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Operations Research in Telecommunication

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Abstract - *Society today has made itself so used to telecommunication that the world would collapse if it was taken. Operations research (OR) is an analytical method of problem-solving and decision-making that is useful in the management of organizations. In operations research, problems are broken down into basic components and then solved in defined steps by mathematical analysis. Numerous companies in industry require Operations Research professionals to apply mathematical techniques to a wide range of challenging questions. It has been successful in providing a systematic and scientific approach to all kinds of government, military, manufacturing, and service operations. OR methodologies in telecommunications has been fruitful for a long time, and the modern telecommunication industry has enjoyed an enormous impetus given by the techniques that OR researchers and practitioners employ, including optimization, simulation, probability and statistics among others.*

I. INTRODUCTION

When compared with other disciplines, Operation Research is a relatively new discipline. The contents and the boundaries of OR are not yet fixed due to it still being in its early days. The main activity of any manager is decision making. All of us in our daily lives too, make a lot of decisions, but these are simple and so taken my common sense, judgement. OR starts when mathematical and quantitative techniques are used to substantiate the decision being taken. These decisions, for which OR is essential are complex decisions, like planning product mixes, planning cities and towns with proper allotments for residential and commercial areas etc.

According to the Operational Research Society of Great Britain , Operational Research is the attack of modern science on complex problems arising in the direction and management of large systems of men, machines, materials and money in industry, business, government and defense. Its distinctive approach is to develop a scientific model of the system, incorporating measurements of factors such as change and risk, with which to predict and compare the outcomes of alternative decisions, strategies or controls. The purpose is to help management determine its policy and actions scientifically.

OR is basically the application of scientific methods to improve decisions, operations and management. Operation research tools are multidisciplinary. Operations Research takes tools from different discipline such as statistics, economics, psychology, engineering etc. and combines these tools to make a new set of knowledge for decision making. Operation research is now a professional discipline that helps in management of scarce recourses. OR provided solutions to problems of military operations during World War II and now it is used in a wide range of industries and fields like production planning, marketing telecommunication, FMCG, sports and many more.

II. TELECOMMUNICATION IN INDIA

India is the world's second-largest telecommunications market, where the wireless segment (97.36 per cent of total telephone subscriptions) dominates the market. India today, is also the second largest country in terms of internet subscribers. The country is now the world's second largest smartphone market and will have almost one billion unique mobile subscribers by 2020.

Telecommunication in India is expected to grow as there is higher penetration in rural areas thanks to improvement in technology. Also, the emergence of an affluent middle class has triggered and will continue to trigger demand for the mobile and internet segments. The digital payments ecosystem is growing by leaps and bounds in India. This is largely possible as India is transitioning to a digital economy.

III. DATA COMMUNICATION

Communication can be defined as the exchange of information between two or more bodies. In engineering, exchange of information is not only between people, information exchange also takes place between machines or systems. Communication has increased significantly in importance in recent years. Voice services have seen unprecedented increase in use throughout the world with the introduction of mobile phones, with embedded data services such as SMS, and web browsing.

Data is referred to as a piece of information formatted in a special way. Data can exist in a variety of forms, such as numbers or text on pieces of paper, as bits and bytes stored in electronic memory, or as facts stored in a person's mind. Strictly speaking, data is the plural of datum , a single piece of information. In practice, however, people use data as both the singular and plural form of the word. In electronics terms data is a digital bit or digitized analog signal. Signals are physical quantity that changes with time. Signal can be a voltage that is

proportional to the amplitude of message. It could also be a sequence of pulses in fiber optics cable or electromagnetic wave irradiated by an antenna. When these signals are transfer between two or more points we say data is transmitted.

Transmission of data from source to destination usually takes place via some transmission media and this depends on two main factors; quality of signal being transmitted and characteristics of transmission medium. Data transmission always uses the form of electromagnetic waves and they are classified into guided electromagnetic waves and unguided electromagnetic waves. Examples of guided waves are twisted pair, coaxial cable and optical fiber. Unguided waves means transmitting electromagnetic waves but they are not guided as example propagation through air, vacuum and seawater.

IV. ANALOG AND DIGITAL SIGNAL

The entire world is full of signals, both natural and artificial. Signals can be analog or digital. Figure 1 illustrates an analog signal. The term analog signal refers to signal that is continuous and takes continuous value. Most phenomenon's in the world today are analog. There are an infinite amount of colors to paint an object (even if the difference is indiscernible to the eye), it is possible for us to hear different sounds and also smell different odors. The common theme among all of these analog signals is their infinite possibilities.

Figure 1: Typical Analog signal

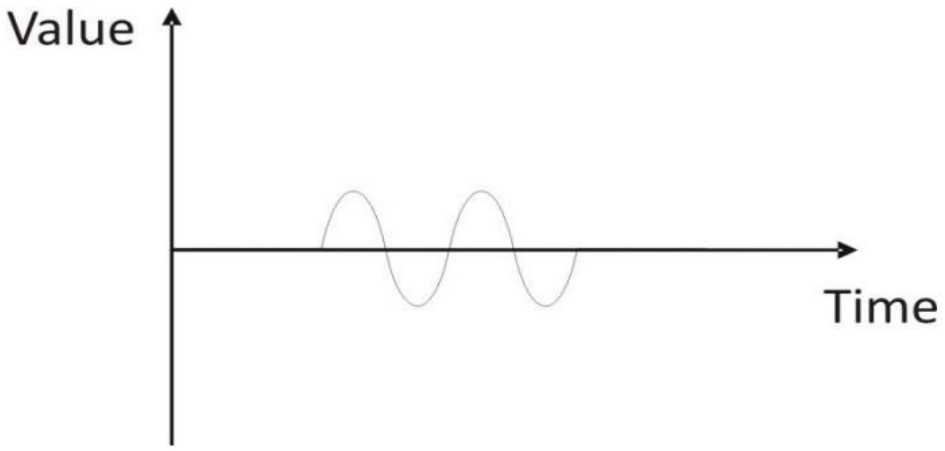

Figure 1 shows a typical representation of analog signal. Because the signal varies with time, time is plotted on horizontal (x-axis), and voltage on the vertical (y-axis). While this signals may be limited to a range of maximum and minimum values. There are still an infinite number of possible values within that range. For example the analog voltage that light the bulbs is clamped between -220V and +220V, but as you increase the resolution more and more, you discover an infinite number of values that the signal can be. For example, pure audio signals are analog. The signal that comes out of a microphone is full of analog frequencies and harmonics, which combine to beautiful music.

A digital signal is a physical signal that is a representation of a sequence of discrete values. The signal must have a finite set of possible values, the number of set which can be anywhere between two and very large number that is not infinity. Digital signal is one of two voltage value (0V or 5V) timing graphs of these signals look like square waves as shown in figure 2.

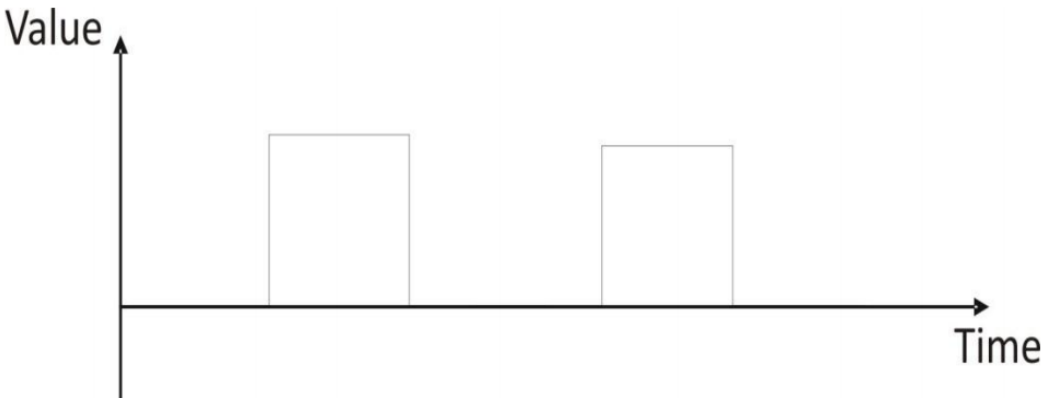

Figure 2: Typical Digital Signal

V. WHY DATA COMMUNICATION?

Data communication refers to the movement of encoded information from one point to another by means of electronic transmission system. It can also be defined as the exchange of data between two devices via some form of transmission medium which can be wired or wireless. Another definition for data communications simply mean the transferring of digital information (usually in binary form) between two or more points (terminals). At both the source and destination, data are in digital form; however, during transmission, they can be in digital or analog form Information is carried by signal, which is a physical quantity that changes with time. The signal can be a voltage proportional to the amplitude of the voice like in simple telephone, a sequence of pulses of light in an optical fiber, or a radio-electric wave radiated by an antenna.

