Subject Name: **Data Communication and Computer Network**

Subject Code: **05101202**

Chapter No. 01 Network Basics

1. Uses of Computer Networks
2. Network Hardware
3. Network Software
4. Reference Models

Uses of Computer Networks

- The **18th century** was the era of the great mechanical systems accompanying the **Industrial Revolution**.
- Major inventions during Industrial Revolution includes Textile Manufacturing, Iron Industry, Steam Power, Machine Tools, Chemicals, Cement, Paper Machine, Agriculture, Mining, Transportation etc
- The **19th century** was the age of the **steam engine**.
- During the **20th century**, the key technology was **information gathering**, **processing** and **distribution**.
- Among other developments, we saw the installation of **worldwide telephone networks**, the **invention of radio** and **television**, the birth and unprecedented growth of the **computer industry**, and the **launching of communication satellites**.

Uses of Computer Networks

- Organizations with **hundreds of offices spread over a wide geographical area** routinely expect to be able to examine the current status of even their most remote outpost at the push of a button.

- Initially, **computer system were highly centralized**, usually within a **single large room**, but after that the scenario was changed.

- As per the requirement of organizations, the concept of **"Computer Network"** was come into the picture.

Uses of Computer Networks

- ***Computer Network*** **:** It is a collection of **autonomous computers** interconnected by a single technology.

- A network that is administered by a single set of management rules that are controlled by one person, group or organization. **Autonomous** systems often use only one routing protocol, although multiple protocols can be used.
- Two computers are said to be **interconnected** if they are able to exchange information.
- The connection need not be via a copper wire; fiber optics, microwaves, infrared, and communication satellites can also be used.

- Networks come in many **sizes** (No of devices) , **shapes** (Topology) and **form**s (Types of Network)

Uses of Computer Networks

- **Computer networking** means connecting two or more computers for the **sharing of information and resources**.
- The size and complexity of a network may vary from just **two computers** connecting together to a much more complex network that connects **all the computers of a worldwide company**.

1.Complexity of Network depends on

2.the number of nodes and

3.Distance between source to destination

4.alternative paths that exist within a **computer network**, as well as

5.the variety of communication media,

6.communications equipment,

7.protocols, and

8.hardware and software platforms found in the **network**.

- The basic reason for the existence of networks is that the PC is a single user device and a network can change a group of isolated PCs into a coordinated **multiuser** computer system.

Uses of Computer Networks

- Definition of **Computer Network**: A Network is a collection of H/W and S/W that enables a group of computers to communicate and provide users with access to shared resources.

- There is considerable confusion in the literature between a **computer network** and a **distributed system.**

- The key distinction is that in a **distributed system**, a collection of independent computers appears to its users as a single coherent system.

- A well-known example of a distributed system is the **World Wide Web**, in which everything looks like a document (**Web page**).

Computer Network VS Distributed Systems

Computer Networks:

– A computer network is an **interconnected collection of autonomous computers** able to exchange information.

– A computer network usually **require users to explicitly login** onto one machine, explicitly submit jobs remotely, explicitly move files/data around the network.

• **Distributed Systems:**

– The **existence of multiple autonomous computers** in a computer network is transparent to the user.

– The operating system automatically allocates jobs to processors, moves files among various computers without explicit user intervention.

Some examples of distributed systems include:

- A **network** operating **system** is made up of software and associated protocols that allow a set of **computer network** to be used together.
- A **distributed operating system** is a software over a collection of independent, networked, communicating, and physically separate computational nodes. They handle jobs which are serviced by multiple CPUs.
- **Some examples of distributed systems include**
- Telecommunication networks
- The internet
- Peep-to-peer networks
- Airline reservation systems
- Distributed databases
- Scientific computing
- Distributed rendering

Uses of Computer Networks

- Uses of computer network at companies and for individuals.

1. Business Applications:

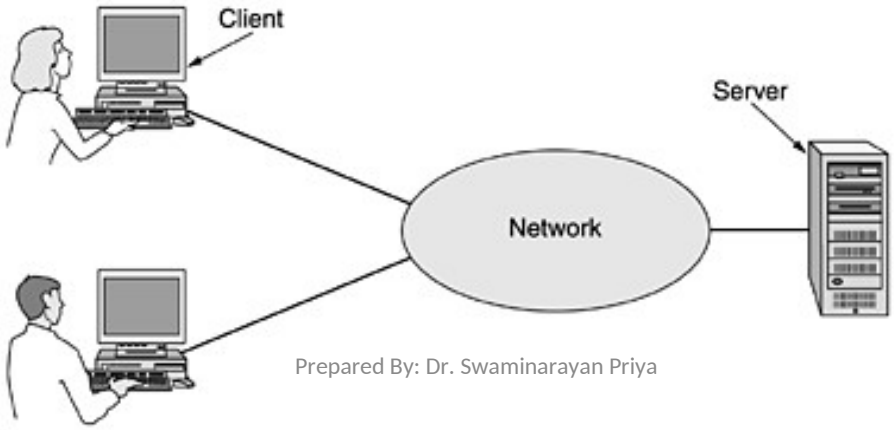
- ***Resource Sharing***: Most of all companies have large no. of computers, initially, each of these computers may have worked isolated but after that management may have decided to connect them to be able to extract and correlate information about the entire company. And one of the main goal of network is Resource Sharing. It means, to make all data, programs, equipment available to anyone on the network without considering physical location of the resources and users.

- One of the example is printer sharing. Instead of a private printer on every stand-alone PC, a high-volume networked printer is cheaper, faster and easier to maintain than a large collection of individual printers.

- Like printer, user can also share scanner, CD burners and many more.

Uses of Computer Networks

- **Sharing of data**, is also necessary in large and medium-sized company and many small size companies are dependent on computerized information like customer records, inventory accounts, financial statements, tax information etc.
- Normally, In a smaller companies, all computers are likely to be in a **single office or perhaps a single building**,
- but for larger ones, the computers and employees may be scattered over **dozens of offices and plants in many countries**. So for accessing all branch office's information, **client-server model** is very much useful.

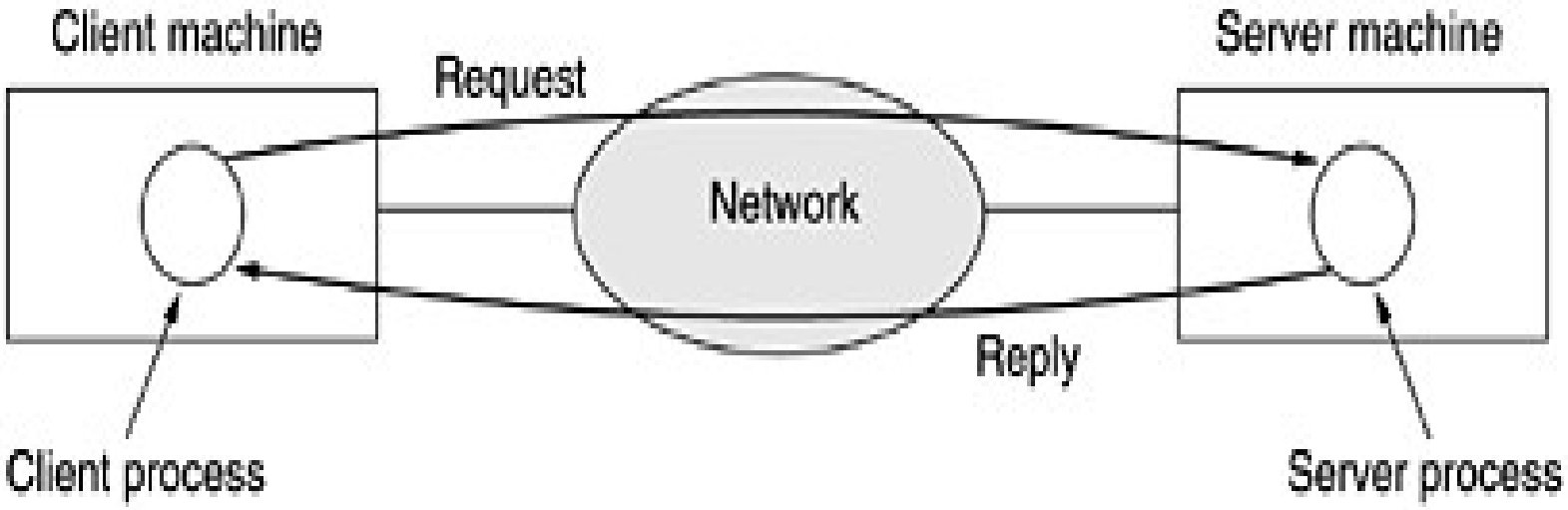


Uses of Computer Networks

- In this model, the data are stored on powerful computers called **Servers**. Server may have **one or more d'bases in** which, all information about companies, employees etc. are available and it is **maintained by a system administrator**.
- And the employees have **simple machines** called **client**, on their desks, through which **they can access remote data**.
- This type of arrangement is known as the client-server model. This **model is applicable** when the **client and server** both are in the same **building** and also when they **are far apart.**

Uses of Computer Networks

- For example, when we access any page on the world wide web, the same model is employed, here web server is being the server and the user's personal computer being the client.



Uses of Computer Networks

- A Second goal of setting up a computer network is ***To provide a powerful communication medium among employees***:
- Well-known communication medium among the employees is email (Electronic Mail) through which employees can easily & speedily communicate with each other. Even employer can easily send notices to their subordinates by email.
- With a network, it is easy for two or more people who work far apart to **write a report together**. When one worker makes a change to an **on-line document**, the others can see the change automatically, instead of waiting several days for a letter. **[online dashboards – eg. Bittle]**
- **Videoconferencing**: Using this technology, employees at distant locations can hold a meeting, seeing and hearing each other and even writing on a shared virtual black board.

Online Meeting Tools

- Zoom
- Google Meet
- Microsoft Teams
- GoToMeeting
- BlueJeans
- Zoho Meeting
- Cisco Webex
- Intermedia AnyMeeting
- FreeConference.com
- JoinMe
- Skype
- etc

Uses of Computer Networks

- To do business electronically with other companies, especially suppliers and customers.
- Some form of **e-commerce**

Tag	Full name	Example
B2C	Business-to-consumer	Ordering books on-line
B2B	Business-to-business	Car manufacturer ordering tires from supplier
G2C	Government-to-consumer	Government distributing tax forms electronically
C2C	Consumer-to-consumer	Auctioning second-hand products on line
P2P	Peer-to-peer	File sharing

G2G (Government to Government)

For eg. Manufacturers of automobiles, aircraft and computers, buy subsystems from a variety of suppliers and then assemble the part. So using computer networks, manufacturers can place orders electronically as and when needed, so it reduces the need for large inventories.

Types of E-Commerce

- **Business to consumer (B2C)**
- As the name suggests, the B2C ecommerce model represents a transaction between **businesses** and **individuals**. B2C ecommerce is the most common business model among both physical and online retailers.
- E.g Macy's, IKEA, and Netflix are all examples of companies that engage in B2C ecommerce.

- **Business to business (B2B)**
- In the B2B ecommerce model both parties involved are businesses. In this type of a transaction, one business provides the other with products and/or services.
- Car Manufacturing ordering tier from
- Slack, a platform for communication between remote businesses, and Xero, a cloud-based accounting software for businesses, are examples of B2B companies.

Types of E-Commerce

- **Consumer to business (C2B)**
- The C2B business model represents a transaction in which individuals create value for businesses, unlike the traditional business-to-consumer model where companies are the ones that deliver value. Consumers provide companies with products and/or services, co-operate on projects, and ultimately help businesses increase their profits.
- Review
- Freelancer, a freelance platform that connects remote workers and companies, is an example of a company that brings two parties to engage in C2B transactions.

