEEE standards have to be adopted by ISO to attain this legal standing.
- Standards work at IEEE is sponsored by ANSI which is affiliated to ISO.
- Standards evolved by CCITT are adopted by ISO under its own series number and vice versa.

UNIT-IV
TELEPHONE NETWORKS

TELEPHONE NETWORKS

Any telecommunication network may be viewed as consisting of the following major
systems:

1. Subscriber end instruments or equipments
2. Subscriber loop systems
3. Switching systems
4. Transmission s:cstems
5. Signalling systems

TELEPHONE NETWORKS

A telephone network is a telecommunications network used for telephone calls between two or more parties.

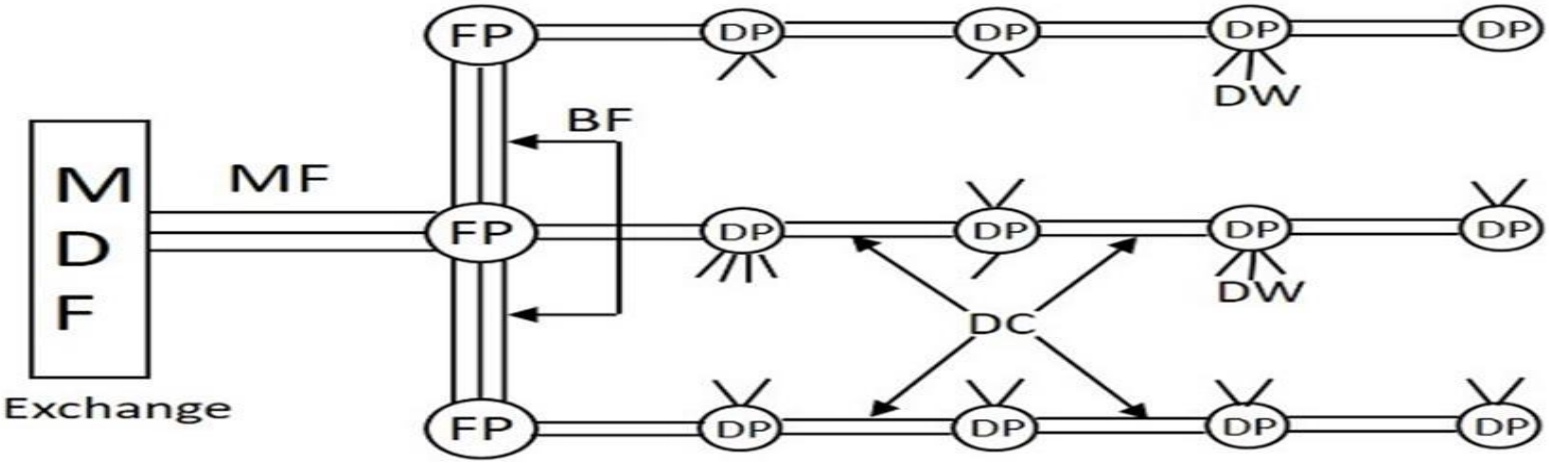
- There are a number of different types of telephone network:
  - ✓A landline network where the telephones must be directly wired into a single telephone exchange. This is known as the public switched telephone network or PSTN.
  - ✓A wireless network where the telephones are mobile and can move around anywhere within the coverage area.
  - ✓A private network where a closed group of telephones are connected primarily to each other and use a gateway to reach the outside world. This is usually used inside and call centers and is called a private branch exchange (PBX).

Subscriber Loop Systems

In a general telephone network, every subscriber has two dedicated lines connecting to the nearest switching exchange.

- which are called the **Loop lines** of that subscriber.
- The laying of lines to the subscriber premises from the exchange office is called **Cabling**

Subscriber loop systems



MDF = main distribution frame

DP = distribution point

DC = distribution cable

MF = main feeder

BF = branch feeder

FP = feeder point

DW = drop wires

Subscriber loop systems

- It is unwieldy to run physically independent pairs from every subscriber premises to the exchange.
- It is fast easier to lay cables containing a number of pairs of wires for different geographical location and run individual pairs as required by the subscriber premises.
- At the subscriber end, the drop wires are taken to a distribution point. The drop wires are the individual pairs that run into the subscriber premises on the MDF.

Subscriber loop systems

Table 9.1 Technical Specifications for Subscriber Lines			
Gauge No. (AWG)	Diameter (mm)	D.C. resistance (Ω/km)	Attenuation (dB/km)
19	0.91	27.3	0.71
22	0.64	54.7	1.01
24	0.51	87.0	1.27
26	0.41	138.0	1.61

Switching Hierarchy and Routing

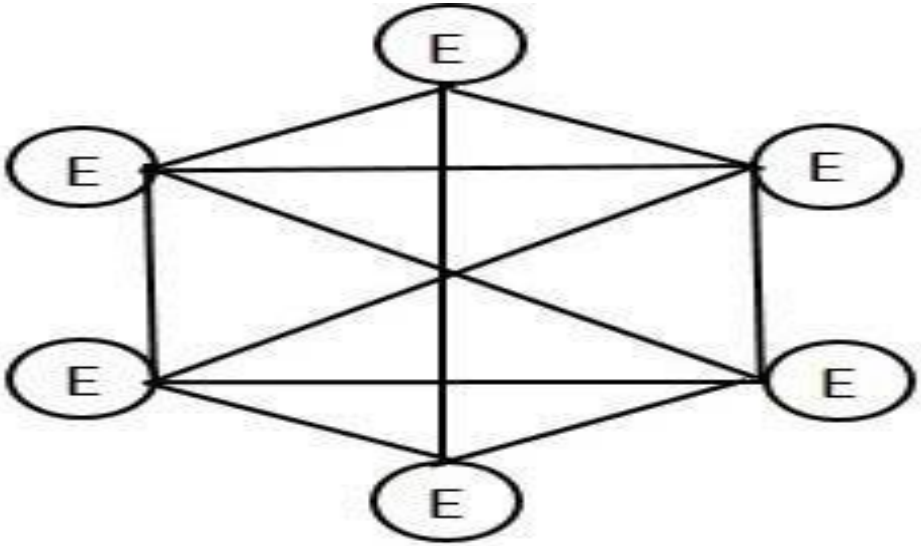
- The next important system in this is the switching hierarchy and routing of the telephone lines.
- The interconnectivity of calls between different areas having different exchanges is done with the help of **trunk lines** between the exchanges.
- The group of trunk lines that are used to interconnect different exchanges are called the **Trunk Groups**

Switching Hierarchy and Routing

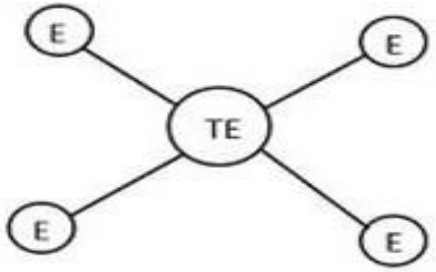
In the process of interconnecting exchanges, there are three basic topologies, such as