The fundamental purpose of data communication is to exchange information which is done by following certain rules and regulations called protocols and standards. Communications between devices are justified for the following reasons:

- Reduces time and effort required to perform business task
- Captures business data at its source
- Centralizes control over business data
- Effect rapid dissemination of information
- Reduces current and future cost of doing business
- Supports expansion of business capacity at reasonably incremental cost as the organization
- Supports organization's objective in centralizing computer system
- Supports improved management control of an organization.

As a rule, the maximum permissible transmission rate of a message is directly proportional to signal power and inversely proportional to channel noise. It is the aim of any communications system to provide the highest possible transmission rate at the lowest possible power and with the least possible noise.

VI. COMPONENTS OF DATA COMMUNICATION

Basic Components of data communication are: Source: It is the transmitter of data. Examples are: Terminal, Computer, Mainframe etc. Medium: The communications stream through which the data is being transmitted. Examples are: Cabling, Microwave, Fiber optics, Radio Frequencies (RF), Infrared Wireless etc. Receiver: The receiver of the data transmitted. Examples are: Printer, Terminal, Mainframe, and Computer.

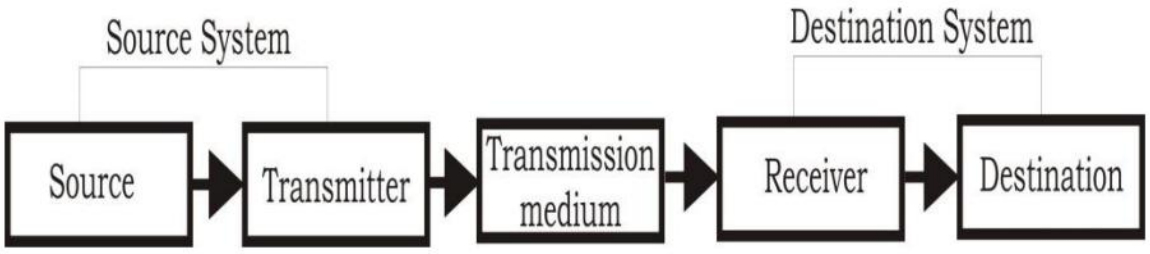

Figure 3: Basic Block Diagram of a Data Communication System

Figure 3 shows the basic block diagram of a typical data communication system. This can further be broken down to three; the source system, transmission system and destination system.

6.1 Source

The source generates the information or data that will be transmitted to the destination. Popular forms of information include text, numbers, pictures, audio, video or a combination of any of these. Information are put together in analog or digital form and broken into group or segment of data called packets.
Each packet consists of the following:

- the actual data being sent
- Header
- information about the type of data
- where the data came from
- where it is going, and
- How it should be reassembled so the message is clear and in order when it arrives at the destination.

6.1.2 Transmitter

The transmitter a device used to convert the data as per the destination requirement. For example a modem, converts the analog (telephonic) signal to digital (computer) signals and alternatively digital to analog.

6.1.3 Transmission medium

The transmission medium is the physical path by which data travels from transmitter to receiver. Example of such channels is copper wires, optical fibers and wireless communication
channels etc.

6.1.4 Receiver

This receives the signals from the transmission medium and converts it into a form that is suitable to the destination device. For example, a modem accepts analog signal from a transmission channel and transforms it into digital bit stream which is acceptable by computer system.

6.1.5 Destination

It is simply a device for which source device sends the data.

VII. WHAT IS COMPUTER NETWORK?

Computer network is interconnectivity of two or more computer system for purpose of sharing data. A computer network is a communication system much like a telephone system, any connected device can use the network to send and receive information. In essence a computer network consists of two or more computers connected to each other so that they can share resources. Networking arose from the need to share resources in a timely fashion.

Sharing expensive peripherals is often promoted as the primary reason to network. But this is not a sufficient reason. In considering the cost benefits of sharing, we find some impressive arguments against networking. With today more affordable technology, we can easily dedicate inexpensive peripherals and not bother with a network. Desktops and laptops are getting less expensive as their capacities increase. As a result the local hard disk is becoming common place and is frequently dedicated to a local desktop or laptop. Flash drives and external hard disks now has enough storage for uses.

VIII. WHY COMPUTER NETWORKING?

These are serious considerations but only part of the picture. When viewed as a system, networking has some powerful arguments in its favor. In most cases organizations withmultiple computer systems should network them for the following reasons:

1. Sharing of peripherals can be justified as a “shared resource”, with the result that speed and quality are improved and Mean Time Between Failure (MTBF) is increased. Sharing in a properly designed network improves the reliability of the entire system. When a device fails, another one is ready to fill the void while repairs are being made.

2. Better response time can be achieved through networking. The speed with which a request is answered is a crucial factor in computing. After all, most jobs performed by a computer can be done with pencil and paper. When you buy a computer, you are buying speed more than capability. Better response time through networking is in no way guarantee. In fact, inefficient use of the network will quickly result in unacceptably poor response. The elements needed for superior performance, however, are part of most networks. If properly implemented, a computer network will be more efficient that stand-alone computers or network terminals and will equal or surpass stand-alone computer performance.

3. The peripherals attached to a network tend to be faster than those dedicated to stand-alone computers. The bandwidth of all the local area network far exceeds the speed capability of a stand-alone computer. For many applications the computer, not the network, is the bottleneck. But since a local area network is by definition a multiple processor system, the possibility exists for sharing the processing load across several microprocessors, which is similar to parallel processing. You may not be able to speed up the computer itself, but you can speed up the results.

4. Often overlooked in an evaluation of networking is its organization benefit. Departments, companies, corporations, and institutions are all organizations, which imply interaction and team work. Without networking, the personal computer has been a powerful but isolated device. Its output has been difficult to integrate into the organization mainstream, so its value has been limited. In some instances the isolated personal computer has even created serious threats of data loss.

Networking is a communications mechanism that ties the isolated computer systems into the organization. In a networking environment, being able to communicate and share data encourages continuity and compatibility so that administrative chores can be systematized. For example, the task of backing up the data can be assigned to a particular individual, rather than left as an afterthought to each employee.

IX. TYPES OF NETWORK

There are several different types of computer networks. Computer networks can be characterized by their size as well as their purpose. The size of a network can be expressed by the geographic area they occupy and number of computers that are part of the network. Networks can cover anythingfrom a handful of devices within a single room to millions of devices spread across the entire globe.

Personal Area Network A personal area network (PAN) is the interconnection of information technology devices within the range of an individual person, typically within a range of 10 meters. For example, a person traveling with a laptop, a personal digital assistant (PDA), and a portable printer could interconnect them without having to plug anything in, using some form of wireless technology. Typically, this kind of personal area network could also be interconnected without wires to the Internet or other networks. PANs can be used for communication among the personal devices themselves (intrapersonal communication), or for connecting to a higher level network and the Internet (an uplink). However, it is possible to have multiple individuals using this same network within a residence. If this is the case we can refer to the network as Home Area network (HAN). In this type of setup, all the devices are connected together using both wired and/or wireless. All networked devices can be connected to a single modem as a gateway to the Internet. See figure 4.