- **Consumer to consumer (C2C)**
- C2C ecommerce happens when the two parties involved are consumers that trade with one another. eBay and Craigslist are examples of online marketplaces where individuals buy and sell products to each other.
- ShopGoodwill
- AuctionZip
- **Listia: No Cash Needed. Just Donate Your Old Stuff**
- **UBid: Overstock, Closeout, and Recertified Products**

Types of E-Commerce

- **Government to business (G2B)**
- The G2B ecommerce models happen when the government provides companies with goods and services. Government procurement, data centres, and e-learning are all examples of G2B ecommerce.

- **Consumer to government (C2G)**
- Every time consumers pay taxes, health insurance, electronic bills, or request information concerning the public sector, they're engaging in C2G.

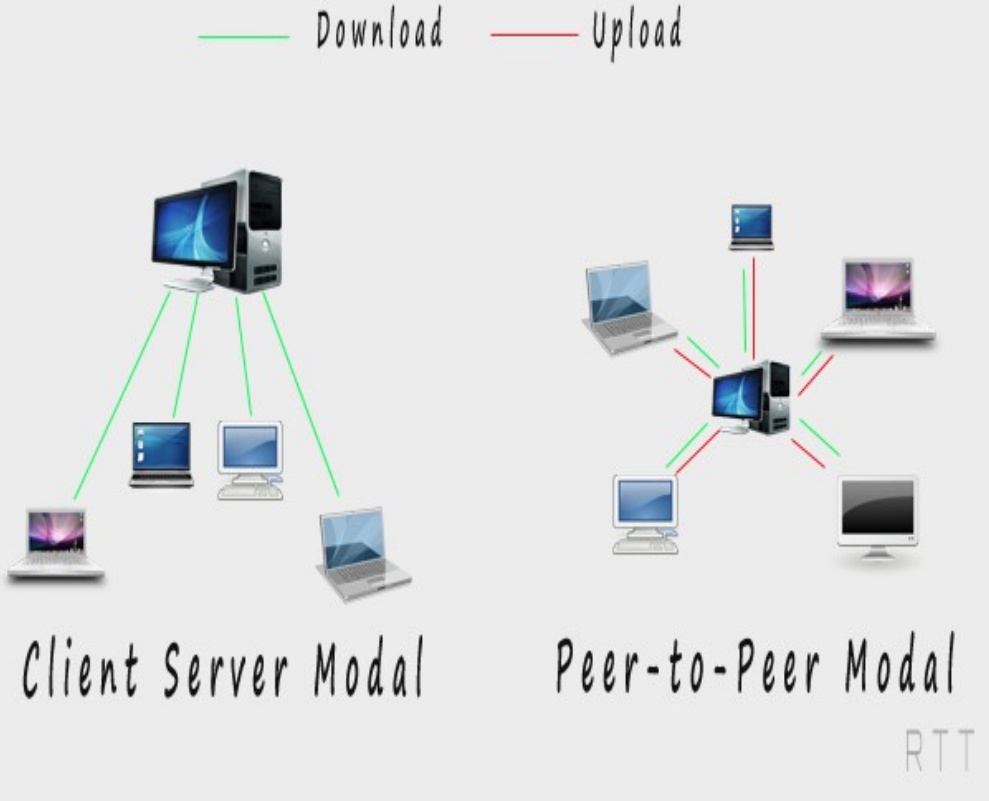
- **Business to government (B2G)**
- The B2G model refers to companies and businesses that provide goods and services for the government. For example, OpenGov is a company that offers governments cloud-based platforms for communication, reporting, and budgeting.

Uses of Computer Networks

2. Network for people:

- ***Access to remote information***: This is the most practical use of networks for people. Many people pay their bills, manage their bank accounts and handle their investments electronically.
- People can access WWW, which contains information about the arts, business, cooking, health, history, hobbies, science, sports, recreations and many more.
- ***Person-to-person or peer-to-peer communication:*** Peer to peer communication is different than client-server model, in there is no **fixed division into clients** and servers. All the computers are considered at the same level.
- In **peer to peer system,** each user maintain his own d'base locally and a list of other nearby people which are members of the systems. With the help of this list, new people can also communicate with the other people who are the members of that group.
- However, the next generation of peer-to-peer systems eliminates the central database by having each user maintain his own database locally, as well as providing a list of other nearby people who are members of the system.

Client Server Vs Peer-to-peer Model



Pros and cons of P2P

1.No need to take permission for communication
2.Limited size – maximum 10 to 12 computers are connected
3.No need for special software like NOS
4.Set-up is very easy
5.No maintenance cost
6.No centralized storage (it uses decentralized storage)
7.Data are scattered
8.Storage management is difficult
9.Less security

BASIS FOR COMAPAISON	CLIENT-SERVER	PEER-TO-PEER
Basic	There is a specific server and specific clients connected to the server.	Clients and server are not distinguished; each node act as client and server.
Service	The client request for service and server respond with the service.	Each node can request for services and can also provide the services.
Focus	Sharing the information.	Connectivity.
Data	The data is stored in a centralized server.	Each peer has its own data.
Server	When several clients request for the services simultaneously, a server can get bottlenecked.	As the services are provided by several servers distributed in the peer-to-peer system, a server in not bottlenecked.
Expense	The client-server are expensive to implement.	Peer-to-peer are less expensive to implement.
Stability	Client-Server is more stable and scalable.	Peer-to-Peer suffers if the number of peers increases in the system.

Uses of Computer Networks

- ***Interactive Entertainment:***
- People can also use network for entertainment like game playing, video on demand etc.

Uses of Computer Networks (Mobile Users)

- E.g. of mobile computers are **notebook computers** and PDA (*Personal Digital Assistants*).
- Many owners of these computers have desktop machines back at the office and want to connect to their home base even when away from home.
- **Laptop**: A portable computer small enough to use on one's lap.
  Notebook: A light, portable computer that is **generally thinner** than a laptop.

- Wireless networks are important to the **military.**
- Wireless networking and mobile computing are often related, but they are not identical.

Wireless Vs Mobile

Following table shows a distinction between **fixed wireless** and **mobile wireless**.

Wireless	Mobile	Applications
		Desktop computers in offices
		A notebook computer used in a hotel room
		Networks in older, unwired building
		Portable Office; PDA for store inventory

Uses of Computer Networks (Mobile Users)

Wireless	Mobile	Applications
No	No	Desktop computers in offices
No	Yes	A notebook computer used in a hotel room
Yes	No	Networks in older, unwired building
Yes	Yes	Portable Office; PDA for store inventory

2) Network Hardware

- **Computer Networks are classifying according to their Transmission Technology and their scale.**

1. **There are two types of transmission technology that are in widespread use.**

- **Transmission Technology defines how the data are transferred from one node to another node.**
- **They are as follows:**

1. **Broadcast links.**
2. **Point-to-point links.**

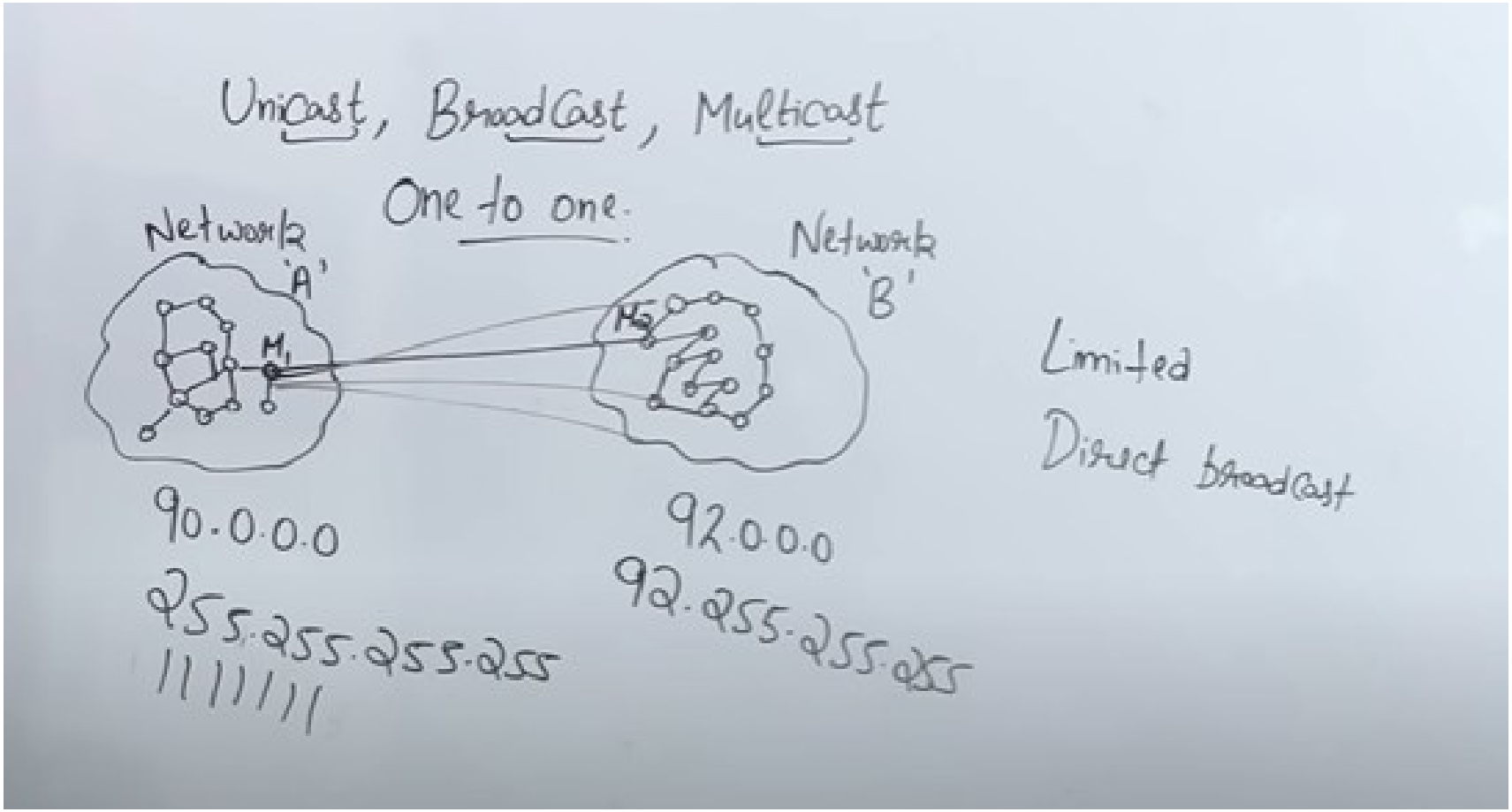
Transmission Technology (Broad-Cast Network)

- **Broadcast networks have a single communication channel that is shared by all the machines on the network.**
- **Short messages, called packets in certain contexts, sent by any machine are received by all the others.**
- **An address field within the packet specifies the intended recipient. Upon receiving a packet, a machine checks the address field. If the packet is intended for the receiving machine, that machine processes the packet; if the packet is intended for some other machine, it is just ignored.**
- **Broadcast systems generally also allow the possibility of addressing a packet to all destinations by using a special code in the address field. When a packet with this code is transmitted, it is received and processed by every machine on the network. This mode of operation is called broadcasting.**

Transmission Technology (Broad Cast Network)

- Some broadcast systems also support transmission to a subset of the machines, something known as multicasting.
- One possible scheme is to reserve one bit to indicate multicasting. The remaining n - 1 address bits can hold a group number. Each machine can ''subscribe'' to any or all of the groups. When a packet is sent to a certain group, it is delivered to all machines subscribing to that group.
- Broadcast transmission with one sender and one receiver is sometimes called unicasting.
- Broadcast transmission from one sender to all receivers is sometimes called broadcasting.