- Mesh Topology
- Star Topology
- Hierarchical

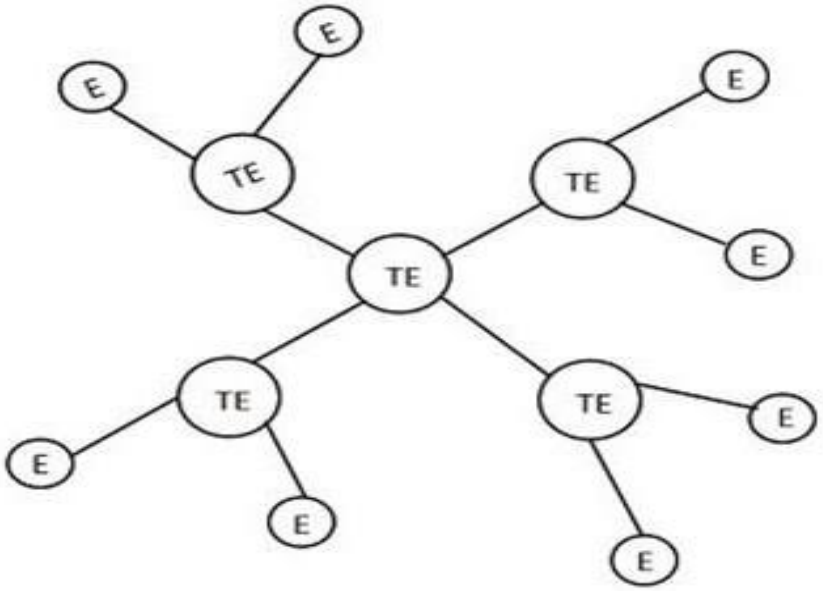
Mesh Topology



Star Topology

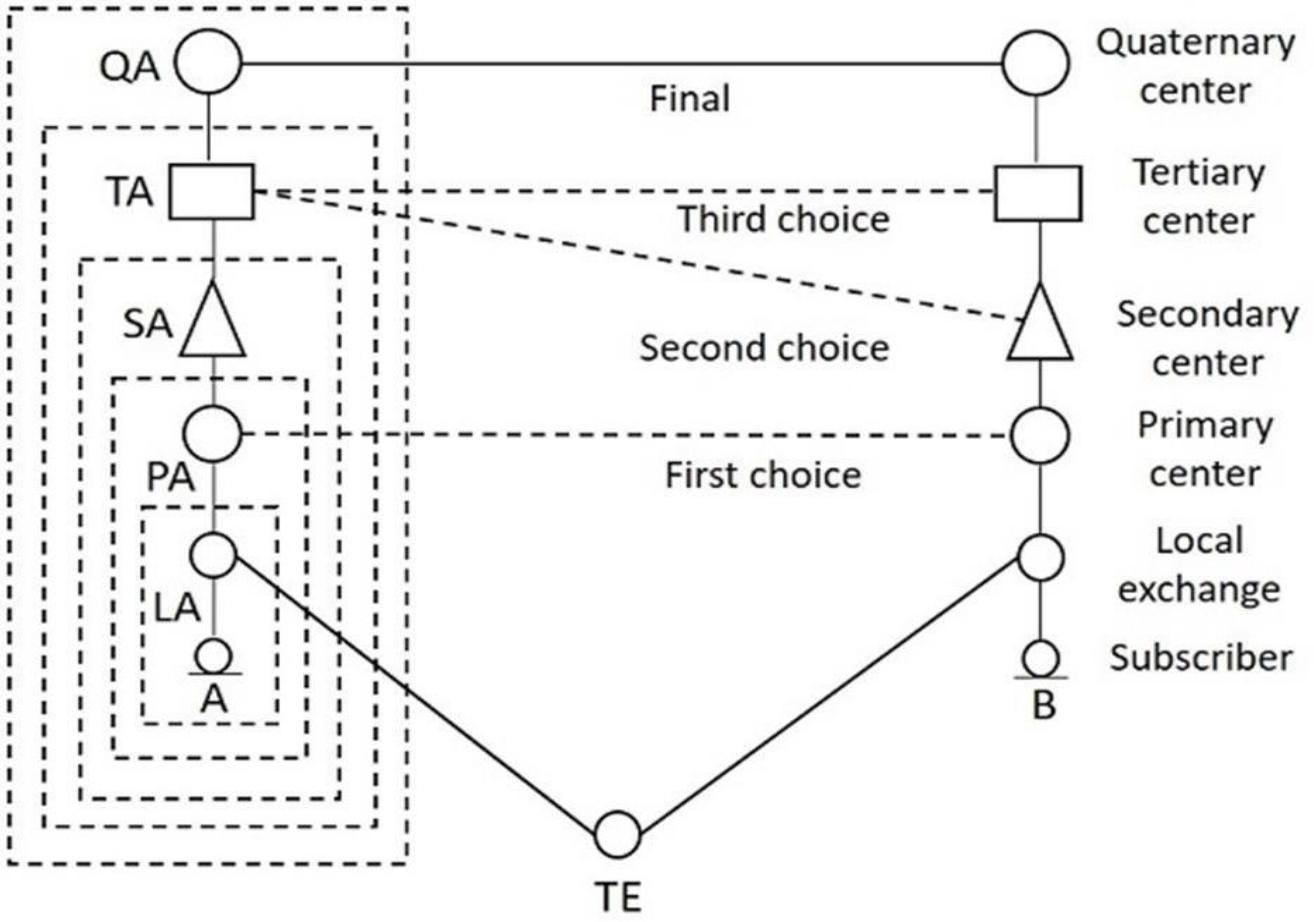


Star Topology



Two-level Star

Hierarchical



Transmission Plan

The apportionment of links between national and international circuits is necessary to ensure “quality” telecommunications.

High quality standards, the following guidelines were put forward by the CCITT

- The maximum number of circuits to be used in an international call is 12.
- No more than four international circuits be used in tandem between the originating and the terminating international switching centers.
- In exceptional cases and for a low number of calls, the total number of circuits may be 14, but even in this case, the international circuits are limited to a maximum of four.

Transmission Plan

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- No more than four international circuits be used in tandem between the originating and the terminating international switching centres.
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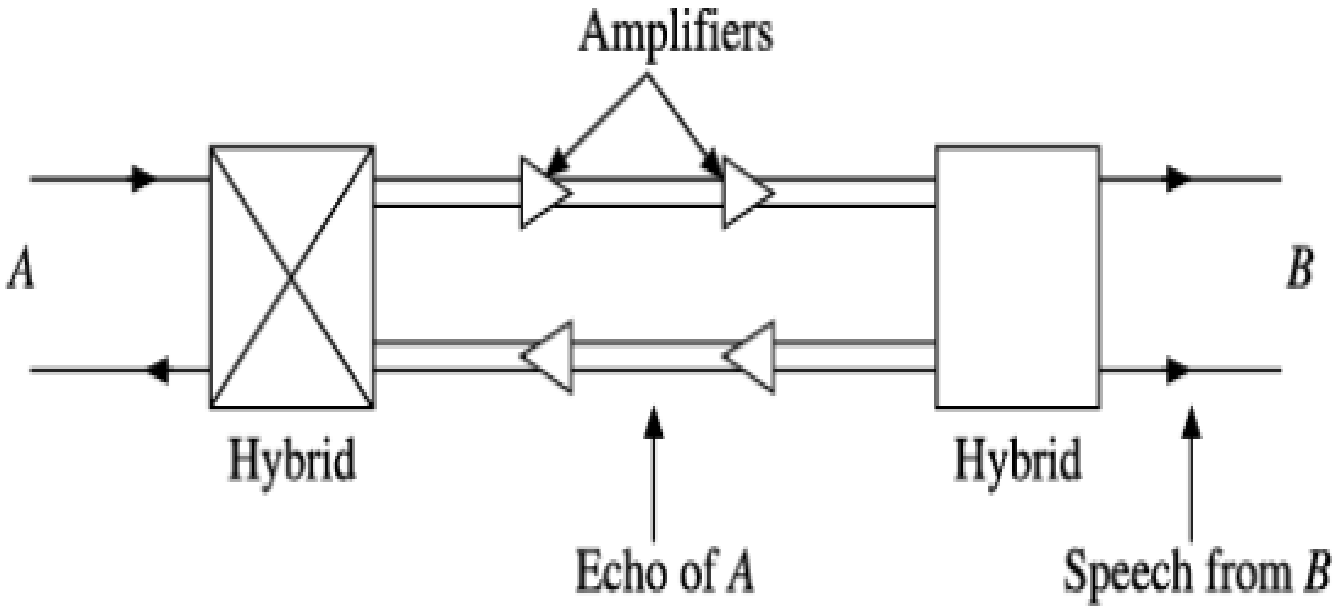
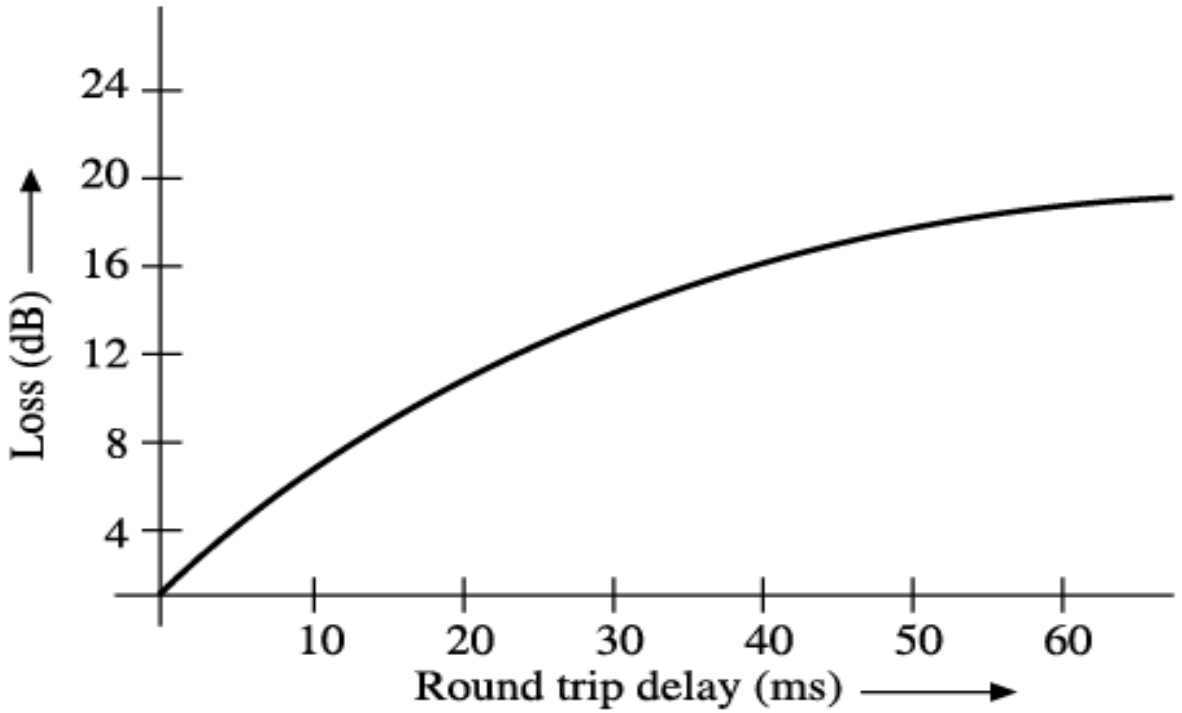
Transmission Plan



Echo as reflected signal.