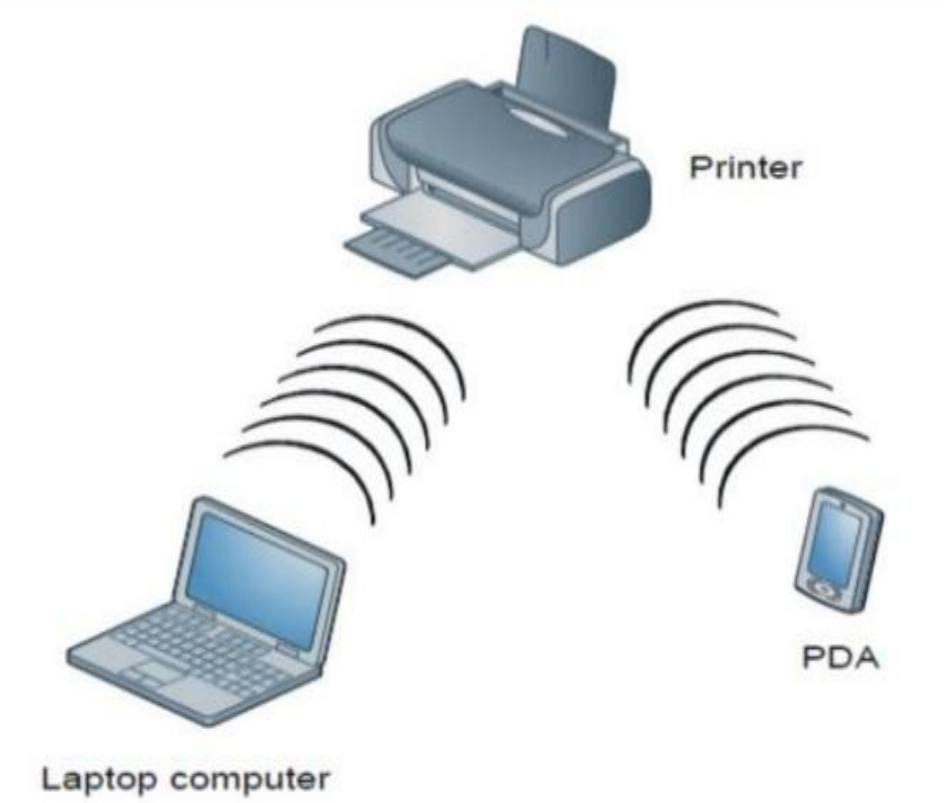

Figure 4: Personal Area Network

Local Area Network A local area network (LAN) is usually privately owned and links the devices in a single office, building, or campus. Depending on the needs of an organization and type of technology used, a LAN can be as simple as two desktops and a printer in someone's home office; or it can extend throughout a company and include audio and video peripherals. Currently, LAN size is limited to a few kilometers. In addition to the size, LANs are distinguished from other types of networks by their transmission media and topology. In general, a given LAN will use only one type of transmission medium. LANs are designed to allow resources to be shared between personal computers or workstations. Early LANs had data rates in the 4 to 16 mega-bits-per-seconds (Mbps). Today, however, speeds are normally 100Mbps or 1000Mbps. Wireless LANs (WLAN) are the newest evolution in LAN technology.

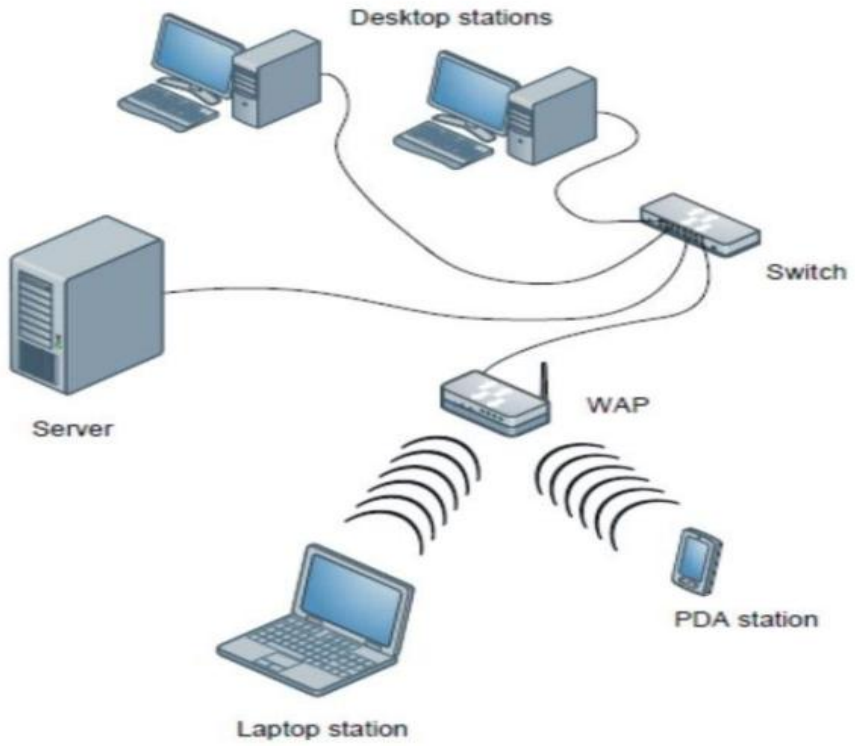

Figure 5: Local Area Network

Metropolitan Area Network A metropolitan area network (MAN) is a network with a size between a LAN and a WAN. It normally covers the area inside a town or a city. It is designed for customers who need a high-speed connectivity, normally to the internet, and have endpoints spread over a city or part of city. A good example of a MAN is part of the telephone company network that can provide a high-speed DSL line to the customer.

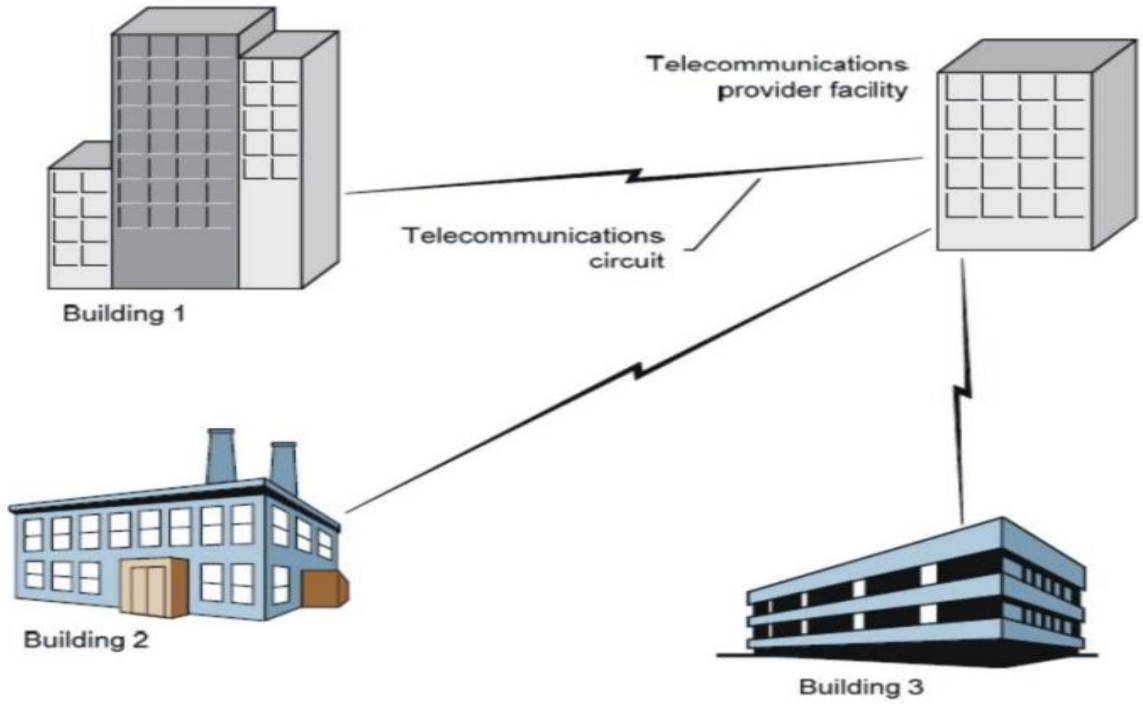

Figure 6: Metropolitan area Network

Wide Area Network A wide area network (WAN) provides long-distance transmission of data, image, audio, and video information over large geographic areas that may comprise a country, a continent, or even the whole world. A WAN can be as complex as the backbones that connect the Internet or as simple as a dial-up line that connects a home computer to the internet.

We normally refer to the first one as a switched WAN and to the second as a point-to-point WAN. The switched WAN connects the end systems, which usually comprise a router (internetworking connecting device) that connects to another LAN or WAN. The point-to-point WAN is normally a line leased from a telephone or cable TV provider that connects a home computer or a small LAN to an internet service provider (ISP). A good example of a switched WAN is X.25, the asynchronous transfer mode (ATM) network.