(1) M1 (Network A) to M2(Network B) = Unicasting
(2) M1 to all (within Network A) = Limited Broadcasting (Address – 255.255.255.255)
(3) M1 to all (Network B) = Direct Broadcasting (Address – 92.255.255.255)
(4) M1 to group of Computers = Multicasting
Internet Group Management Protocol - IGMP – used for Multicasting

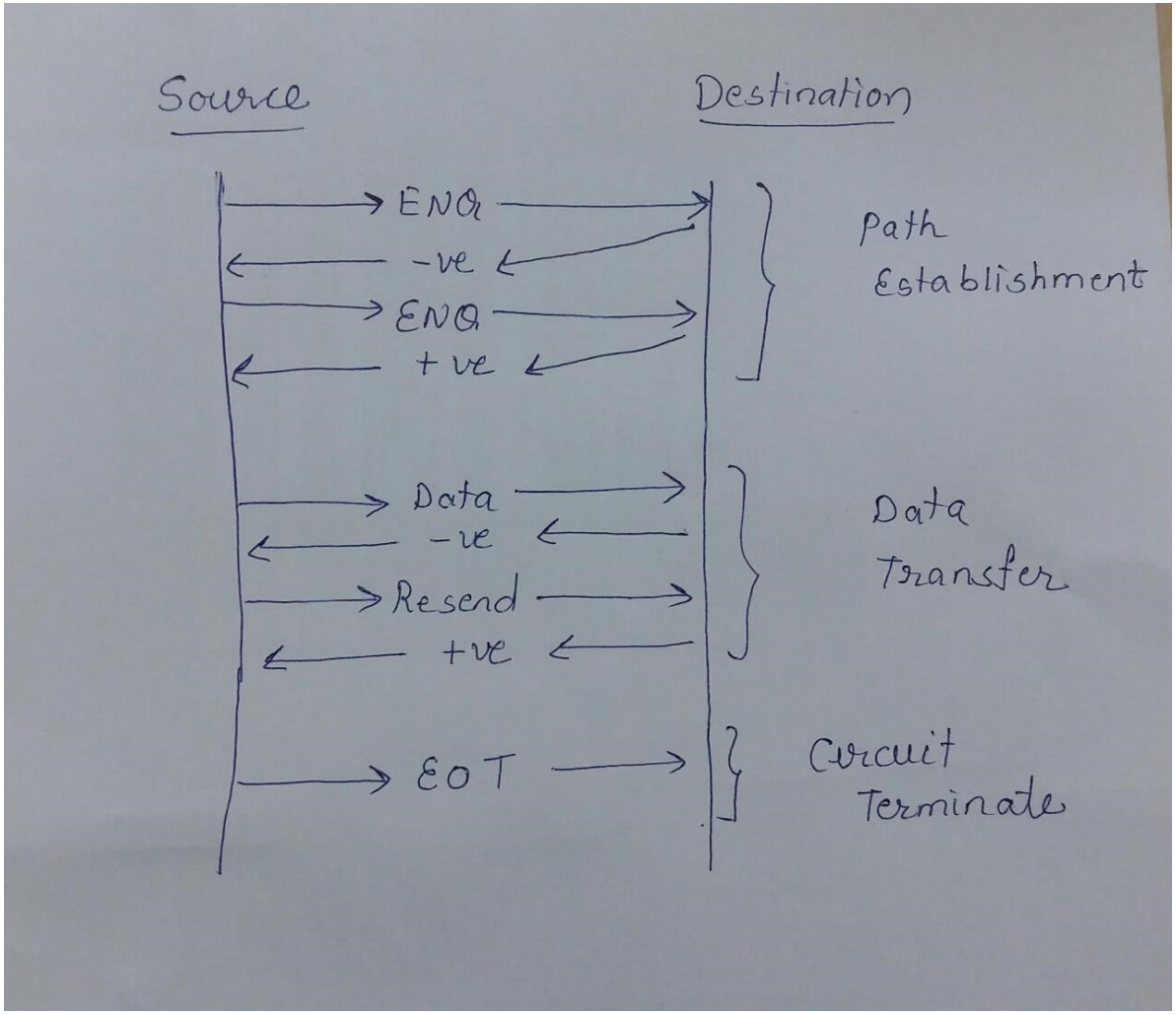


Transmission Technology (Point-to-point network)

- point-to-point networks consist of many connections between individual pairs of machines. To go from the source to the destination, a packet on this type of network may have to first visit one or more intermediate machines. Often multiple routes, of different lengths, are possible, so finding good ones is important in point-to-point networks.
- In Point to point network, there is a dedicated channel between source and destination. Here the communication process is divided into three phases.
- Path Establishment, Data Transfer and Circuit Termination

- Note: As a general rule (although there are many exceptions), smaller, geographically localized networks tend to use broadcasting, whereas larger networks usually are point-to-point.

Point to Point Network



Classification of N/W according to their scale

Interprocessor distance	Processors located in same	Example
1 m	Square meter	Personal area network
10 m	Room	Local area network
100 m	Building	
1 km	Campus	
10 km	City	Metropolitan area network
100 km	Country	Wide area network
1000 km	Continent	
10,000 km	Planet	The Internet

Classification of N/W according to their scale (LAN)

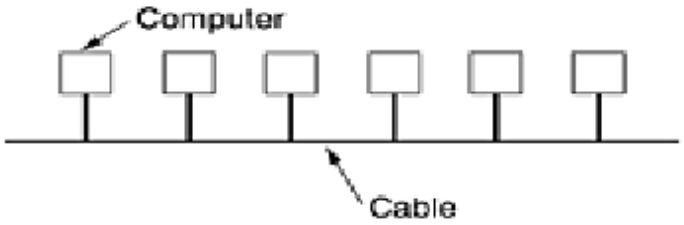
- Local area networks, generally called LANs, are privately-owned networks within a single building or campus of up to a few kilometers in size.
- They are widely used to connect personal computers and workstations in company offices and factories to share resources (e.g., printers) and exchange information.
- LANs are distinguished from other kinds of networks by three characteristics:

1. their size,
2. their transmission technology, and
3. their topology.

- LANs are restricted in size, which means that the worst-case transmission time is bounded and known in advance.

Classification of N/W according to their scale (LAN)

- LANs use a transmission technology consisting of a cable to which all the machines are attached.
- Traditional LANs run at speeds of 10 Mbps to 1000 Mbps, have low delay (microseconds or nanoseconds), and make very few errors.
- Newer LANs operate at up to 10 Gbps.
- Various topologies are possible for broadcast LANs.
- In a bus (i.e., a linear cable) network, at any instant at most one machine is the master and is allowed to transmit. All other machines are required to refrain from sending.



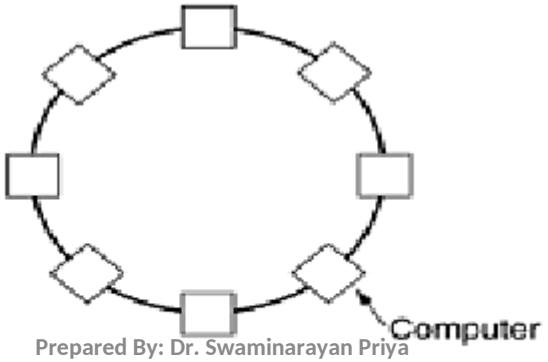
(a)

Classification of N/W according to their scale (LAN)

- An arbitration mechanism is needed to resolve conflicts when two or more machines want to transmit simultaneously.
- The arbitration mechanism may be centralized or distributed.
- IEEE 802.3, popularly called Ethernet, for example, is a bus-based broadcast network with decentralized control, usually operating at 10 Mbps to 10 Gbps.
- Computers on an Ethernet can transmit whenever they want to; if two or more packets collide, each computer just waits a random time and tries again later.

Classification of N/W according to their scale (LAN)

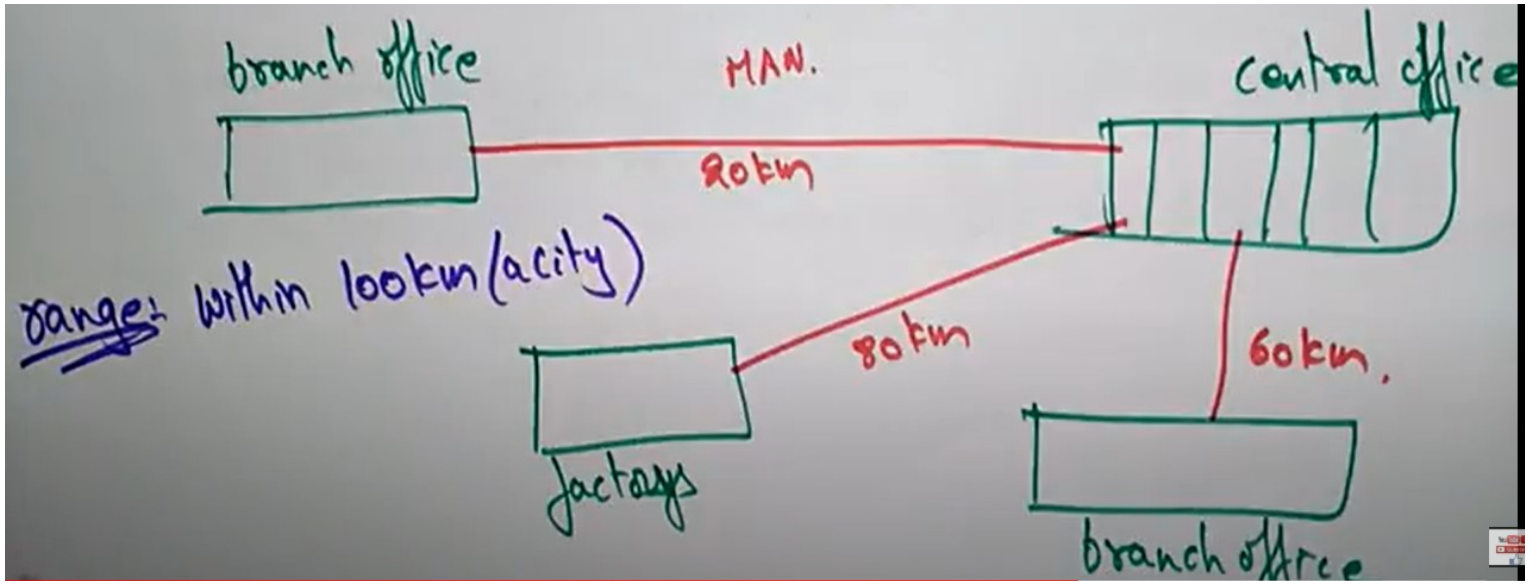
- A second type of broadcast system is the ring. In a ring, each bit propagates around on its own, not waiting for the rest of the packet to which it belongs. Typically, each bit circumnavigates the entire ring in the time it takes to transmit a few bits, often before the complete packet has even been transmitted.
- As with all other broadcast systems, some rule is needed for arbitrating simultaneous accesses to the ring. Various methods, such as having the machines take turns, are in use. IEEE 802.5 (the IBM token ring), is a ring-based LAN operating at 4 to 16 Mbps.
- FDDI(Fiber Distributed-Data Interface) is another example of a ring network.