Transmission Plan



Attenuation vs. echo delay.

Transmission Systems

There are different types of transmission systems

- Radio systems
- Coaxial cable system
- Optical fiber system

Transmission Systems

- Fibre optic transmission systems have been discussed in detail
- we concentrate on radio and coaxial cable systems.
- Radio communication deals with electronic radiation of electromagnetic energy from one point to another through the atmosphere or free space.
- It is possible only in a certain portion of the electromagnetic frequency spectrum.

Transmission Systems

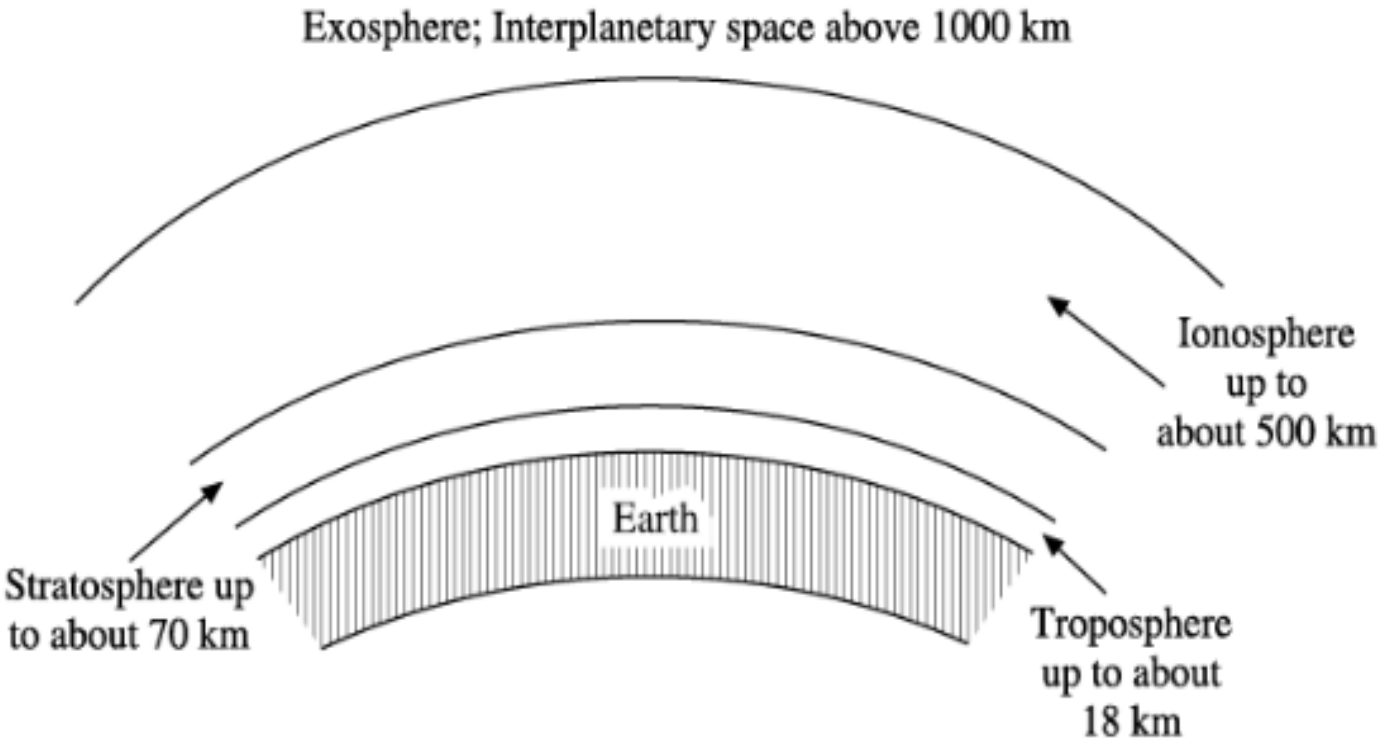
- This portion includes frequencies from 9 kHz to 4000Hz.
- While there are international allocations for the radio spectrum up to 275 0Hz, most of the commercial uses take place between 100 kHz and 20 0Hz.
- Different layers of the atmosphere play a role in propagating radio waves.

Transmission Systems

Depending upon the mechanism of signal propagation, the Radio communication has four varieties of communication, such as:

- Skywave or Ionospheric Communication
- Line-of-sight (LOS) microwave communication limited by horizon
- Tropospheric Scatter Communication
- Satellite Communication

Transmission Systems



Layers of atmosphere.

Numbering Plan

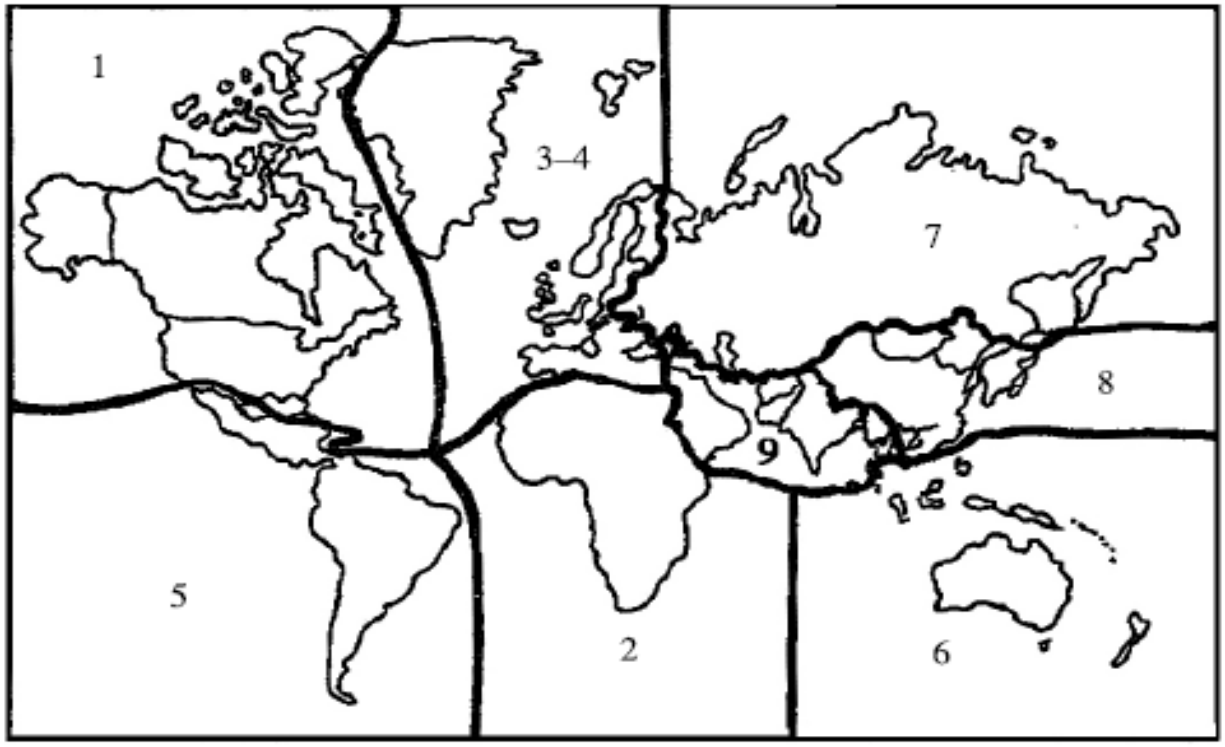
- Main Exchange: A large central exchange which serves the main business center of a town
- Satellite Exchanges: The smaller exchanges serving different localities .
- Multi-exchange area: The area containing the complete network of the main exchange and the satellites.

Numbering Plan

Types of Numbering Plans:

- **Open Numbering Plan**
- **Semi-Open Numbering Plan**
- **Closed Numbering Plan**

Numbering Plan



World numbering zones.