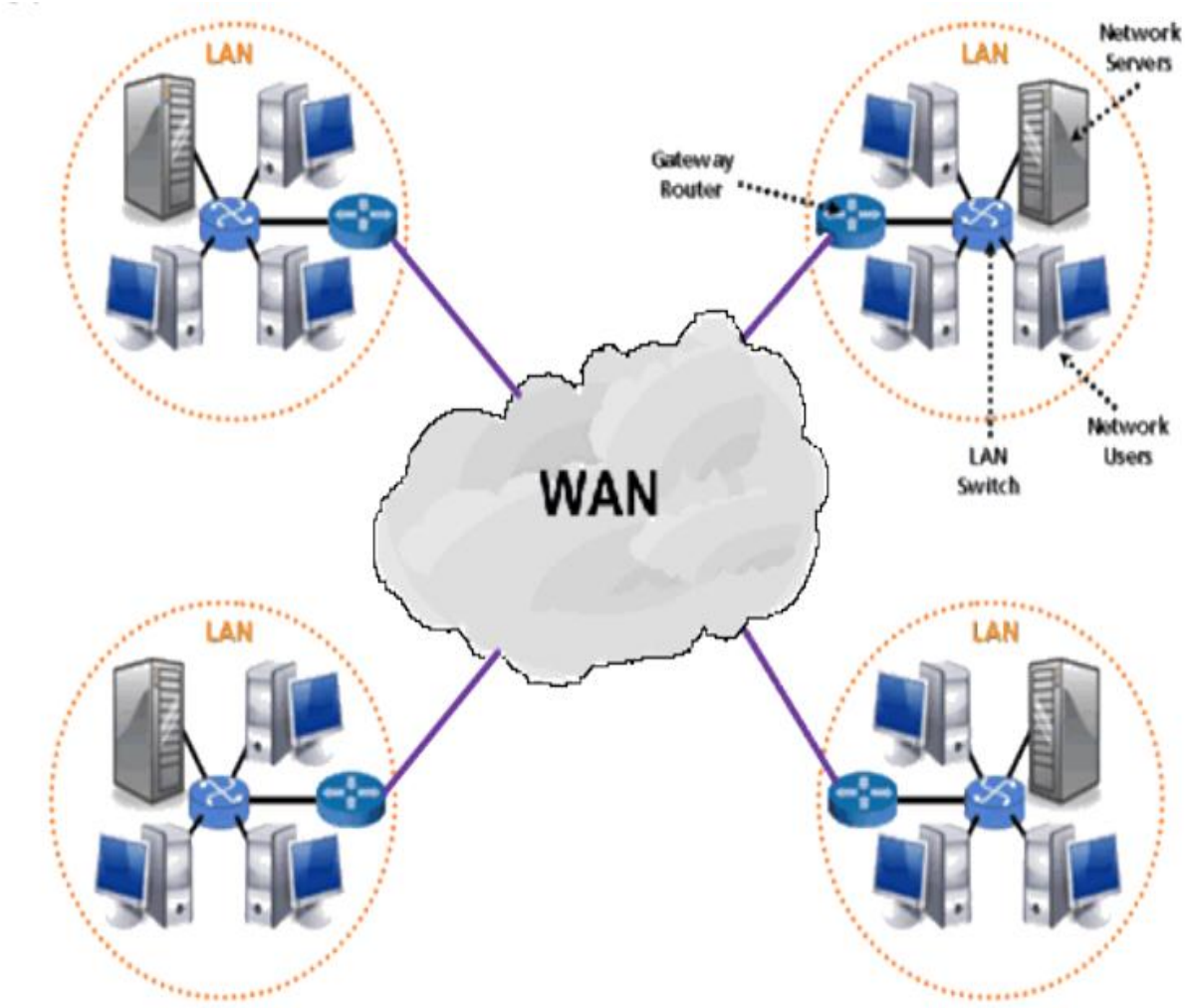

Figure 7: Wide Area Network

X. NETWORK TOPOLOGIES

The term topology in computer networking refers to the way in which a network is laid out physically. Two or more devices connect to a link; two or more links form a topology. The topology of a network is the geometric representation of the relationship of all links and linking devices (usually called nodes) to one another. The cost and flexibility of a network
installation are partly affected by as is system reliability. Many network topologies are commonly used, but they all have certain similarities. Information is carried either through space (wireless) or cable. The cable must control the movement of information on the network so that data can be transmitted in a reliable manner. There are four basic topologies possible: mesh, star, bus, and ring.

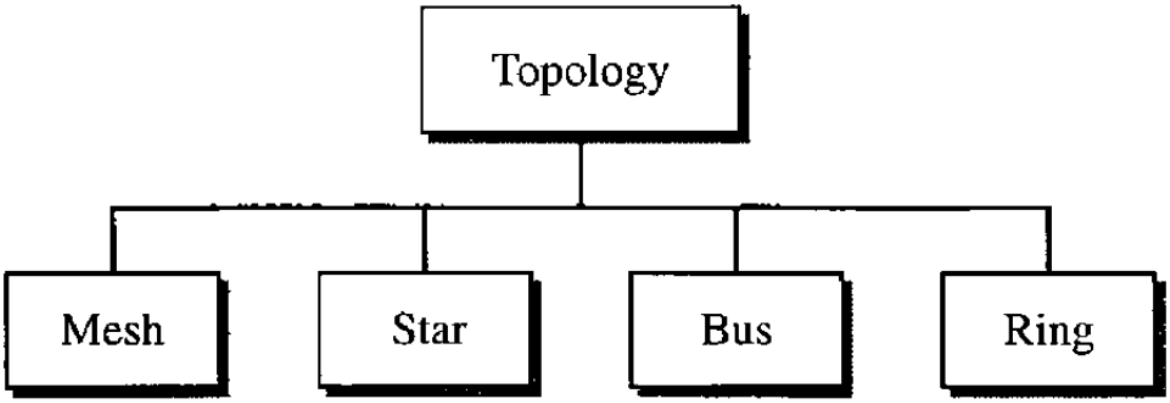

Figure 8: Network Topology categories

XI. BUS TOPOLOGY

The Bus topology consists of a single cable that runs to every work-station. The bus topology is also known as linear bus. In other words, all the nodes (computers and servers) are connected to the single cable (called bus), by the help of interface connectors. This central cable is the back bone of the network and every workstation communicates with the other device through this bus.

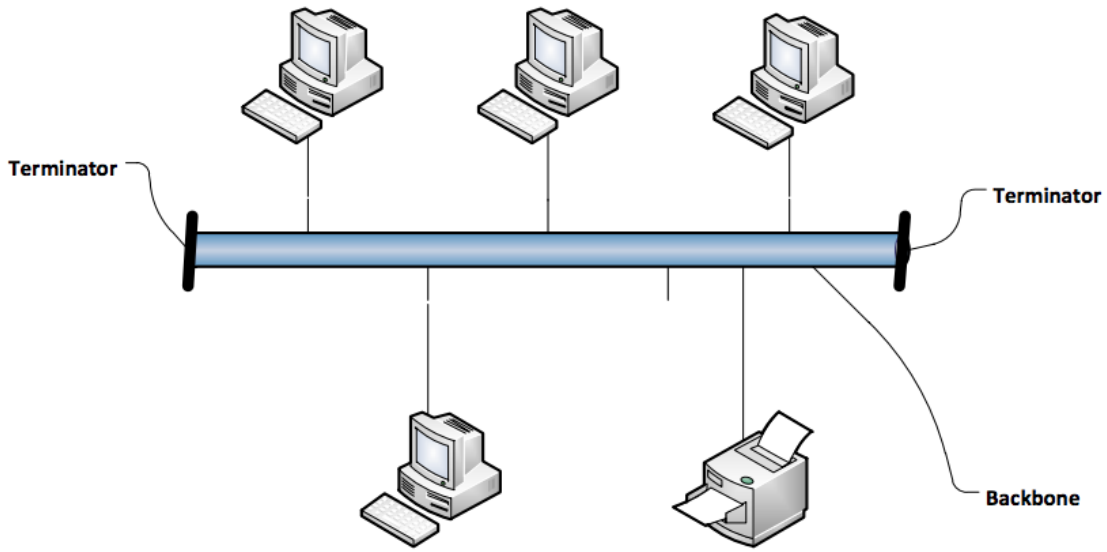

Figure 9: Bus Topology

Computers on a bus topology network communicate by addressing data to a particular computer and putting that data on the cable in the form of electronic signals. To understand how computers communicate on a bus you need to be familiar with three concepts: Sending the signal: Network data in the form of electronic signals is sent to all of the computers on the network; however, the information is accepted only by the computer whose address matches the address encoded in the original signal. Only one computer at a time can send messages. Because only one computer at a time can send data on a bus network, network performance is affected by the number of computers attached to the bus. The more computers on a bus, the more computers there will be waiting to put data on the bus, and the slower the network. There is no standard measure for the impact of numbers of computers on any given network. The amount the network slows down is not solely related to the number of computers on the network. It depends on numerous factors including:

- Terminator
- Terminator
- Backbone

Hardware capacities of computers on the network Number of times computers on the network transmit data Type of applications being run on the network Types of cable used on the network Distance between computers on the network The bus is a passive topology. Computers on a bus only listen for data being sent on the network. They are not responsible for moving data from one computer to the next. If one computer fails, it does not affect the rest of the network. In active topology computers regenerate signals and move data along the network.

Signal Bounce: Because the data, or electronic signal, is sent to the entire network, it will travel from one end of the cable to the other. If the signal were allowed to continue uninterrupted, it would keep bouncing back and forth along the cable and prevent other computers from sending signals. Therefore, the signal must be stopped.