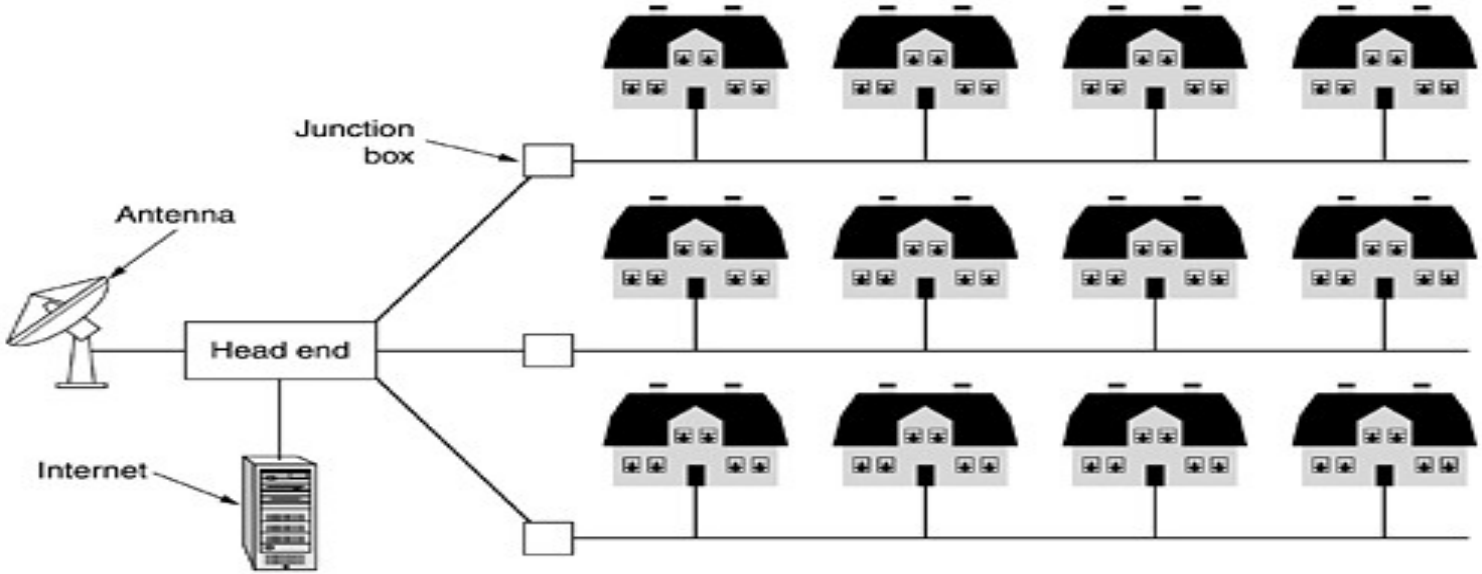


Classification of N/W according to their scale (MAN)

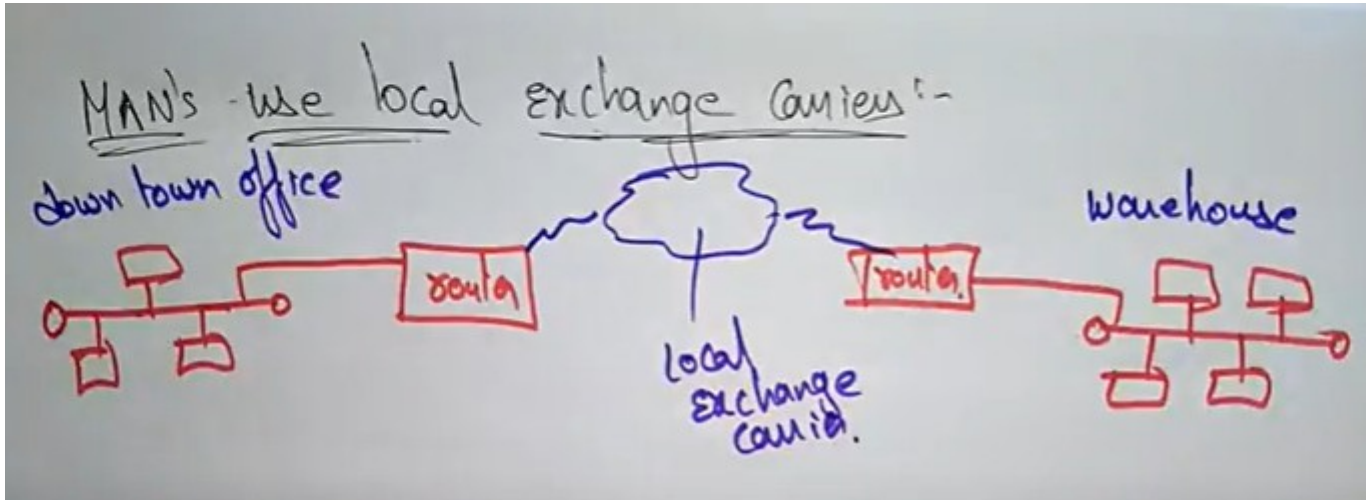
- A metropolitan area network, or MAN, covers a group of nearby corporate offices or a city.
- The best-known example of a MAN is the cable television network available in many cities.
- It may be a single network such as a cable television network or
- it may be a means of connecting a number of LANs into a large network, so that resources may be shared LAN-to-LAN as well as device-to-device.
- For eg. A company can use a MAN to connect the LANs in all of its offices through out a city.
- A MAN may be wholly owned and operated by a private company or it may be a service provided by a public company such as telephone company.
- It is costly
- It uses telecommunication media
- A MAN can support both data and voice.

MAN


branch office
MAN.
central office
20km
range: within 100km (a city)
80km
60km.
factorys
branch office



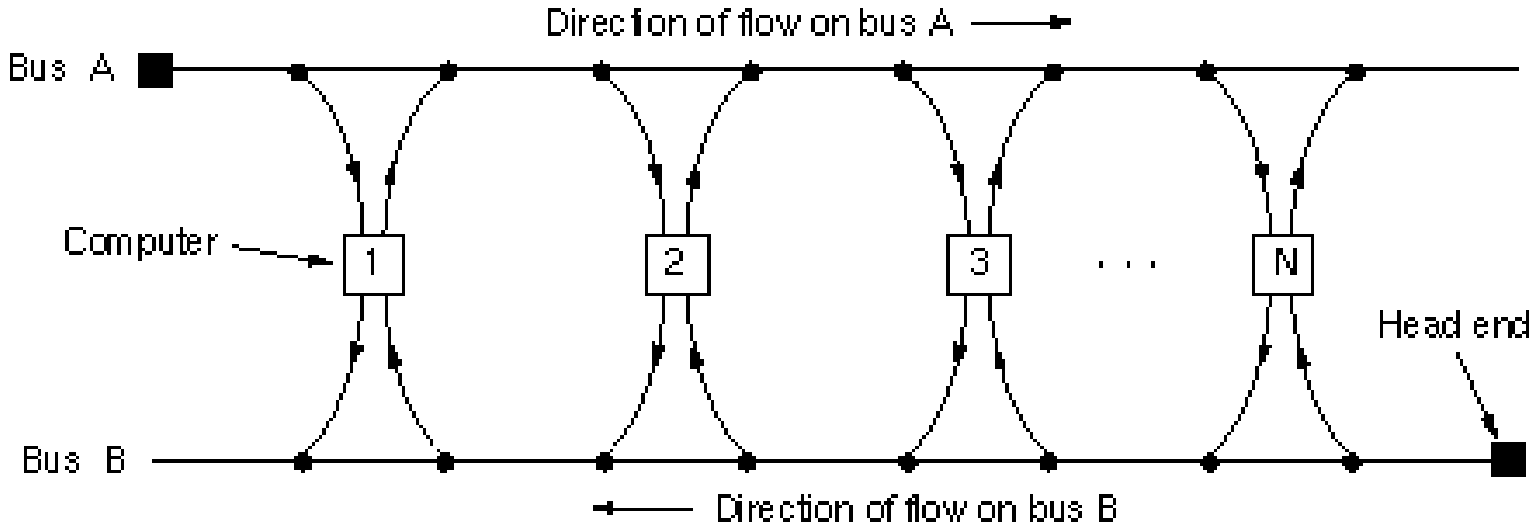
MAN uses Local Exchange Carriers



A metropolitan area network based on cable TV.

- **A MAN mostly works on the data link layer, which is Layer 2 of OSI Model**
- **Speed of MAN ranges in terms of Mbps**

- **A MAN just has one or two cables and doesn't contain switching elements, which transport packets over one of several potential output lines. Not having to switch simplifies the design.**
- **The main reason for each distinguishing between MAN as a special category is that a standard had been adopted them, and this standard is now being implemented.**
- **It is called DQDB (Distributed Queue Dual Bus) or 802.6 standard.**



- **DQDB consists of two unidirectional cables (buses) to which all the computers are connected.**
- **Each bus has a head-end, a device that initiates transmission activity.**
- **Traffic that is indented for a computer to the right of the sender uses the upper bus and traffic to the left uses the lower one.**

Classification of N/W according to their scale (MAN)

- A key aspect of a MAN is that there is a broadcast medium to which all the computers are attached.

- Devices used for MAN implementation:
  1. Modem (Intern-connecting devices such as HUB,Switch,router)
  2. Wire/Cable

- Real life examples of MAN
  1. Cable TV Network in a city
  2. Telephone Networks providing high-speed DSL lines
  3. Many telephone companies provide a popular MAN service called SMDS (Switched Multi-megabit Data Services)

- Switched multimegabit data service (SMDS) was a connectionless service used to connect LANs, MANs and WANs to exchange data.

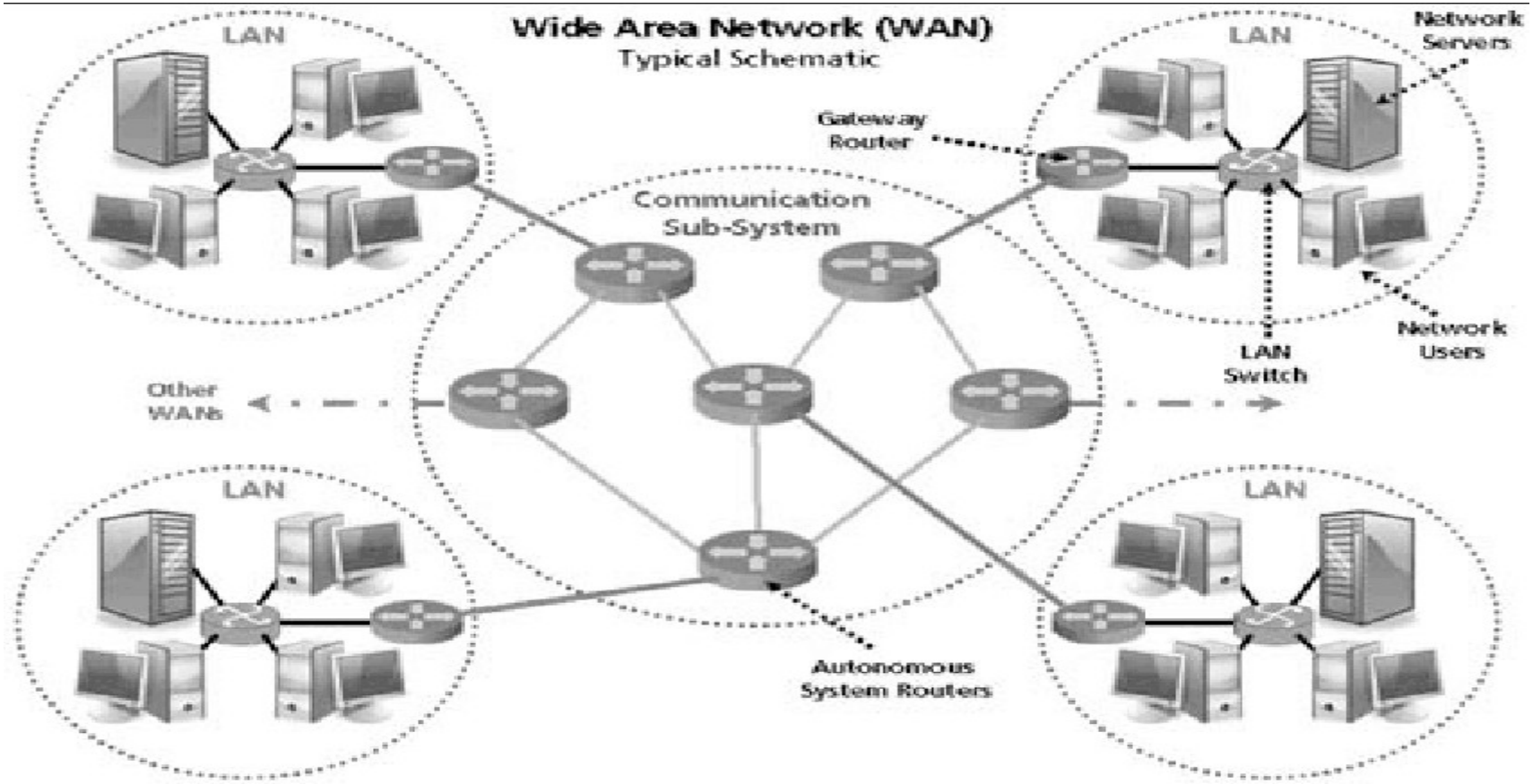
- SMDS was based on the IEEE 802.6 DQDB (Distributed Queue Dual Bus) standard.