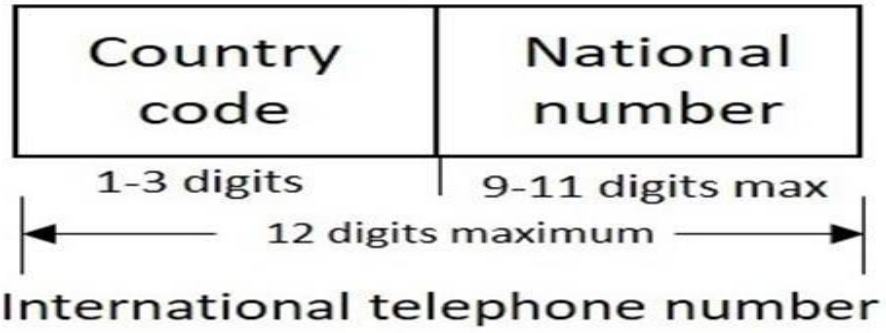
Numbering Plan

- Each zone is given a single digit code For the European zone, two codes have been allotted because of the large number of countries within this zone.
- Ever international telephone number consists of two parts as shown in Figure .
- The country code contains one, two or three digits, the first digit being the zone code in which the country lies.
- For example, in zone 3, France has the country code ‘33’ Albania ‘355’.
- In zone 9, India has the country code ‘91’ and Maldives 96O’.
- All the countries in the North American zone have the code as ‘1’

Numbering Plan

- All the countries in the North American zone have the code as ‘1’ .
- All the countries in the USSR have the code as ‘T. The standard country codes are listed in CCITT Rec. E.163.

Numbering Plan



- The Area Code or the Trunk Code
- Exchange Code
- Subscriber Line Number

Numbering Plan

Numbering Plan

- In the closed numbering scheme of North America, an area code consists of three digits, an exchange code three digits, and a subscriber line number four digits.
- Thus, a fixed 10-digit number forms the national number.
- In India where a semi open numbering scheme is used, a national number has 7—9 digits.
- But the apportionment between the STD code and the subscriber number varies widely.
- STD codes have 2—6 digits and the subscriber numbers 3—7 digits.
- The exchange codes are 1—3 digits long and the subscriber line numbers 2—4 digits.
- A numbering area in a region always has the region code as the first digit of the STD code.

Numbering Plan

For example, in region 2

- The city of Ahmedabad has the STDcode as ‘272’
- Nearby suburban town Bhopal has the code ‘2707’, and in regions, The city of Bangalore has the code ‘812’
- The hill town Tirumala the code 15747’.

Numbering Plan

There are four possible approaches to dialing procedures:

- Use a single uniform procedure for all calls. viz, local, national and international calls.
- Use two different procedures, one for international calls and the other for local and national calls.
- Use three different procedures, one for international calls, second for national trunk calls, and the third for local calls.
- Use four different procedures, three procedures same as given in 3 above and a fourth procedure for calls in the adjacent numbering areas.

Charging Plan

A charging plan for a telecommunication service levies three different charges on a subscriber:

1. An initial charge for providing a network connection
2. A rental or leasing charge
3. Charges for individual calls made

Charging Plan

The individual calls can be charged based on the following categories.

- Duration independent charging
- Duration dependent charging

Charging Plan

- In the olden days when STD and ISD facilities were not available, the trunk calls were established with the help of operators who were also responsible for the call charging .
- The subscriber meters are then useful only for local calls.
- To avoid the capital cost of providing meters and the operating costs of reading them at regular intervals and preparing the bills.
- some administrations have adopted a flat rate tariff system where some fixed charges for all estimated average number of local calls are included in the rental.
- This scheme is advantageous to subscribers who make a large number of calls but unfair to sparing users.

Signaling Techniques

There are three forms of signaling involved in a telecommunication network.

- Subscriber loop signaling
- Intra exchange or register signaling
- Interexchange or inter-register signaling

Signaling Techniques

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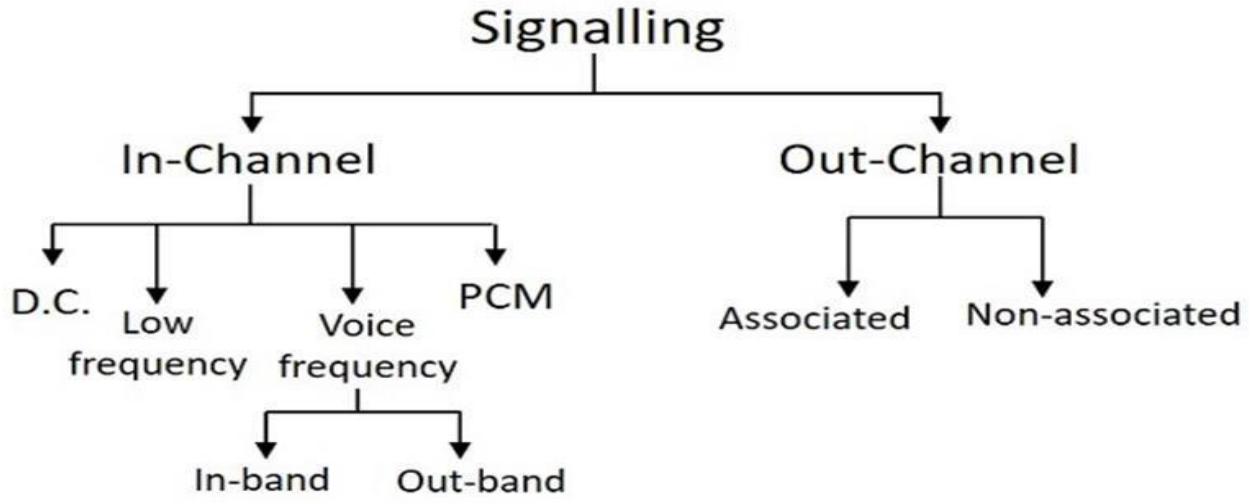
- Interexchange or inter-register signaling

Line signaling: The network-wide signaling that involves end-to-end signaling between the originating exchange and the terminating exchange

Signaling Techniques



The two main types of signaling techniques are:

- In-Channel Signaling
- Common Channel Signaling

Signaling Techniques

In-Channel Signaling:

- It is also known as Per Trunk Signaling.
- This uses the same channel, which carries user voice or data to pass control signals related to that call or connection.
- No additional transmission facilities are needed, for In-channel signaling .

Signaling Techniques

Common Channel Signaling:

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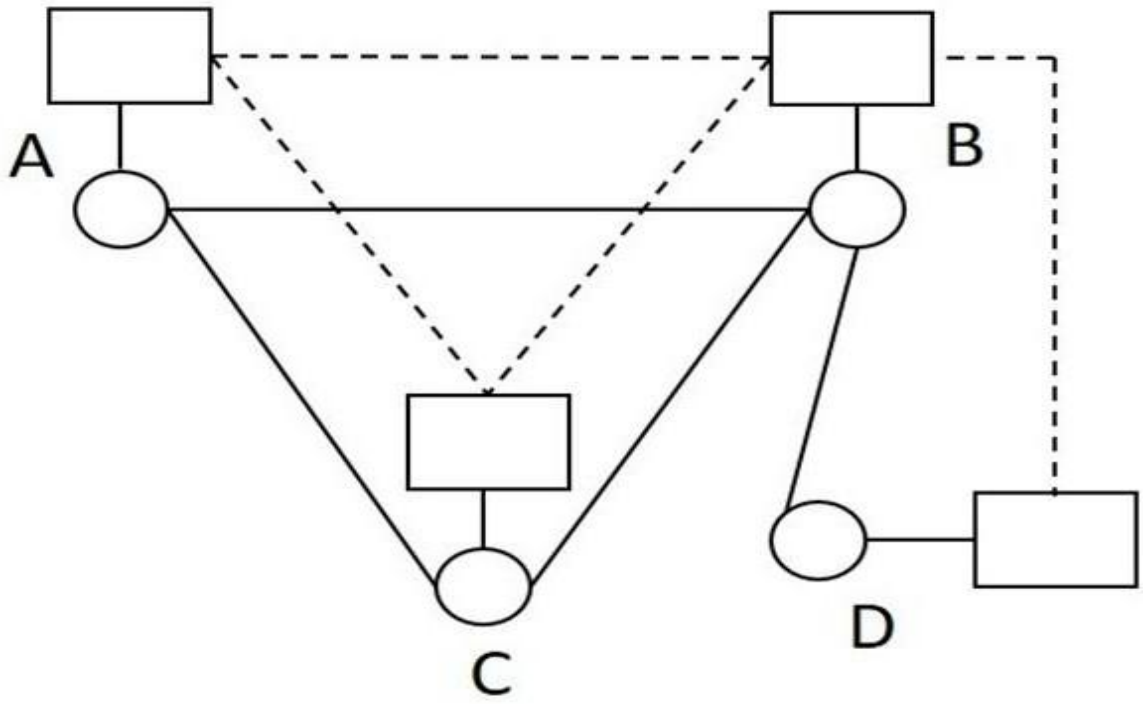
common channel signaling is implemented in two modes:

- Channel associated mode
- Channel non-associated mode

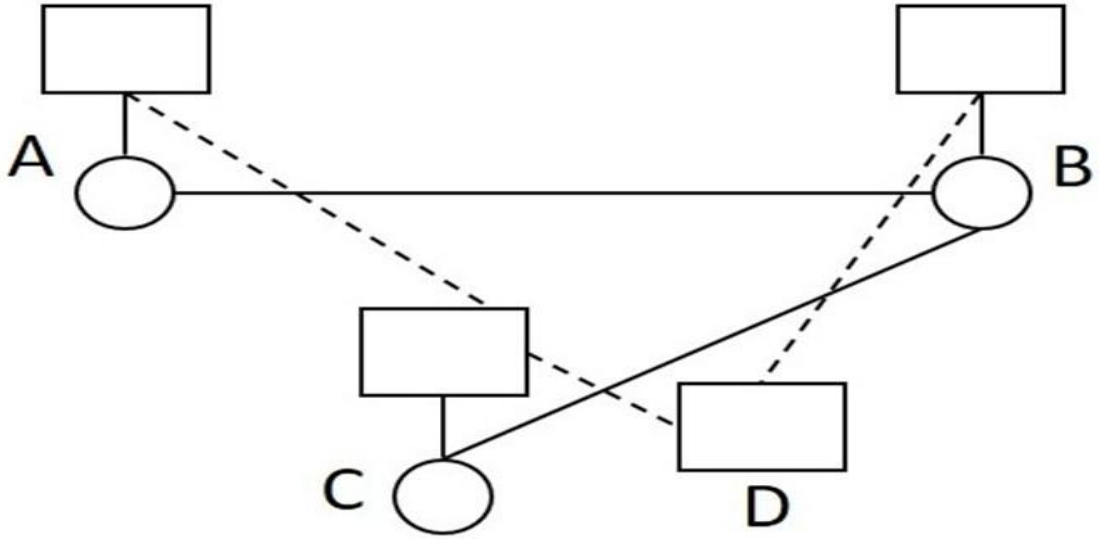
Common Channel Signaling:



The signaling paths for the speech paths A-B, A-C-B and B-D are A-B, A-C-B and B-D respectively. The advantages of this signaling are:

- The implementation is economic
- The assignment of trunk groups is simple

Channel Non-associated Mode



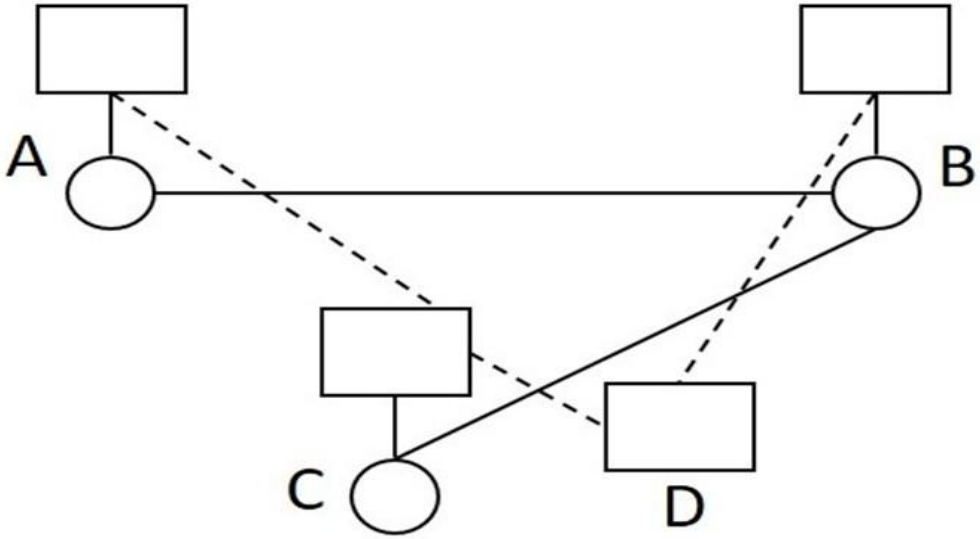
The signaling paths for the speech paths A-B and B-C are A-C-D-B and B-D-C respectively. The network topologies are different for signaling and speech networks

Signaling Techniques

In channel vs common channel

Inchannel	Common channel
Trunks are held up during signalling.	Trunks are not required for signalling.
Signal repertoire is limited.	Extensive signal repertoire is possible.
Interference between voice and control signals may occur.	No interference as the two channels are physically separate.
Separate signalling equipment is required for each trunk and hence is expensive.	Only one set of signalling equipments is required for a whole group of trunk circuits and therefore CCS is economical.
The voice channel being the control channel, there is a possibility of potential misuse by the customers.	Control channel is in general inaccessible to users.
Signalling is relatively slow.	Signalling is significantly fast.
Speech circuit reliability is assured.	There is no automatic test of the speech circuit.
It is difficult to change or add signals.	There is flexibility to change or add signals.
It is difficult to handle signalling during speech period.	There is freedom to handle signals during speech.
Reliability of the signalling path is not critical.	Reliability of the signalling path is critical.

Channel Non-associated Mode



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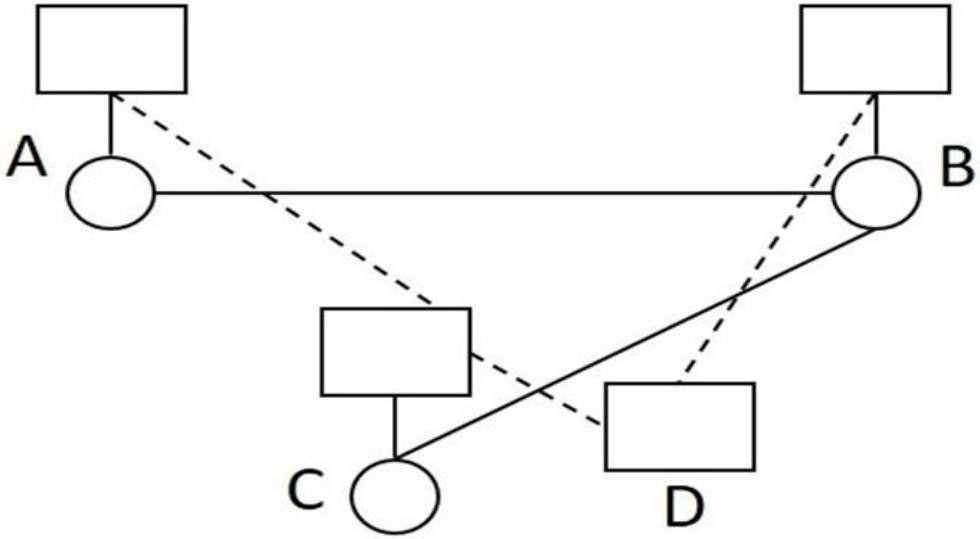
Channel Non-associated Mode



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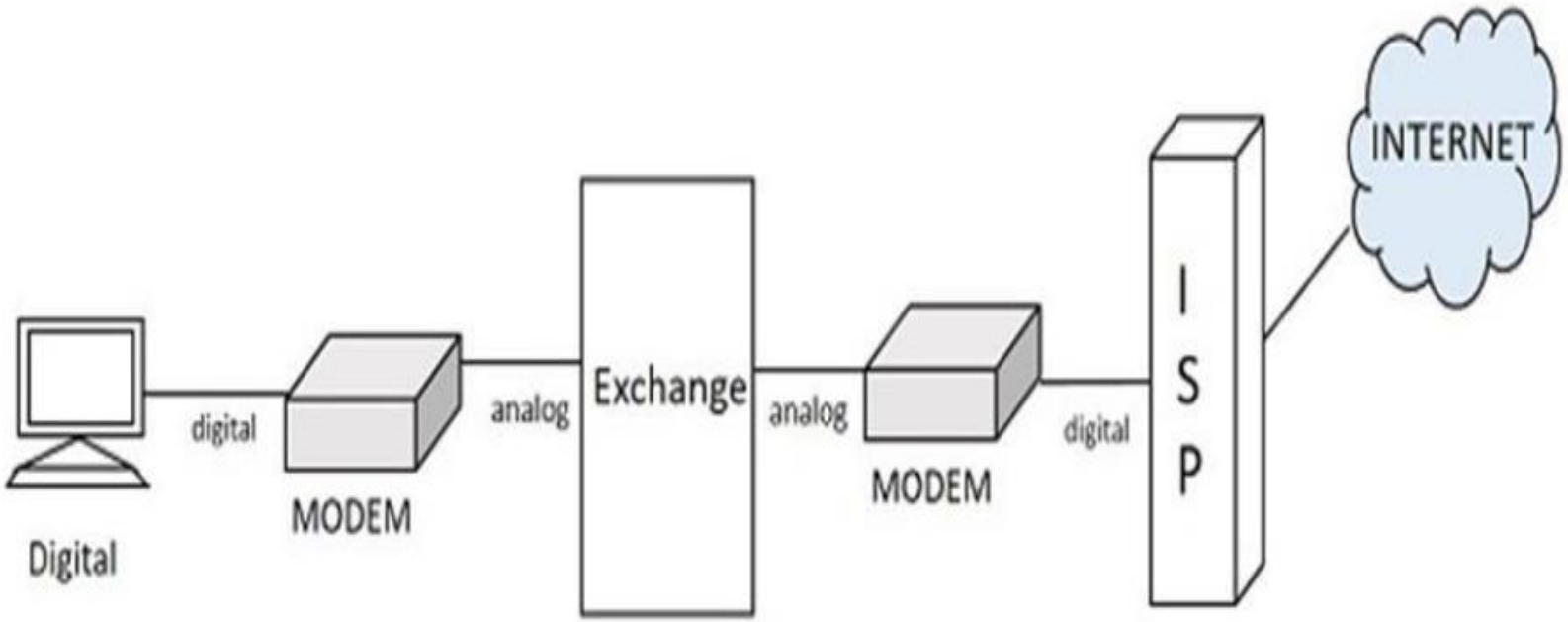
UNIT-V
INTEGRATED SERVICES DIGITAL NETWORKS

integrated services digital networks:

- The transmission of data and voice both were possible through normal POTS, Plain Old Telephone Systems.
- The process of connecting a home computer to the Internet Service Provider used to take a lot of effort.
- The usage of the modulator-demodulator unit, simply called the MODEM was the essential thing to establish a connection.