The Terminator: To stop the signal from bouncing, a component called a terminator is placed at each end of the cable to absorb free signals. Absorbing the signal clears the cable so that other computers can send data. Every cable end on the network must be plugged into something. For example, a cable end could be plugged into a computer or a connector to extend the cable length. Any open cable ends-ends not plugged into something – must be terminated to prevent signal bounce.

In bus topology nodes are connected to the bus cable by drop lines and taps. See figure 10. A drop line is a connection running between the device and the main cable. A tap is aconnector that either splices into the main cable or punctures the sheathing of a cable to create a contact with the metallic core. As a signal travels along the backbone, some of its energy is transformed into heat. Therefore, it becomes weaker and weaker as it travels farther and farther. For this reason there is a limit on the number of taps a bus can support and on the distance between those taps.

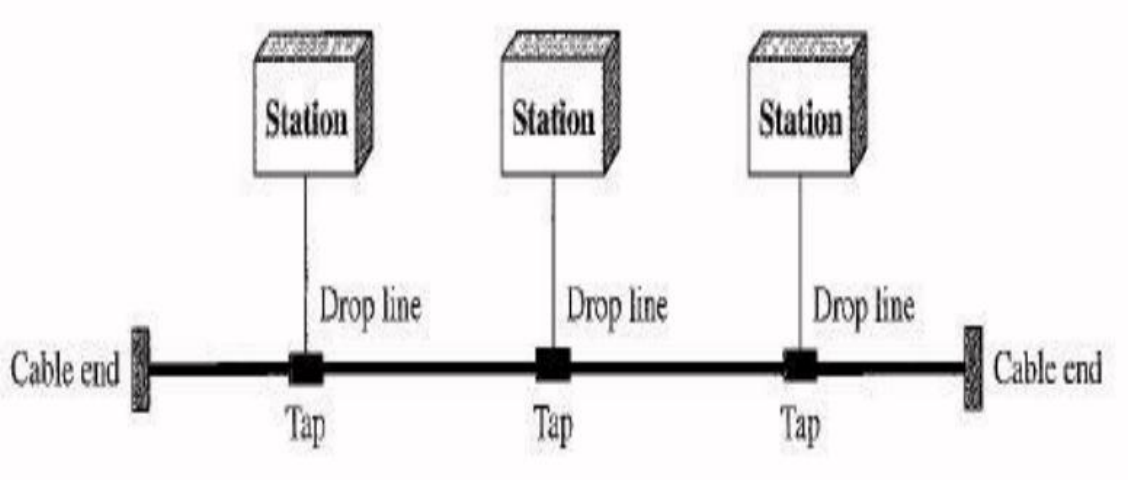

Figure 10: Bus Topology with three stations

11.1 Advantages of Linear Bus Topology

- It is easy to set-up and extend bus network.
- Cable length required for this topology is the least compared to other networks.
- Bus topology very cheap.
- Linear Bus network is mostly used in small networks.

11.2 Disadvantages of Linear Bus Topology

- There is a limit on central cable length and number of nodes that can be connected.
- Dependency on central cable in this topology has its disadvantages. If the main cable (i.e. bus) encounters some problem, whole network breaks down.
- Proper termination is required to dump signals. Use of terminators is must.
- It is difficult to detect and troubleshoot fault at individual station.
- Maintenance costs can get higher with time.
- Efficiency of Bus network reduces, as the number of devices connected to it increases.
- It is not suitable for networks with heavy traffic.
- Security is very low because all the computers receive the sent signal from the source.

XII. RING TOPOLOGY

The ring topology connects computers on a single circle of cable. There are no terminated ends. A ring topology connects one host to the next and the last host to the first. The signal travels around the loop in one direction and pass through each computer. Unlike the passive bus topology, each computer acts like a repeater to boost the signal and send it on to the next computer. Because the signal passes through each computer, the failure of one computer can impact the entire network.

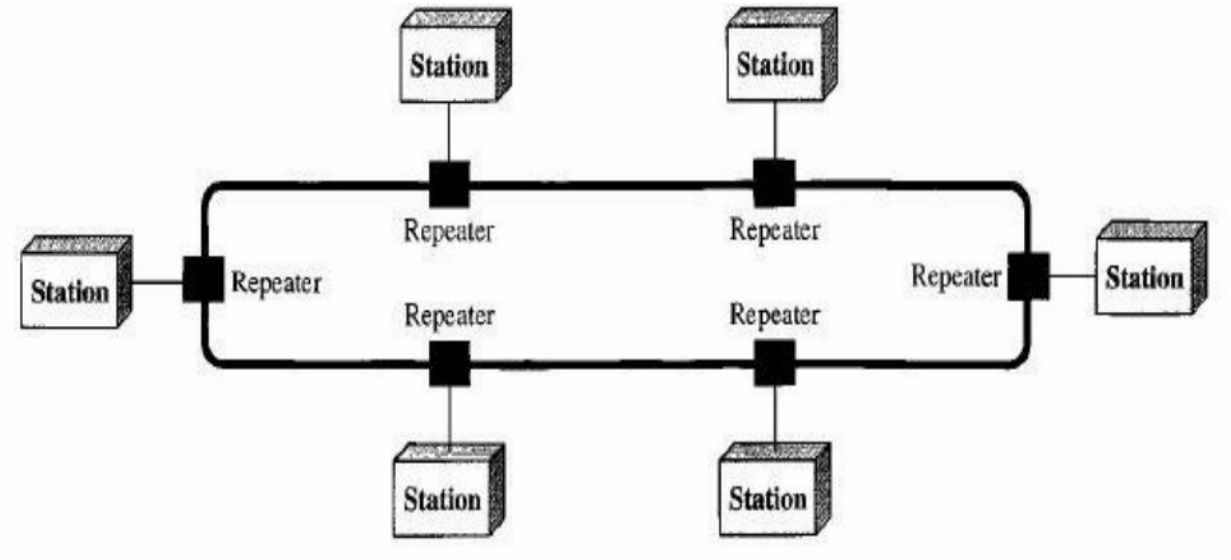

Figure 11: Ring Topology

One method of transmitting data around a ring is called token passing. The token is passed from computer to computer until it gets to a computer that has data to send. The sending computer modifies the token, puts an electronic address on the data, and sends it around the ring.

12.1 Advantages of Ring Topology

1) This type of network topology is very organized. Each node gets to send the data when it receives an empty token. This helps to reduces chances of collision. Also in ring topology all the traffic flows in only one direction at very high speed.
2) Even when the load on the network increases, its performance is better than that of Bus topology.
3) There is no need for network server to control the connectivity between workstations.
4) Additional components do not affect the performance of network.
5) Each computer has equal access to resources.

12.2 Disadvantages of Ring Topology

1) Each packet of data must pass through all the computers between source and destination. This makes it slower than Star topology.
2) If one workstation or port goes down, the entire network gets affected.
3) Network is highly dependent on the wire which connects different components.
4) MAU"s and network cards are expensive as compared to Ethernet cards and hubs.

XIII. STAR TOPOLOGY

In the star topology, computers are connected by cable segments to centralized component, called a hub or switch.Signals are transmitted from the sending computer through the hub or switch to all computers on the network. This topology originated in the early days of computing with computers connected to a centralized mainframe computer. It is now a common topology in microcomputer networking. Each device has a dedicated point-to-point link only to a central controller, usually called a hub. The devices are not directly linked to one another. Unlike a mesh topology, a star topology does not allow direct traffic between devices. The controller acts as an exchange: If one device wants to send data to another, it sends the data to the controller, which then relays the data to the other connected device (see Figure 12)

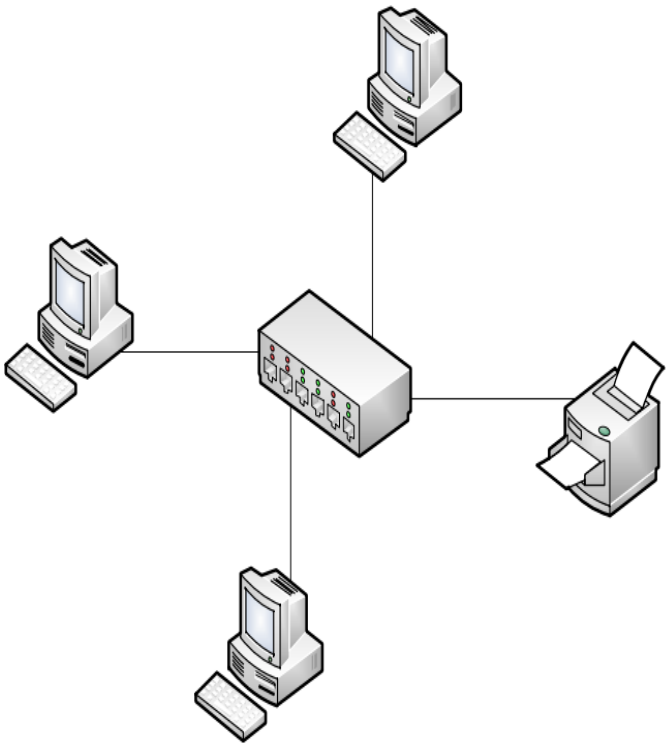

Figure 12: Star Topology

The star network offers centralized resources and management. However, because each computer is connected to a central point, this topology requires a great deal of cable in a large network installation. Also, if the central point fails, the entire network goes down.