Pros and Cons of MAN

- **Advantages of MAN**
- The dual bus used in MAN helps the transmission of data in both directions simultaneously
- **Disadvantages of MAN**
- More cable requirement for MAN connection from one place to another
- It is difficult to make system secure from the hackers

Wide Area Network

- ✓ **Wide Area Network, or WAN, is a geographically distributed network composed of local area networks (LANs) joined into a single large network using services provided by common carriers.**



Classification of N/W according to their scale (WAN)

WAN (Wide Area Network)

- Wide area networks (WANS) are commonly implemented in enterprise networking environments in which company offices are in different cities, states, or countries or on different continents.
- Not constrained to one physical location
- A WAN spans a large geographical area, often a country or continent.
- It enables users to share and access applications
- It provides long-distance transmission of data, voice, image and video information over large geographical areas.

- WAN may utilize public or private communication devices usually combinations and can therefore span an unlimited numbers of miles.

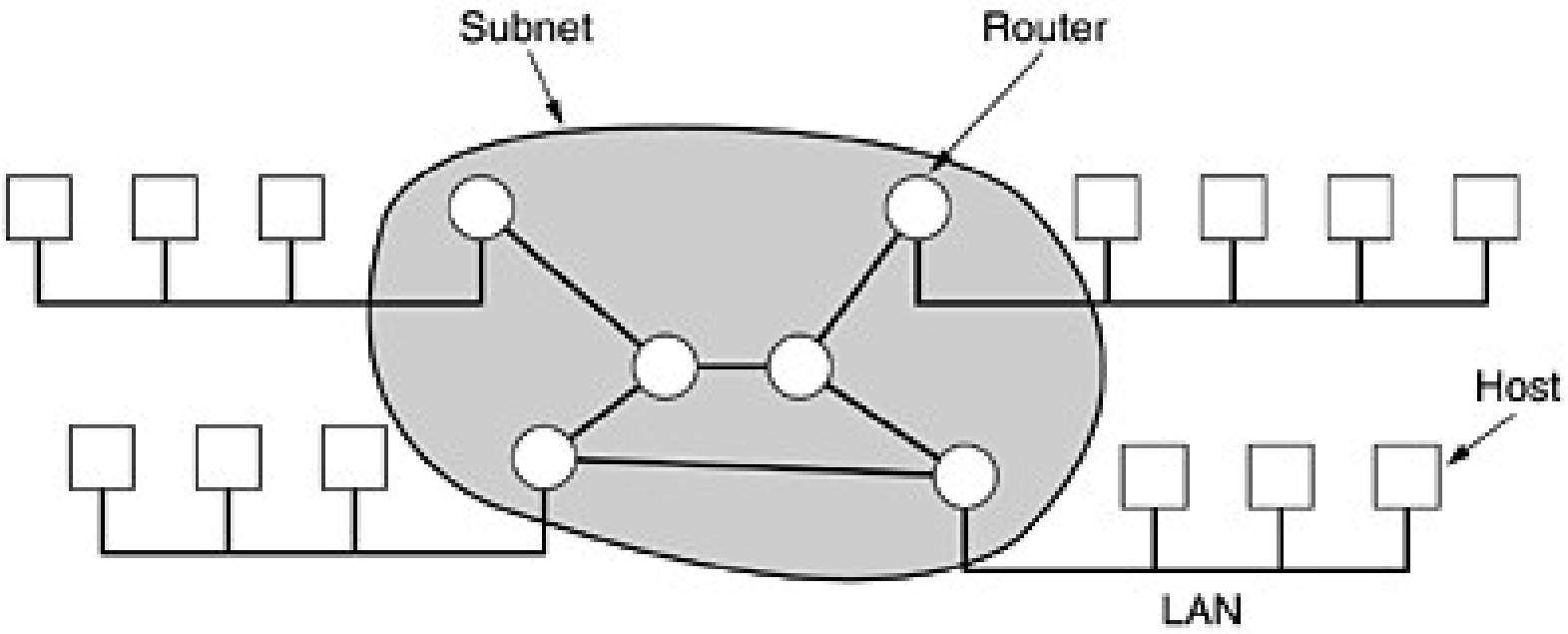
Wide Area Network

- A **leased line** is a **dedicated connection** between your premises and the local exchange.
- **Broadband** is **not a dedicated connection** between your premises and the local exchange.

- **An enterprise network**: A **WAN** that is wholly **owned** and **used** by a single company is often, referred to as an enterprise network.

- **WAN must have capacity for Bandwidth, Connectivity and user access**
- **Organization can use VPN (Virtual Private Network) to facilitate Connectivity and security between LANs**
- **Company can increase Bandwidth using leased line but it comes with high setup cost**
- **It also requires Antivirus software or firewalls for security**

Classification of N/W according to their scale (WAN)



Relation between hosts on LANs and the subnet.

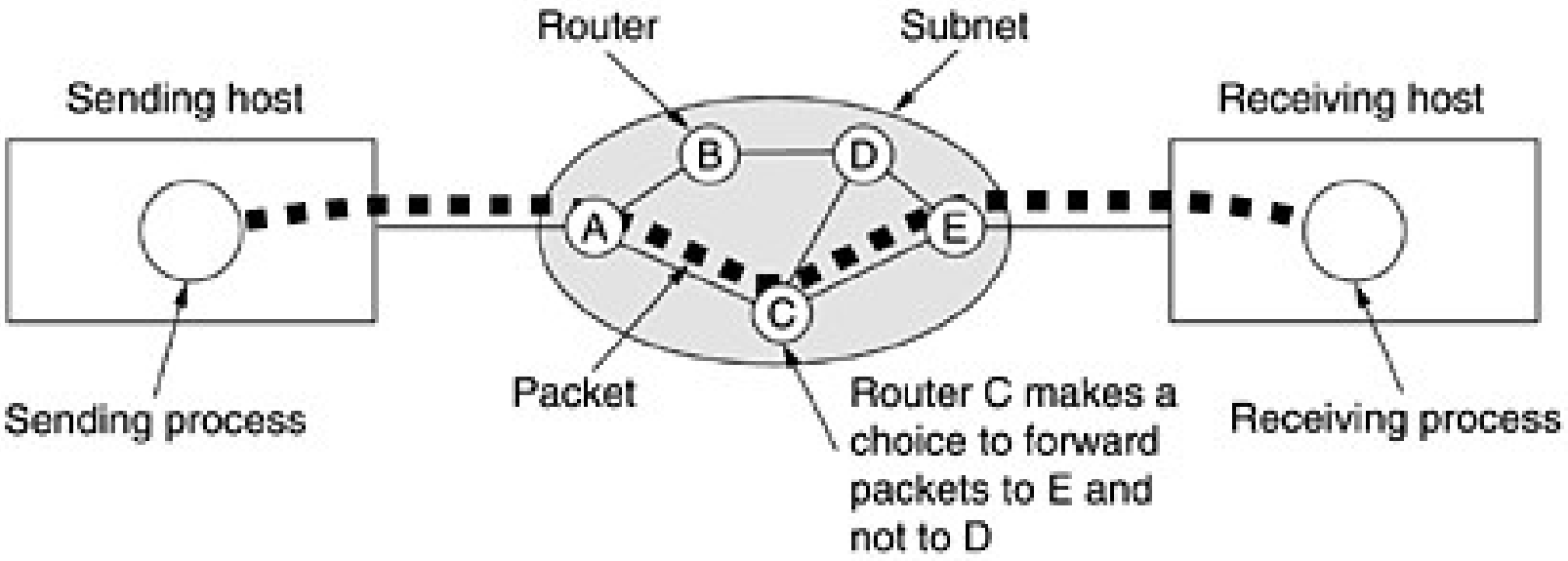
Classification of N/W according to their scale (WAN)

- **WAN contains a collection of machines intended for running user (i.e., application) programs.**
- **These machines are hosts. The hosts are connected by a communication subnet, or subnet.**
- **The hosts are owned by the customers (e.g., people's personal computers),**
- **whereas the communication subnet is typically owned and operated by a telephone company or Internet service provider. The job of the subnet is to carry messages from host to host, just as the telephone system carries words from speaker to listener.**
- **In most wide area networks, the subnet consists of two distinct components: transmission lines and switching elements.**
- **Transmission lines move bits between machines. They can be made of copper wire, optical fiber, or even radio links.**

Classification of N/W according to their scale (WAN)

- **Switching elements are specialized computers that connect three or more transmission lines. When data arrive on an incoming line, the switching element must choose an outgoing line on which to forward them. These switching computers are known as router.**
- **Here each host is frequently connected to a LAN on which a router is present, although in some cases a host can be connected directly to a router.**
- **The collection of communication lines and routers (but not the hosts) form the subnet.**

Classification of N/W according to their scale (WAN)



A stream of packets from sender to receiver

Classification of N/W according to their scale (WAN)

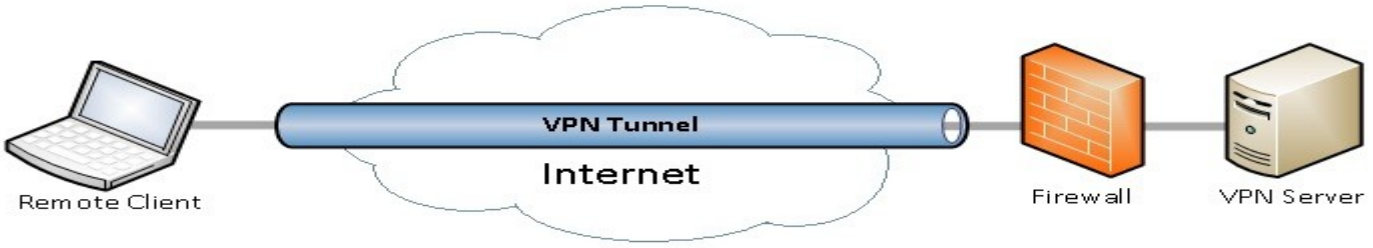
- In most WANs, the network contains numerous transmission lines, each one connecting a pair of routers. If two routers that do not share a transmission line wish to communicate, they must do this indirectly, via other routers. When a packet is sent from one router to another via one or more intermediate routers, the packet is received at each intermediate router in its entirety, stored there until the required output line is free, and then forwarded. A subnet organized according to this principle is called a store-and-forward or packet-switched subnet.
- Nearly all wide area networks (except those using satellites) have store-and-forward subnets. When the packets are small and all the same size, they are often called cells.

Classification of N/W according to their scale (WAN)

- In Packet-switched subnet, when a process on some host has a message to be sent to a process on some other host, the sending host first cuts the message into packets, each one bearing its number in the sequence. These packets are then injected into the network one at a time in quick succession. The packets are transported individually over the network and deposited at the receiving host, where they are reassembled into the original message and delivered to the receiving process. A stream of packets resulting from some initial message is illustrated in previous figure.

- WAN technologies **were previously limited** to
- expensive leased lines such as T1 lines,
- **slow** packet-switching services such as X.25,
- **cheap** but **low-bandwidth solutions** such as **modems**, and
- dial-up Integrated Services Digital Network (ISDN) connections,

- but this has changed considerably in recent years.
- **Frame relay services** provide **high-speed packet-switching services** that offer **more bandwidth than X.25**, and
- virtual private networks (VPNs) created using **Internet Protocol (IP) tunneling technologies** enable companies to **securely connect** branch offices by using the Internet as a backbone service.