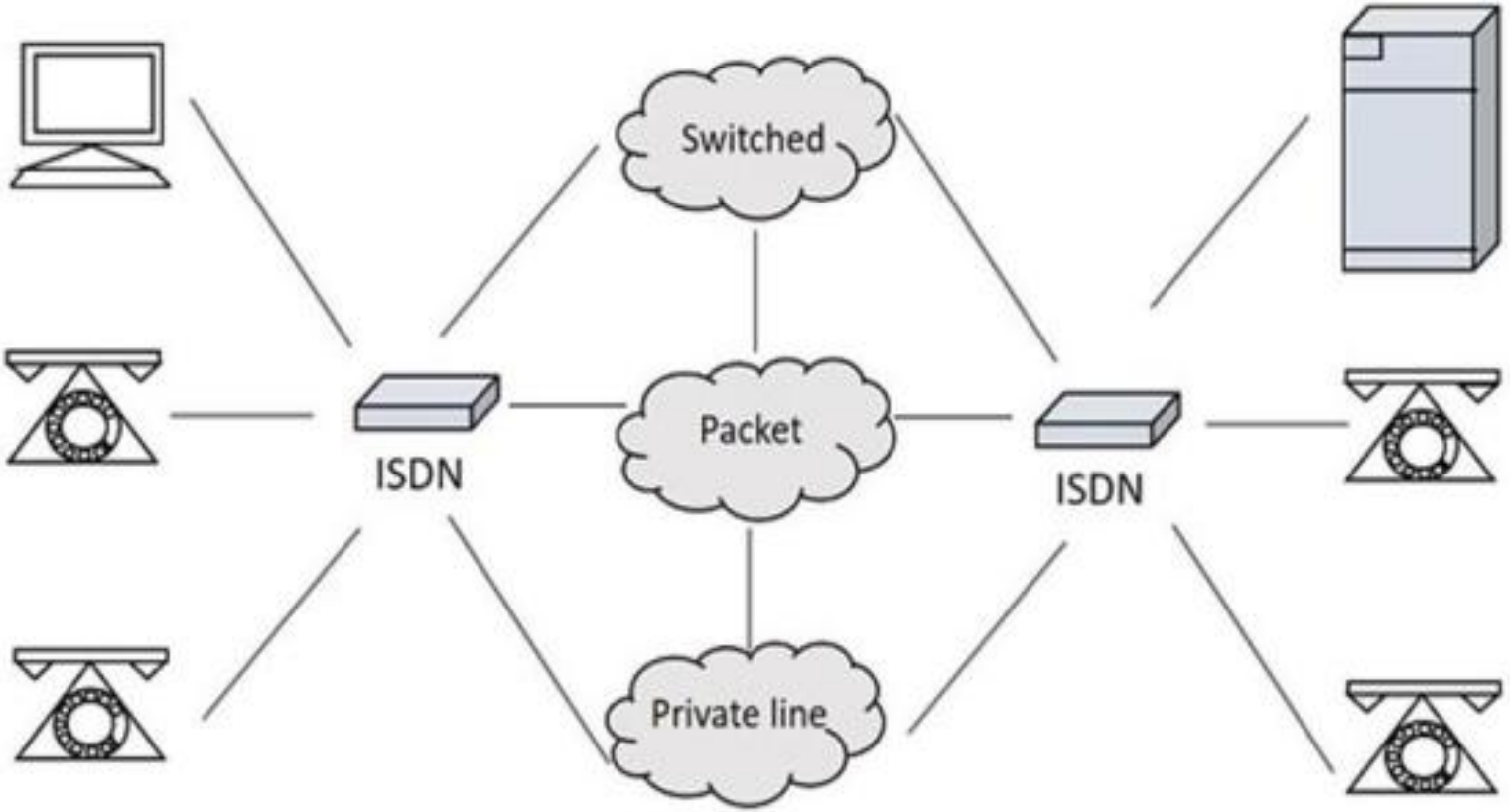
integrated services digital networks:



ISDN

- The introduction of ISDN has resolved this problem allowing the transmission of both voice and data simultaneously.
- This has many advanced features over the traditional PSTN, Public Switched Telephone Network .
- ISDN was first defined in the CCITT red book in 1988.The Integrated Services of Digital.
- Networking, in short ISDN is a telephone network based infrastructure that allows the transmission of voice and data simultaneously at a high speed with greater efficiency.

ISDN



ISDN supports a variety of services. A few of them are listed below:

- Voice calls
- Facsimile
- Videotext
- Tele text
- Electronic Mail
- Database access
- Data transmission and voice
- Connection to internet
- Electronic Fund transfer
- Image and graphics exchange
- Document storage and transfer
- Audio and Video Conferencing
- Automatic alarm services to fire stations, police, medical etc

Types of ISDN

- Among the types of several interfaces present, some of them contains channels such as the B-Channels or Bearer Channels that are used to transmit voice and data simultaneously; the D Channels or Delta Channels that are used for signalling purpose to set up communication.
- The ISDN has several kinds of access interfaces such as:
- Basic Rate Interface (BRI)
- Primary Rate Interface (PRI)
- Narrowband ISDN
- Broadband ISDN
- Broadband Communications. The broadband services provide a continuous flow of information, which is distributed from a central source to an unlimited number of authorized receivers connected to the network.

Advantages of ISDN

- ISDN is a telephone network based infrastructure, which enables the transmission of both voice and data simultaneously.

There are many advantages of ISDN such as:

- As the services are digital, there is less chance for errors.
- The connection is faster.
- The bandwidth is higher.
- Voice, data and video – all of these can be sent over a single ISDN line.

Disadvantages of ISDN

- The disadvantage of ISDN is that it requires specialized digital services and is costlier.
- However, the advent of ISDN has brought great advancement in communications. Multiple.
- transmissions with greater speed are being achieved with higher levels of accuracy .

Motivation for ISD

- Three factors are responsible for the developments towards ISDN:
  1. Sociological or societal needs
  2. Economic necessities
  3. Technological developments.

ISDN supports a variety of services. A short list of some of the important services is:

1 Videotex

2. Electronic mail

3. Digital facsimile

4. Teletex

5. Database access.

These services are described in the following sections.

Videotex

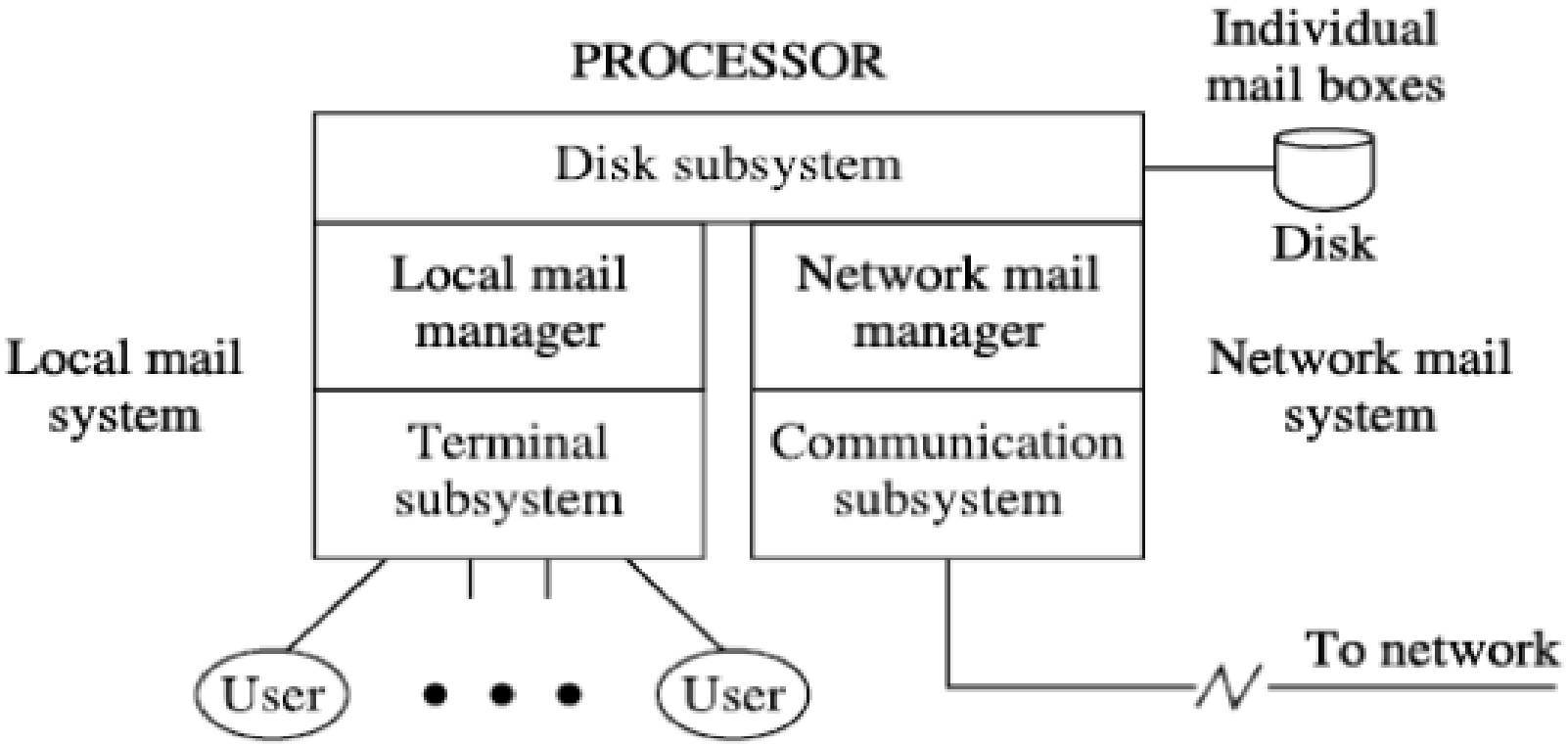
Video tex is a generic term for systems that provide easy to use. Low cost computer based Services via communication facilities. Three forms of video texexist:

1. View

2. Tele text

3. Open channel teletext.

Electronic Mail

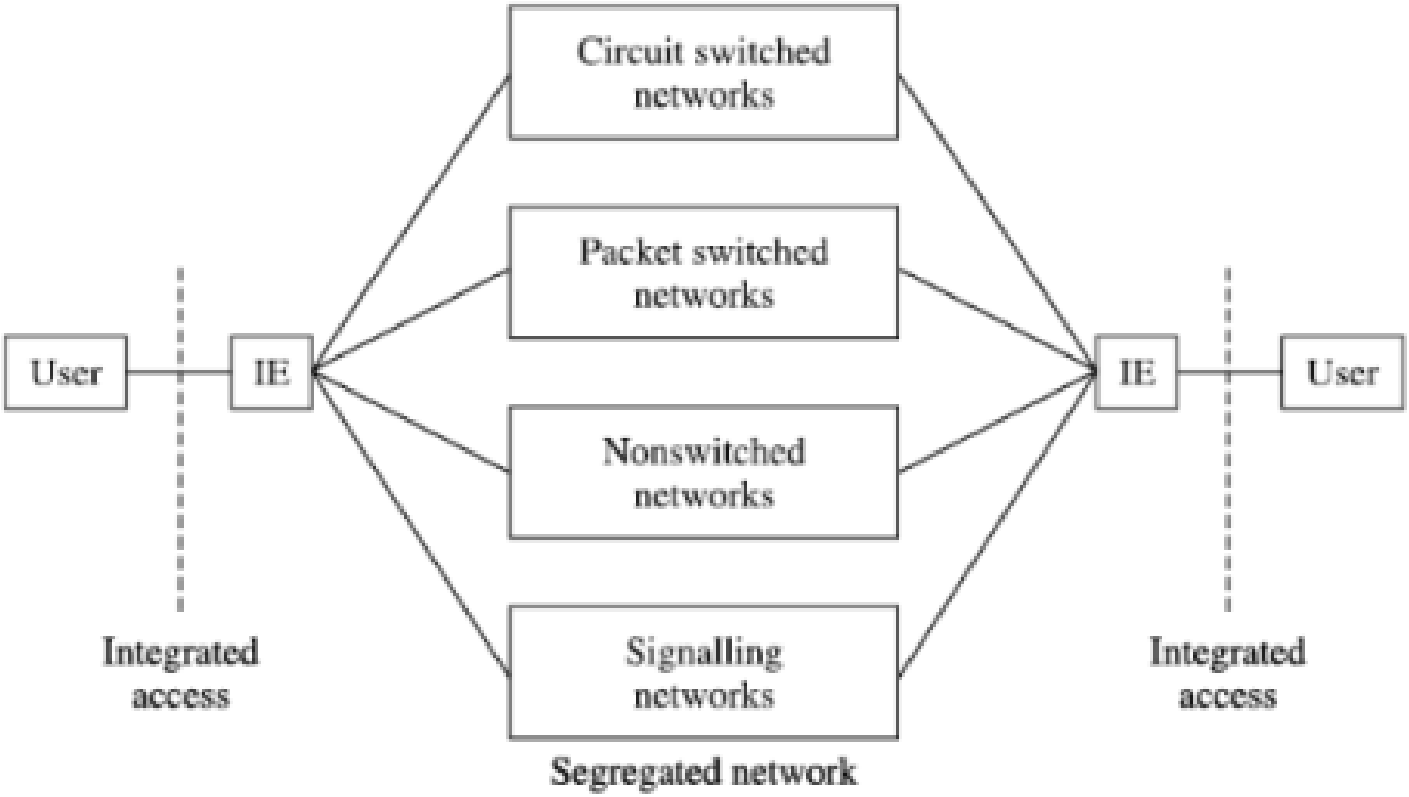


A Typical configuration of the an electronic mail system

NETWORK AND PROTOCOL ARCH ITECTURE

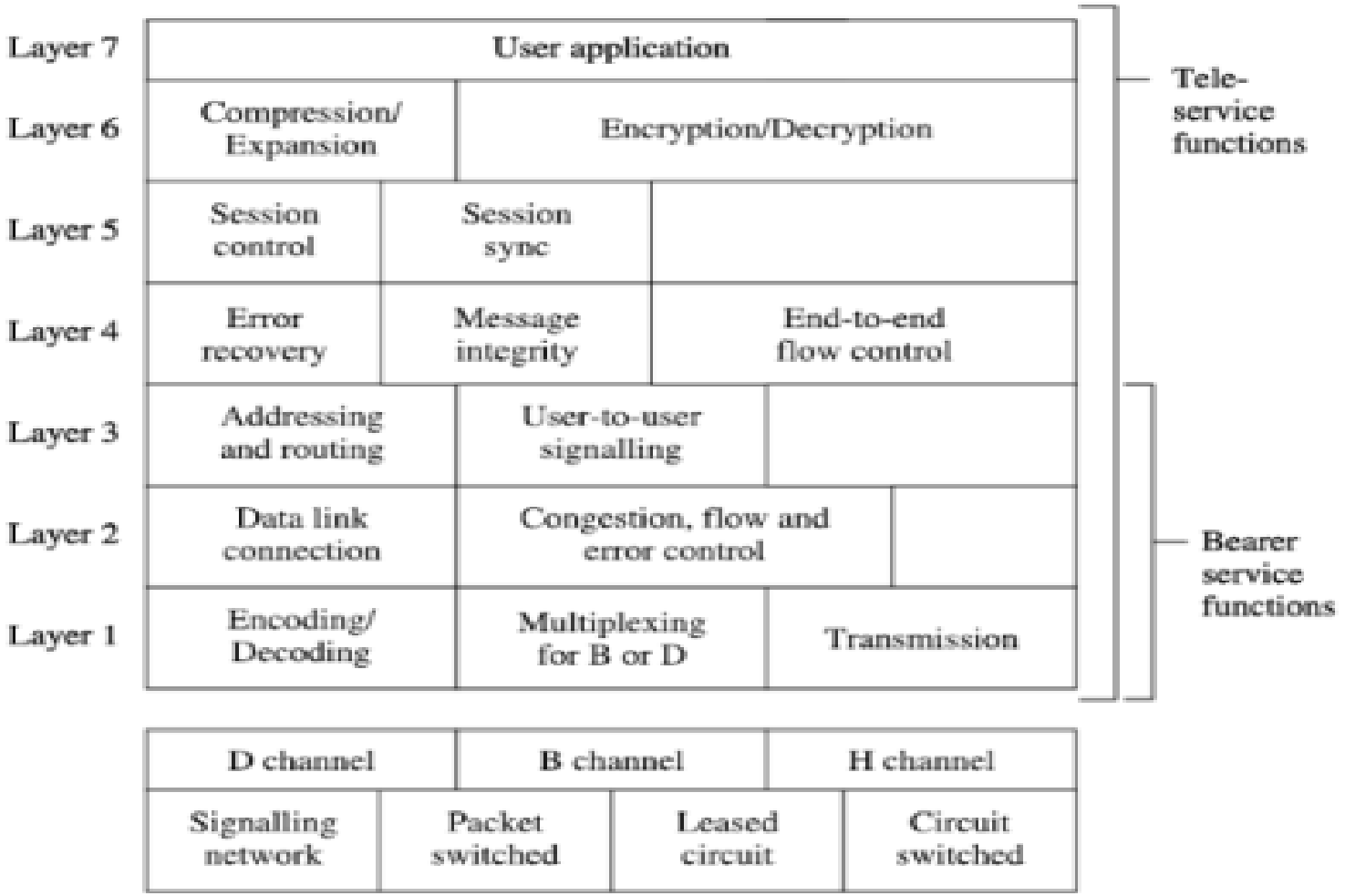
- Network architecture of [SDN followed an evolutionary path. It is natural that an evolutionary approach was taken with regard to ISDN.
- The wide range of telecommunication equipments and networks that were existing could not replaced overnight by ISDN.
- As a first step, the then existing analog telephone networks were converted to digital networks.
- These networks were then be operated along with other existing data and signalling networks.
- It is seen from the figure that four different types of networks form part of the segregated architecture.
- An ISDN exchange and a suitable user-network interface permit an integrated access to the network facilities.