13.1 Advantages of Star Topology

- As compared to Bus topology it gives far much better performance, signals don't necessarily get transmitted to all the workstations. A sent signal reaches the intended destination after passing through no more than 3-4 devices and 2-3 links. Performance of the network is dependent on the capacity of central hub.
- Easy to connect new nodes or devices. In star topology new nodes can be added easily without affecting rest of the network. Similarly components can also be removed easily.
- Centralized management. It helps in monitoring the network.
- Failure of one node or link doesn't affect the rest of network. At the same time it is easy to detect the failure and troubleshoot it.

13.2 Disadvantages of Star Topology

- Too much dependency on central device has its own drawbacks. If it fails whole network goes down.
- The use of hub, a router or a switch as central device increases the overall cost of the network.
- Performance and as well number of nodes which can be added in such topology is depended on capacity of central device.

XIV. MESH TOPOLOGY

In a mesh topology, every device has a dedicated point-to point link to every other device. The term dedicated means that the link carries traffic only between the two devices it connects. In a mesh topology, Node1 must be connected to n 1 nodes, node2 must be connected to (n – 1) nodes, and finally node n must be connected to (n – 1) nodes. We need n(n - 1) physical links. In other words, we can say that in a mesh topology, we need n(n – 1)/2

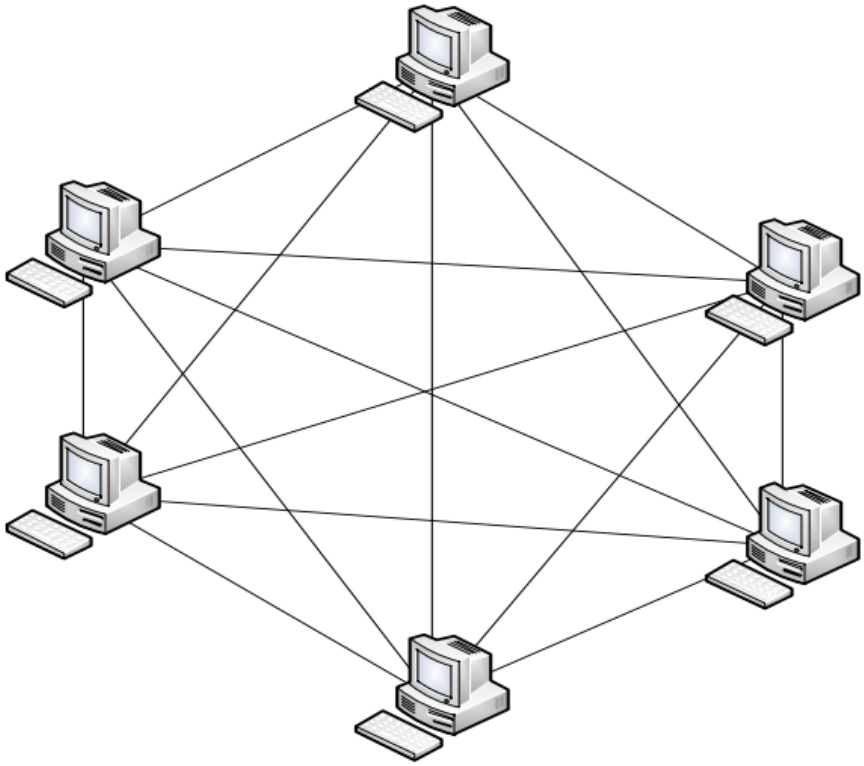

Figure 13: Mesh topology

To accommodate many links, every device on the network must have (n – 1) input/output (I/O) ports to be connected to the (n – 1) stations as shown in Figure above. For these reasons a mesh topology is usually implemented in a limited fashion, as a backbone connecting the main computers of a hybrid network that can include several other topologies. One practical example of a mesh topology is the connection of telephone regional offices in which each regional office needs to be connected to every other regional office.

14.1 Advantages of Mesh topology

- Data can be transmitted from different devices simultaneously. This topology can withstand high traffic.
- Even if one of the components fails there is always an alternative present. So data transfer doesn't get affected.
- Expansion and modification in topology can be done without disrupting other nodes.

14.1 Disadvantages of Mesh topology

- There are high chances of redundancy in many of the network connections.
- Overall cost of this network is way too high as compared to other network topologies.
- Set-up and maintenance of this topology is very difficult. Even administration of the network is tough.

XV. HYBRID TOPOLOGY

Before starting about Hybrid topology, we saw that a network topology is a connection of various links and nodes, communicating with each other for transfer of data. We also saw various advantages and disadvantages of Star, Bus, Ring, Mesh. Hybrid, as the name suggests, is mixture of two different things. Similarly in this type of topology we integrate two or more different topologies to form a resultant topology which has good points (as well as weaknesses) of all the constituent basic topologies rather than having characteristics of one specific topology. This combination of topologies is done according to the requirements of the organization.

For example, if there is an existing ring topology in one office department while a bus topology in another department, connecting these two will result in Hybrid topology. Remember connecting two similar topologies cannot be termed as Hybrid topology. Star-Ring and Star-Bus networks are most common examples of hybrid network.

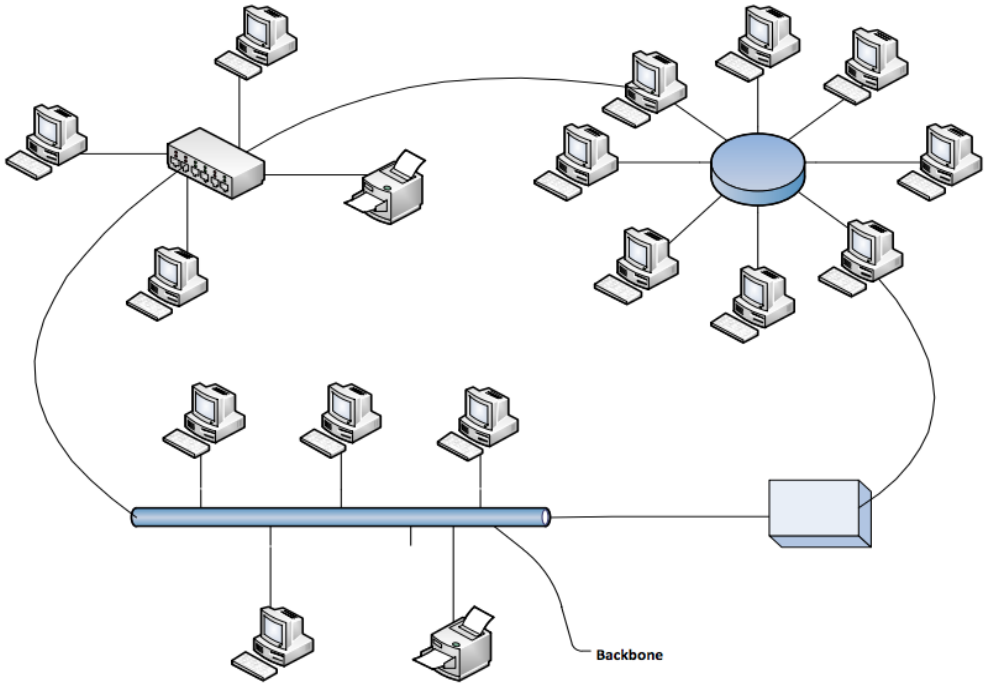

Figure 14: Hybrid Network

15.1 Advantages of Hybrid Network Topology

- Reliable: Unlike other networks, fault detection and troubleshooting is easy in this type of topology. The part in which fault is detected can be isolated from the rest of network and required corrective measures can be taken, WITHOUT affecting the functioning of rest of the network.
- Scalable: It's easy to increase the size of network by adding new components, without disturbing existing architecture.
- Flexible: Hybrid Network can be designed according to the requirements of the organization and by optimizing the available resources. Special care can be given to nodes where traffic is high as well as where chances of fault are high.
- Effective: Hybrid topology is the combination of two or more topologies, so we can design it in such a way that strengths of constituent topologies are maximized while there weaknesses are neutralized.

For example we saw Ring Topology has good data reliability (achieved by use of tokens) and Star topology has high tolerance capability (as each node is not directly connected to other but through central device), so these two can be used effectively in hybrid star-ring topology.