Feature	LAN	WAN
Speed	1000 Mbps	150 Mbps
Bandwidth for Transmission	High	Low
Data Transfer Rate	High	Low
Geographical Coverage	Small	Large
Connecting Hardware	10Base-T Cable	Leased Line or Satellite
Technology Used	Token Ring & Ethernet	ATM, Frame Relay, X.25
Transmission Errors	Few	More
Setup Cost	Low	High
Maintenance Costs	Less	More
Network Topology	Peer to Peer	Client Server Model
Security	More Secure than WAN	Open to Threats
Standard	Ethernet	T1
Signal Deterioration	No	Yes
Equipment Needed	Hub, Switch	Router, Modem
Expansion	Using a NIC	Using an Extra Router
Range	1 km	Up to 10000 kms
Printer Sharing	Yes, if in the same LAN	No

Classification of N/W according to their scale (Wireless Network)

- Wireless networks can be divided into three main categories:

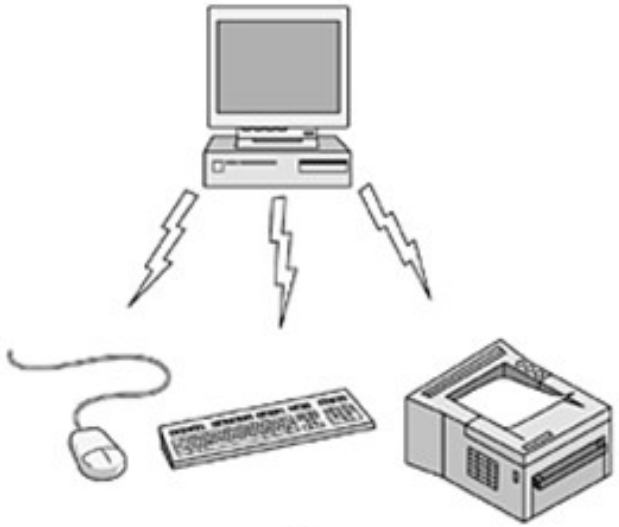
1.System interconnection. 2. Wireless LANs. 3. Wireless WANs.

- System interconnection is all about interconnecting the components of a computer using short-range radio. Almost every computer has a monitor, keyboard, mouse, and printer connected to the main unit by cables, but some companies got together to design a short-range wireless network called Bluetooth to connect these components without wires.
- Bluetooth also allows digital cameras, headsets, scanners, and other devices to connect to a computer by merely being brought within range. No cables, no driver installation, just put them down, turn them on, and they work. For many people, this ease of operation is a big plus.

Classification of N/W according to their scale (Wireless Network)

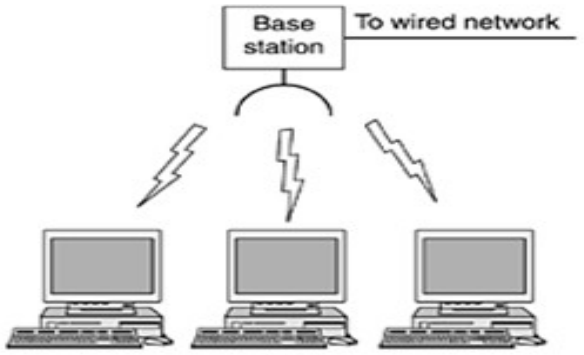
- In the simplest form, system interconnection networks use the master-slave paradigm of Fig. 1-11(a).
- The system unit is normally the master, talking to the mouse, keyboard, etc., as slaves. The master tells the slaves

- what addresses to use,
- when they can broadcast,
- how long they can transmit,
- what frequencies they can use,
- and so on



Classification of N/W according to their scale (Wireless Network)

- **Wireless LANs :**
- **These are systems in which every computer has a radio modem and antenna with which it can communicate with other systems. Often there is an antenna on the ceiling that the machines talk to, as shown in Fig. 1-11(b).**
- **However, if the systems are close enough, they can communicate directly with one another in a peer-to-peer configuration.**
- **Wireless LANs are becoming increasingly common in small offices and homes, where installing Ethernet is considered too much trouble, as well as in older office buildings, company cafeterias, conference rooms, and other places.**
- **There is a standard for wireless LANs, called IEEE 802.11, which most systems implement and which is becoming very widespread.**



(b)

Classification of N/W according to their scale (Wireless Network)

- **Wireless WANs : The radio network used for cellular telephones is an example of a low-bandwidth wireless system. This system has already gone through three generations.**
- **The first generation was analog and for voice only.**
- **The second generation was digital and for voice only.**
- **The third generation is digital and is for both voice and data.**
- **In a certain sense, cellular wireless networks are like wireless LANs, except that the distances involved are much greater and the bit rates much lower.**
- **Wireless LANs can operate at rates up to about 50 Mbps over distances of tens of meters.**
- **Cellular systems operate below 1 Mbps, but the distance between the base station and the computer or telephone is measured in kilometers rather than in meters.**
- **The initial focus is high-speed wireless Internet access from homes and businesses, bypassing the telephone system. This service is often called local multipoint distribution service. A standard for it, called IEEE 802.16, has also been developed.**

Comparisons of 1G to 5G

Features	1G	2G	3G	4G	5G
Start/Devlopment	1970/1984	1980/1999	1990/2002	2000/2010	2010/2015
Technology	AMPS, NMT, TACS	GSM	WCDMA	LTE, WiMax	MIMO, mm Waves
Frequency	30 KHz	1.8 Ghz	1.6 - 2 GHz	2 - 8 GHz	3 - 30 Ghz
Bandwidth	2 kbps	14.4 - 64 kbps	2 Mbps	2000 Mbps to 1 Gbps	1 Gbps and higher
AccessSystem	FDMA	TDMA/CDMA	CDMA	CDMA	OFDM/BDMA
Core Network	PSTN	PSTN	Packet Network	Internet	Internet

Classification of N/W according to their scale (Home Networks)

- The fundamental idea is that in the future most homes will be set up for networking. Every device in the home will be capable of communicating with every other device, and all of them will be accessible over the Internet.
- Many devices are capable of being networked. Some of the more obvious categories (with examples) are as follows:

1. Computers (desktop PC, notebook PC, PDA, shared peripherals).
2. Entertainment (TV, DVD, VCR, camcorder, camera, stereo, MP3).
3. Telecommunications (telephone, mobile telephone, intercom, fax).
4. Appliances (microwave, refrigerator, clock, heater, lights).
5. Telemetry (utility meter, smoke/burglar alarm, thermostat).

Smart Home

- Your refrigerator reminds you about buying vegetables while coming back home or reminds you that you are overeating
- You may be informed about some stranger trying to break into you house in your absence or baby sitter taking a nap instead of taking care of the baby
- The smart spectacles start making noise to help the old people finding out where they have forgotten them
- You can yell out "where are my keys?" and your keys would reply "Here we are"
- You realize that you have forgotten to switch off the lights of your house after reaching office and instruct remotely to do so to your house monitoring system via Internet or phone
- The shower adjusts the temperature of the water looking at your preferences and the temperature outside

- **Projects**: Aladdin by Microsoft, Aware Home by Georgia Institute of Technology, Gator-Tech Smart House by University of Florida
- **Protocols:** x10 , ZigBee

Classification of N/W according to their scale (Internetworks)

- A **collection of interconnected networks** is called an **internetwork or internet**.
- Many networks exist in the world, often with different hardware and software. People connected to one network often want to communicate with people attached to a different one. The fulfillment of this desire requires that different, and frequently incompatible networks, be connected, sometimes by means of machines called **gateways** to **make the connection** and **provide the necessary translation**, both in terms of hardware and software.
- An internetwork is formed when distinct networks are interconnected.
- For e.g. **connecting a LAN and a WAN** or **connecting two LANs forms an internetwork**

1.3 Network Software (Protocol Hierarchies)

- Network is a combination of hardware and software. The **hardware** consists of the physical equipment that carries signals. **Software** consists of instruction sets that make possible the services that we expect from a network.
- To **reduce their design complexity**, most networks are organized as a **stack of layers** or levels, each one built upon the one below it.
- The number of layers, the name of each layer, the contents of each layer, and the function of each layer differ from network to network.
- The purpose of **each layer is to offer certain services to the higher layers,** shielding those layers from the details of how the offered services are actually implemented. In a sense, each layer is a kind of **virtual machine**, offering certain services to the layer above it.
- Layer n on one machine carries on a conversation with layer n on another machine.
- The **rules and conventions** used in this conversation are collectively known as the **layer n protocol.**
- Basically, a **protocol** is an **agreement between the communicating parties** on **how communication is to proceed.**

1.3 Network Software (Protocol Hierarchies)

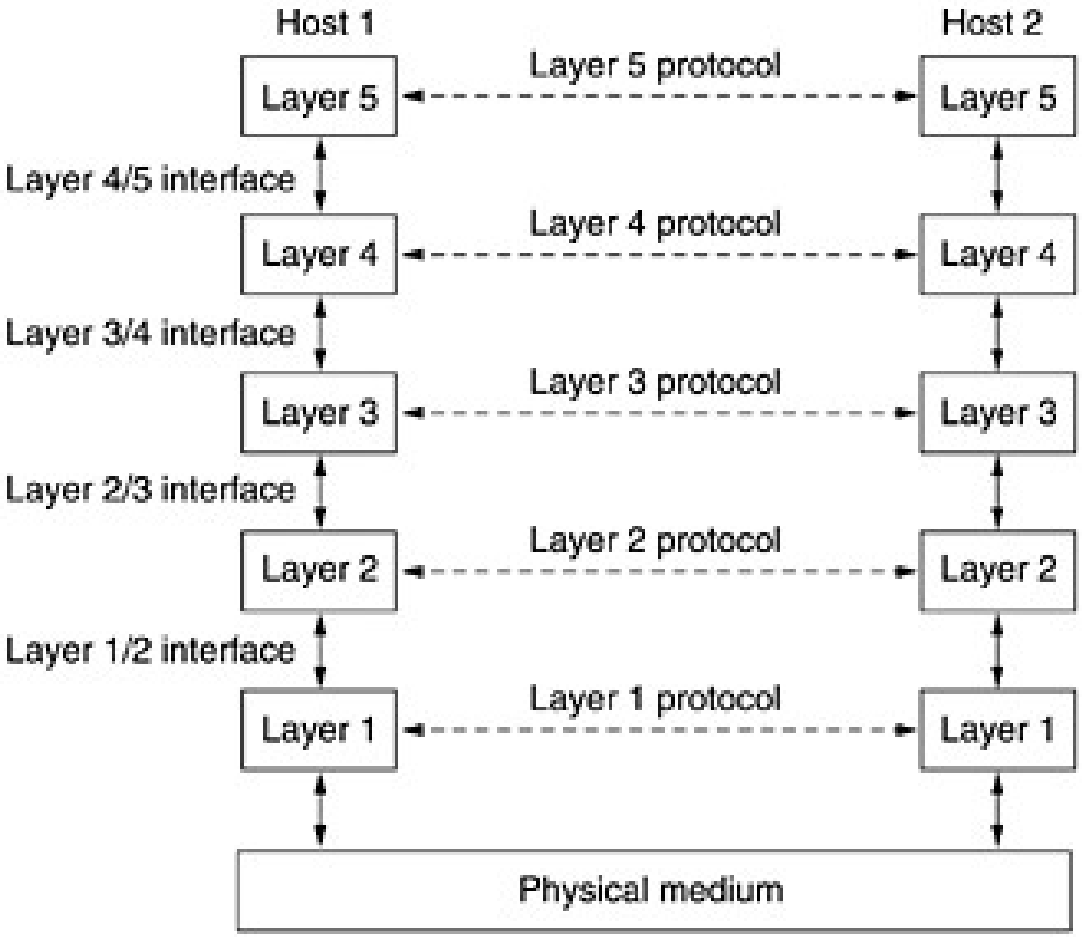


Figure 1-13. Layers, protocols, and interfaces

1.3 Network Software (Protocol Hierarchies)

- In reality, no data are directly transferred from layer n on one machine to layer n on another machine. Instead, each layer passes data and control information to the layer immediately below it, **until the lowest layer is reached.** Below layer 1 is the physical medium through which actual communication occurs.
- Between each pair of adjacent layers is an interface. The **interface** defines **which primitive operations and services the lower layer makes** available to the upper one.
- **A set of layers and protocols** is called a **network architecture.**