ISDN Architecture



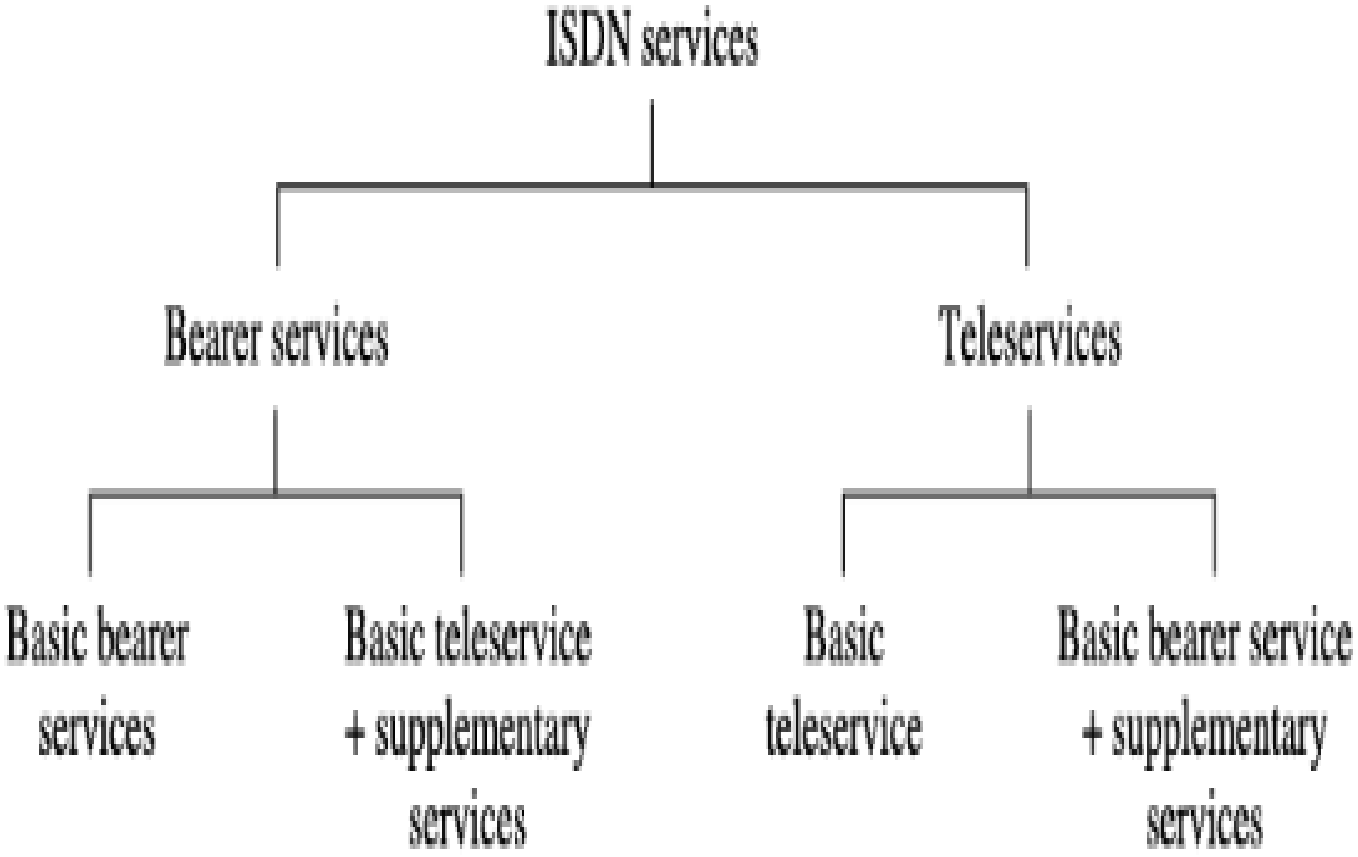
ISDN Architecture

ISDN Protocol architecture

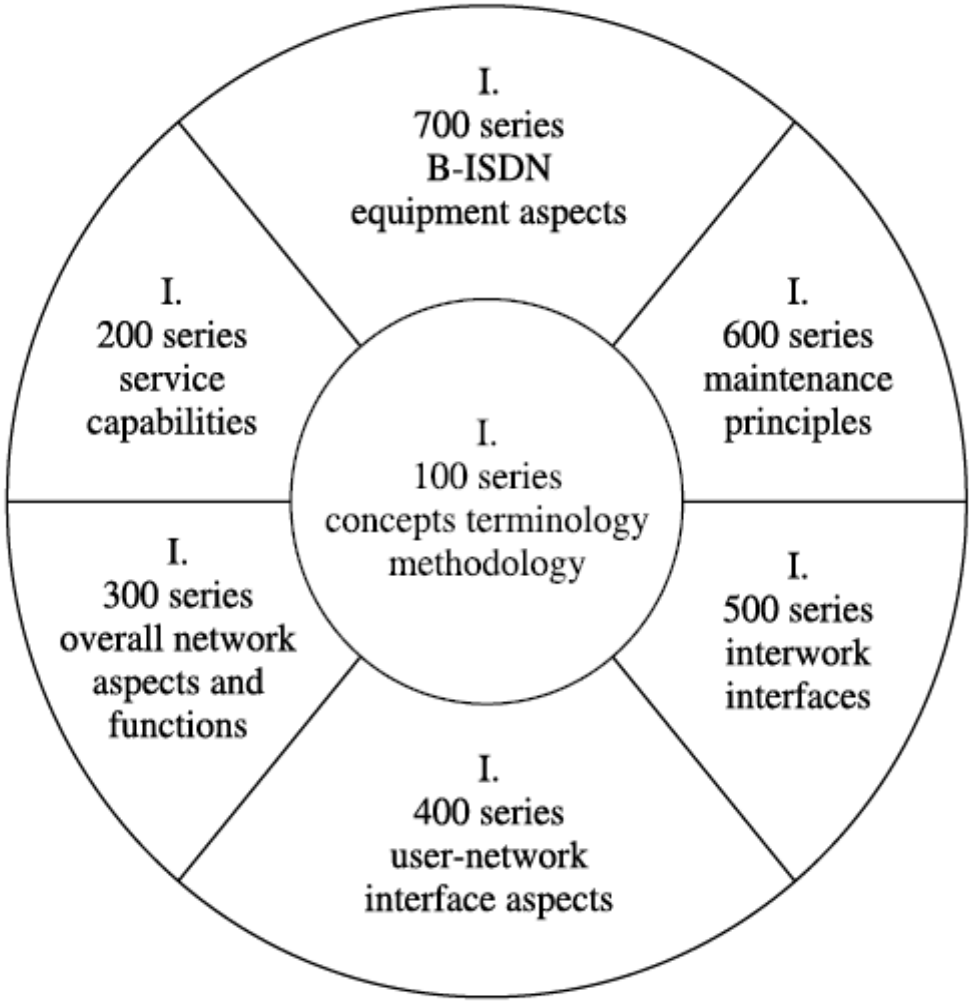


ISDN Protocol architecture

ISDN Services



ISDN STANDARDS



BROADBAND ISDN

- Broadband ISDN (BISDN) is defined as a network capable of supporting data rates greater than the primary rate (1S44 or 2.048 Mbps) supported by ISDN. In the context of BISDN,
- The original ISDN concept is often termed narrowband ISDN
- (NISDN). BISDN services are broadly classified as
  - Interactive services
  - Distribution services.

Interactive services may be classified as

1. Conversational sen-ices
2. Messaging services
3. Retrieval services.

Distribution services are classified as

1. Broadcast services
2. Cyclic services.

VOICE DATA INTEGRATION

Digitised voice	Data
Periodic bursty in nature	Aperiodic bursty in nature
Fixed length bursts	Variable length bursts
Small packet size	Large packet size
Packetisation time critical	Packetisation time is not critical
Hard bound on delay	Soft bound on delay
Hard bound on the variance of delay	Soft bound on the variance of delay
Loss of parts of speech acceptable	Loss of parts of data unacceptable
Low overhead as there is no error recovery	High overhead due to error detection and recovery