15.2 Disadvantages of Hybrid Topology

- Complexity of Design: One of the biggest drawbacks of hybrid topology is its design. It is not easy to design this type of architecture and it's a tough job for designers. Configuration and installation process needs to be very efficient.
- Costly Hub: The hubs used to connect two distinct networks, are very expensive. These hubs are different from usual hubs as they need to be intelligent enough to work with different architectures and should be function even if a part of network is down.
- Costly Infrastructure: As hybrid architectures are usually larger in scale, they require a lot of cables; cooling systems, sophisticate network devices, etc.

XVI. COMMUNICATION PROTOCOL

A protocol is a set of rules that govern data communications. It represents an agreement between the communicating devices. Without a protocol, two devices may be connected but not communicating, just as a person speaking English cannot be understood by a person who speaks only Spanish. Acommunication protocol is a description of the rules that communication devices must follow to communicate with each other. A Protocol is one of the components of a data communications system. Without protocol communication cannot occur. The sending device cannot just send the data and expect the receiving device to receive and further interpret it correctly.There are three key elements of a protocol:

- Syntax is the structure or format of the data. It is the arrangement of data in a particular order.
- Semantics gives the meaning of each section of bits and indicates the interpretation of each section. It also tells what action/decision is to be taken based on the interpretation.
- Timing tells the sender about the readiness of the receiver to receive the data It tells the sender at what rate the data should be sent to the receiver to avoid overwhelming the receiver.

Transmission Control Protocol (TCP) TCP/IP is the basic communication protocol for two or more computers or electronic devices (e.g. mobile phone) to communicate with one another on a network setup. TCP/IP stands for Transmission Control Protocol/Internet Protocol. TCP/IP defines how electronic devices (like computers) should be connected to the Internet, and how data should be transmitted between them. TCP/IP is the major protocol in communication network that communication can do without. Inside the TCP/IP standard there are several protocols for handling data communication these are: TCP (Transmission Control Protocol) communication between applications; UDP(User Datagram Protocol) simple communication between applications; IP (Internet Protocol) communication between computers; ICMP (Internet Control Message Protocol) for errors and statistics; DHCP (Dynamic Host Configuration Protocol) for dynamic addressing; and TCP Uses a Fixed Connection.

Transmission Control Protocol: Transmission Control Protocol takes care of the communication between your application software (i.e. your browser) and your network software. TCP is responsible for breaking data down into IP packets before they are sent, and for assembling the packets when they arrive. TCP is for communication between applications. If one application wants to communicate with another via TCP, it sends a communication request. This request must be sent to an exact address. After a "handshake" between the two applications, TCP will set up a "full-duplex" communication between the two applications. The "full-duplex" communication will occupy the communication line between the two computers until it is closed by one of the two applications.

Internet Protocol: Internet Protocol is Connection-Less i.e., it does not occupy the communication line between two computers. The Network Layer protocol for TCP/IP is the Internet Protocol (IP). It uses IP addresses and the subnet mask to determine whether the datagram is on the local or a remote network. If it is on the remote network, the datagram is forwarded to the default gateway which is a router that links to another network. IP keeps track of the number of transverses through each router that the datagram goes through to reach its destination. Each transvers is called a hop. If the hop count exceeds 255 hops, the datagram is removed and the destination considered unreachable. IPreduces the need for network lines. Each line can be used for communication between many different computers at the same time. With IP, messages (or other data) are broken up into small independent "packets" and sent between computers via the Internet. IP is responsible for "routing" each packet to the correct destination.

Special Purpose Protocol: The special purpose protocols are the set of protocols design to perform a single task on communication network system. Some of these protocols and their function are listed below:

- HTTP - Hyper Text Transfer Protocol: HTTP takes care of the communication between a web server and a web browser. HTTP is used for sending requests from a web client (a browser) to a web server, returning web content (web pages) from the server back to the client.
- HTTPS - Secure HTTP: HTTPS takes care of secure communication between a web server and a web browser. HTTPS typically handles credit card transactions and other sensitive data.
- SSL - Secure Sockets Layer: The SSL protocol is used for encryption of data for secure data transmission.
- MIME - Multi-purpose Internet Mail Extensions: The MIME protocol lets SMTP transmit multimedia files including voice, audio, and binary data across TCP/IP networks.
- IMAP - Internet Message Access Protocol: IMAP is used for storing and retrieving e-mails.
- FTP - File Transfer Protocol: FTP takes care of transmission of files between computers.
- NTP - Network Time Protocol: NTP is used to synchronize the time (the clock) between computers.
- DHCP - Dynamic Host Configuration Protocol: DHCP is used for allocation of dynamic IP addresses to computers in a network.
- SNMP - Simple Network Management Protocol: SNMP is used for administration of computer networks.
- LDAP - Lightweight Directory Access Protocol: LDAP is used for collecting information about users and e-mail addresses from the internet.
- ICMP - Internet Control Message Protocol: ICMP takes care of error-handling in the network.
- ARP - Address Resolution Protocol: ARP is used by IP to find the hardware address of a computer network card based on the IP address.
- RARP - Reverse Address Resolution Protocol: RARP is used by IP to find the IP address based on the hardware address of a computer network card.

XVII. TRANSMISSION MODES

A transmission may be simplex, half duplex, or full duplex. In simplex transmission, signals are transmitted in only one direction; one station is transmitter and the other is receiver. In half-duplex operation, both stations may transmit, but only one at a time. In full-duplex operation, both stations may transmit simultaneously.

Simplex Transmission In simplex mode, the communication is unidirectional, as on a one-way street. Only one of the two devices on a link can transmit; the other can only receive. Keyboards and traditional monitors are examples of simplex devices. The keyboard can only

introduce input; the monitor can only accept output. The simplex mode can use the entire capacity of the channel to send data in one direction. Examples are Radio and Television broadcasts. They go from the TV station to your home television.

Half Duplex Transmission In half-duplex mode, each station can both transmit and receive, but not at the same time. When one device is sending, the other can only receive, and vice versa. The half-duplex mode is like a one-lane road withtraffic allowed in both directions. When cars are traveling in one direction, cars going the other way must wait. In a half-duplex transmission, the entire capacity of a channel is taken over by whichever of the two devices is transmitting at the time.

Full Duplex Transmission In full-duplex mode, both stations can transmit and receive simultaneously. The full-duplex mode is like a two way street with traffic flowing in both directions at the same time. One common example of full-duplex communication is the telephone network. When two people are communicating by a telephone line, both can talk and listen at the same time. Figure 15 illustrates the data flow