1.3 Network Software (Protocol Hierarchies)

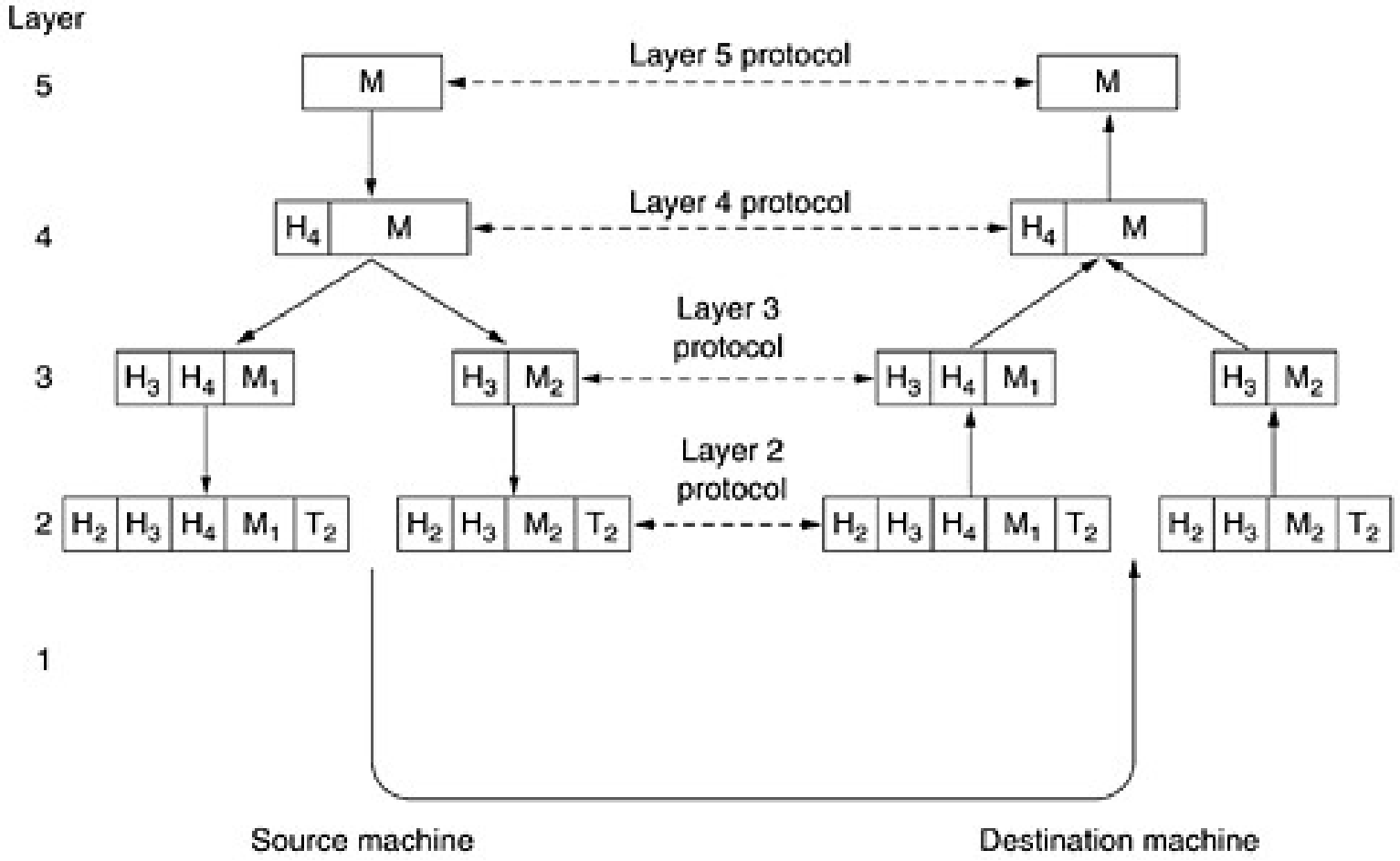


Figure 1-15. Example information flow supporting virtual communication in layer 5.

1.3 Network Software (Protocol Hierarchies)

- Now consider a more technical example: how to provide communication to the top layer of the five-layer network in Fig. 1-15.
- A message, M, is produced by an application process running in layer 5 and given to layer 4 for transmission. Layer 4 puts a header in front of the message to identify the message and passes the result to layer 3. The header includes control information, such as sequence numbers, to allow layer 4 on the destination machine to deliver messages in the right order if the lower layers do not maintain sequence. In some layers, headers can also contain sizes, times, and other control fields.

Network Software

1.3.2 Design Issues for the Layers

- **Addressing:** Every layer needs a mechanism for identifying senders and receivers.

- Another set of design decisions concerns the **rules for data transfer**. In some systems, data only **travel in one direction**; in others, data can go both ways. The protocol must also determine how **many logical channels** the connection corresponds to and what their priorities are. Many networks provide **at least two logical** channels per connection, one for normal data and one for urgent data.

- **Error control** is an important issue because physical communication circuits are not perfect. Many error-detecting and error-correcting codes are known, but both ends of the connection must agree on which one is being used.

Network Software (1.3.2 Design Issues for the Layers)

- Not all communication channels **preserve the order of messages sent on them**. To deal with a possible loss of sequencing, the protocol must make explicit provision for the receiver to allow the pieces to be reassembled properly.

- An issue that occurs at every level is how to keep a fast sender from swamping a slow receiver with data. This subject is called **flow control**. Some of them involve some **kind of feedback from the receiver** to the sender, either directly or indirectly, about the receiver's current situation. Others limit the sender to an **agreed-on transmission rate.**

- Another problem that must be solved at several levels is the inability of all processes to accept arbitrarily **long messages**. This property leads to mechanisms for **disassembling, transmitting, and then reassembling messages.**

Network Software (1.3.2 Design Issues for the Layers)

- A related issue is the problem of what to do when processes insist on transmitting data in units that are so **small** that sending each one separately is inefficient. Here the solution is to gather several small messages heading toward a common destination into a single large message and dismember the large message at the other side.

- **Multiplexing – Demultiplexing** : When it is inconvenient or expensive to set up a separate connection for each pair of communicating processes, the underlying layer may decide to use the same connection for multiple, unrelated conversations.

- **Routing:** When there are multiple paths between source and destination, a route must be chosen. Sometimes this decision must be split over two or more layers.

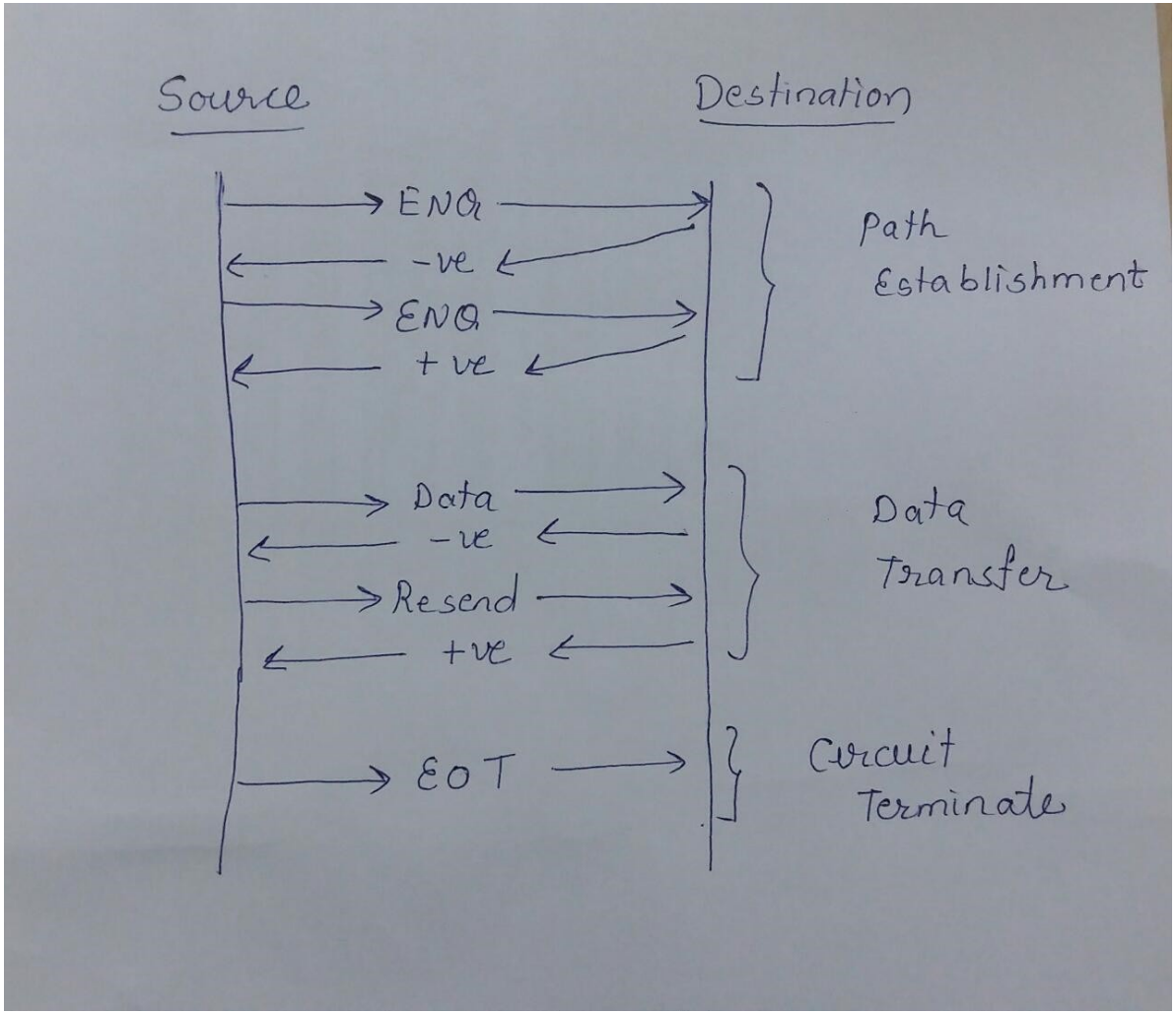
Network Software
(1.3.3 Connection-Oriented and Connectionless Services)

- Layers can offer two different types of service to the layers above them: **connection-oriented** and **connectionless**.

- In a connection-oriented network service, the service user first establishes a connection, uses the connection, and then releases the connection.

- In contrast, connectionless service is modeled after the postal system. Each message (letter) carries the full destination address, and each one is routed through the system independent of all the others.. Normally, when two messages are sent to the same destination, the first one sent will be the first one to arrive. However, it is possible that the first one sent can be delayed so that the second one arrives first.

Connection Oriented Network



Network Software (1.3.3 Connection-Oriented and Connectionless Services)

- Each service can be characterized by a **quality of service**. Some services are reliable in the sense that they never lose data. Usually, a reliable service is implemented by having the receiver acknowledge the receipt of each message so the sender is sure that it arrived. The **acknowledgement process introduces overhead and delays**, which are often worth it but are sometimes undesirable.

- A typical situation in which a reliable connection-oriented service is appropriate is **file transfer**. The owner of the file wants to be sure that all the bits arrive correctly and in the same order they were sent. Very few file transfer customers would prefer a service that occasionally scrambles or loses a few bits, even if it is much faster.