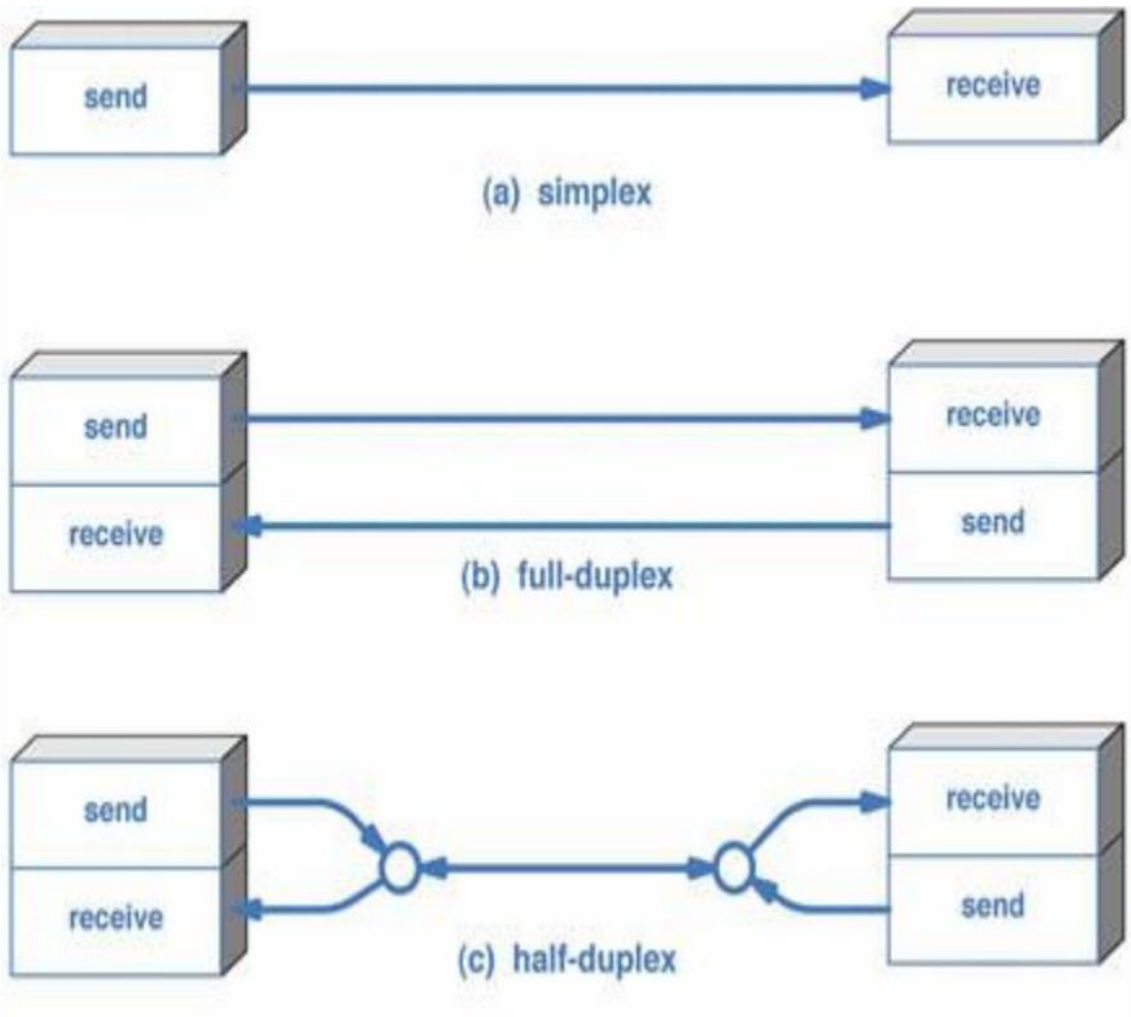

Figure 15: Data Transmission Mode

XVIII. DATA TRANSMISSION MEDIA

Transmission media is a pathway that carries the information from sender to receiver. We use different types of cables or waves to transmit data. Data is transmitted normally through electrical or electromagnetic signals. An electrical signal is in the form of current. An electromagnetic signal is series of electromagnetic energy pulses at various frequencies. These signals can be transmitted through copper wires, optical fibers, atmosphere, water and vacuum Different Medias have different properties like bandwidth, delay, cost and ease of installation and maintenance. Transmission media is also called Communication channel. Transmission media is broadly classified into two groups. Wired or Guided Media or Bound Transmission Media and Wireless or Unguided Media or Unbound Transmission Media. (See the diagram below).

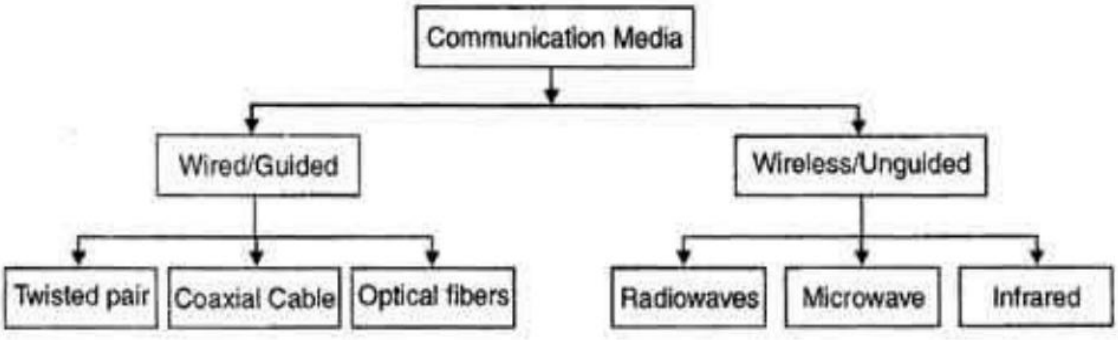

Figure 16: Data Transmission Media

The data transmission capabilities of various Medias vary differently upon: Bandwidth. It refers to the data carrying capacity of a channel or medium. Higher bandwidth communication channels support higher data rates; Radiation. It refers to the leakage of signal from the medium due to undesirable electrical characteristics of the medium; Noise Absorption. It refers to the susceptibility of the media to external electrical noise that can cause distortion of data signal; Attenuation. It refers to loss of energy as signal propagates outwards. The amount of energy lost depends on frequency. Radiations and physical characteristics of media contribute to attenuation.

XIX. APPLICATION OF OPERATIONS RESEARCH IN DATA ROUTING

A Telecommunication network performs the function of data transmission from one point or device, called the transmitter to another point or device, called the receiver.There are both wired as well as wireless telecommunication networks that are existing and are widely used, however, here just the wired networks have been considered.In a wired network, data is transmitted through fixed paths via the use of either electrical cables or optical fibers.

A network tends to consist of a wide number of switches that are interconnected to one another giving rise to a number of potential paths for data transfer between any 2 given nodes. As a result of this, an important issue that arises in any data transmission is of the path to be chosen for such data transmission. This is called the process of routing. The cables are passive when it comes to routing, whereas the switches actively route the signals through the network.A network can either be Packet Switched (like the Internet) or Circuit Switches (like the old telephone network).

In a packet switched network, the data is forwarded by the nodes. Packets transmitted between any 2 nodes may choose different routes.The method of routing used here is called Open Shortest Path First (OSPF Routing). Here, each switch builds a table containing different routes to the other respective nodes, as well as the shortest path available to any other switch from itself.The routing is distributed in this method, as a result of which packets are split and sent through the available routes from source to destination to ensure faster communication of data. The advantage of this is also that if one part of the network becomes dysfunctional due to some reasons, the other half of the network can handle the traffic, however at the cost of reduced speed.This distribution, however, makes it extremely difficult to control the network as now the data has been divided and is travelling via many paths.This type of routing ensures that the nodes are actively updated with the data, however at the same time if a packet cannot be forwarded due to certain glitches, it is dropped altogether resulting in a buffer.Another issue faced here is that sometimes, due to a number of paths being available, the overall model becomes extremely complex.

XX. OTHER APPLICATIONS OF OR IN TELECOMMUNICATIONS

Apart from being used in networks for the correct and optimal routing of packets from source to destination, Operations Research finds several other applications in the operational side of the Telecommunications industry. For the following, our data is based on our interactions with Reliance Jio.

20.1 Allocation and Distribution in Projects

Various models of OR are used for the purpose of allocation and distribution of various resources like manpower, materials as well as machine hours, in aspects of production of items (such as Sim Cards, Dongles etc.) as well as the packaging and repackaging of the same for the purpose of transport.Operational Research Model of Linear Programming Problem along with the Simplex Method have been used by Reliance Jio when it came to determination of their production of different product lines such as sim cards, routers and dongles. Items meant for sales with similar raw material pool are grouped together in a model to determine the supply. At the same time, heavy

advertisement outlay and an attractive and extensive promotion ensures an exhausted supply of the same, thus giving optimal profitability.At the same time, packaging costs were minimized by pooling all product lines that needed packaging and used the same set of resources into a single LPP model with a minimizing objective.

20.2 Production and Facilities Planning

Apart from helping in determining the optimal product mix (through the use of Linear Programming Problem), Operations Research also finds applications in the Transportation of both materials as well as finished goods. In the case of Reliance Jio, material for Sim Cards finds source from Tokyo in Japan. The same is flown into the country via 80 charters every single day for production to keep up with the demand terms. Reliance Jio has production houses and centers in all established cities of the country and so the first question posed here was where shall the charter be flown into to minimize cost and time. Transportation Models were used for the same and the results stated that Chennai was the destination. Further, from Chennai the material is then sent to different parts of the country with routes being decided using the Transportation Model.Post production, the dongles and sim cards are then sent out to the different retail Jio stores in each city from where they can be accessed by the ultimate customers.

XXI. LIMITATIONS OF OPERATIONS RESEARCH

- A paradox is seen in a business when it comes to the appointment of an OR specialist for the purpose of applying the techniques as such a person is unlikely to know the business' problems, whereas a manager won't be equipped with the knowledge of OR for its application.
- OR aims at taking into account every single variable, quantifying their terms and trying to achieve optimal solutions out of the same. However, in the real world, factors are erroneous and expressing them in quantitative terms is extremely difficult as a result of which relationships that are to be established between these variables require huge calculations, the sort which can be done only via machines.
- The data on the basis of which optimal solutions are generated are subjected to a number of changes, and incorporating these changes into the models becomes extremely expensive as well as redundant, due to the frequency of change.
- Only in a situation where all the factors pertaining to a problem can be quantifiable, will any operations research model provide a solution, or else it won't. At the same time, a model doesn't consider any emotional or qualitative factors for construction of the solution.
- Once a decision is arrived at, it must be implemented delicately and accurately. Any mistake in the same will result in problems arising for the business.

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