Connectionless

- **Characteristics:**

1.Each packet sent independently

2.Routing decisions made at every IS - intermediate system

3.Corresponds to datagram service (parallel) in packet switched network

4.Internet Protocol

5.Example: Telegraph systems, email

❖ **Advantages**

1.Flexibility

2.Robust

3.No unnecessary overhead

❖**Disadvantages**

1.Unreliable

2.Not guaranteed delivery

3.Not guaranteed order of delivery

4.Packets can take different routes

Connection oriented

Characteristics:

A connection is established between ES's (end System) that is used for duration of call

- Call setup
- Data transfer
- Call termination

Advantages

- Fixed path
- Order of message preserved
- No loss of data

Reliable

- But the process of acknowledgement adds overhead and delay

–Example: telephone, ftp, remote login

BASIS OF COMPARISON	CONNECTION-ORIENTED SERVICE	CONNECTION-LESS SERVICE
Prior Connection Requirement	Necessary	Not required
Reliability	Ensures reliable transfer of data.	Not guaranteed.
Congestion	Unlikely	Occur likely.
Transferring mode	It can be implemented using circuit switching and virtual circuit.	It is implemented using packet switching.
Lost data retransmission	Less chance	More chance
Suitability	Suitable for long and steady communication.	Suitable for bursty Transmission.
Packet forwarding	Packets sequentially travel to their destination node and follows the same route.	Packets reach the destination randomly without following the same route.
Delay	There is a delay in transfer of information, but once the connection is established faster delivery can be achieved.	Because to the absence of connection establishment phase, the transmission is faster.
Resource Allocation	Need to be allocated.	No prior allocation of the resource is required.

Network Software (1.3.3 Connection-Oriented and Connectionless Services)

- ***Figure 1-16. Six different types of service.***

	Service	Example
Connection-oriented	Reliable message stream	Sequence of pages
	Reliable byte stream	Remote login
	Unreliable connection	Digitized voice
Connection-less	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Registered mail
	Request-reply	Database query

Network Software (1.3.4 Service Primitives)

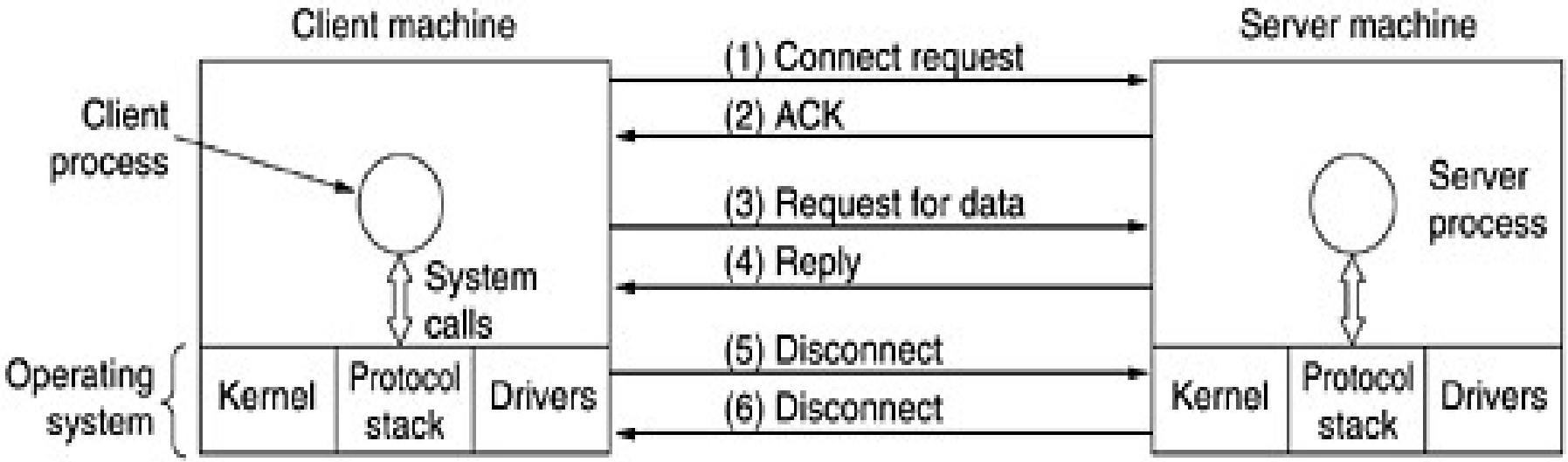
- A **service** is formally specified by a set of primitives (operations) available to a user process to access the service.
- These primitives tell the service to perform some action or report on an action taken by a peer entity.
- The set of primitives available depends on the nature of the service being provided. The primitives for connection-oriented service are different from those of connectionless service.

Figure 1-17. Five service primitives for implementing a simple connection-oriented service.

Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

Network Software (1.3.4 Service Primitives)

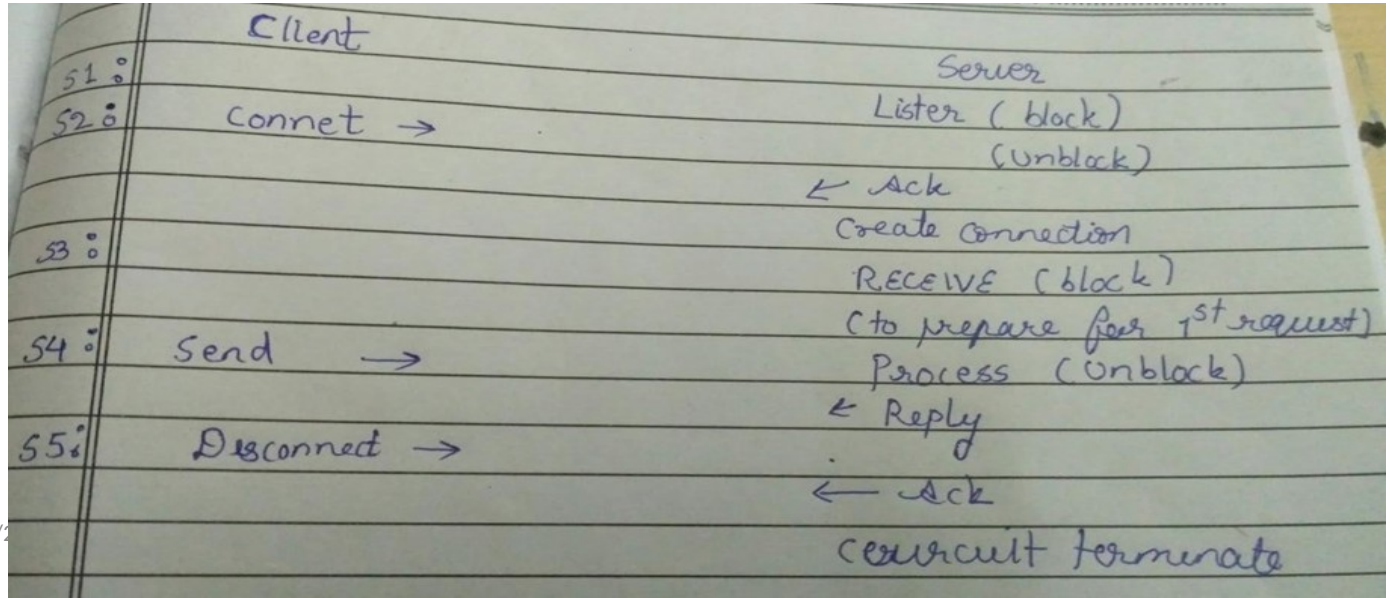
- *Figure 1-18. Packets sent in a simple client-server interaction on a connection-oriented network*



1. **Listen:** The server executes LISTEN to indicate that it is prepared to accept the incoming connection. The server process is **blocked** until a request for connection appears
2. **Connect**: the client process executes a CONNECT call to establish the connection with the server. Specify the address too.

When the server receives this packet it **unblocks the server** and **sends back the acknowledgement** and this releases the client. At this point the client and server both are **running**. The **connection established.**

3. **Receive**: the server executes RECEIVE to prepare the first request. This call **blocks the server,** so that it can process the request.
4. **Send:** the client executes SEND to transmit its request followed by the execution of receive to get the reply. If the client has additional requests it makes now
5. **Disconnect**: The client use DISCONNECT to end the connection. The server also issues a acknowledgement to terminate the connection it send the disconnect.



1.4 Reference Models(1.4.1 The OSI Reference Model)

- Established in 1947, the International Standards Organization (ISO) is a multinational body dedicated to worldwide agreement on International standards.

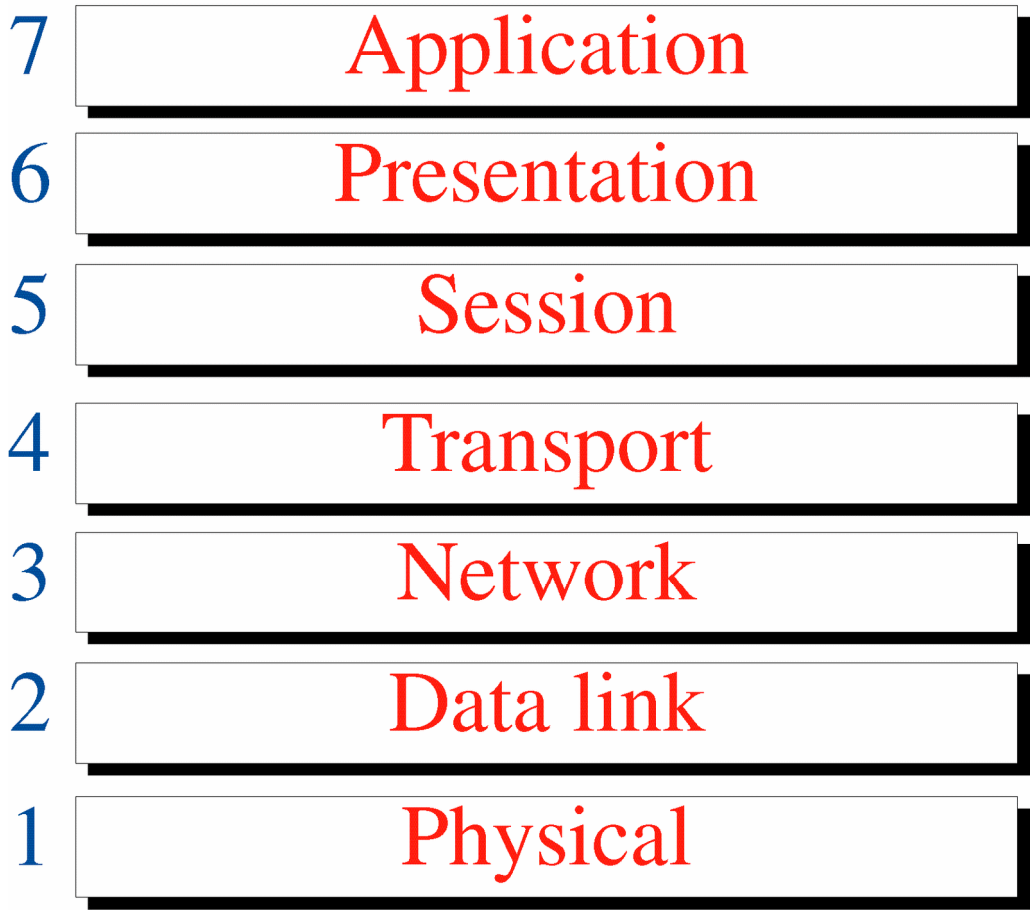
- An ISO standard that covers all aspects of n/w communications is the **OSI (Open System Interconnection)** Model.

- An open system is a model that allows any **two different systems to communicate regardless of their underlying architecture.**

- **Purpose**: The main purpose of the OSI model is to open communication between different systems without requiring changes to the logic of the underlying hardware and software.

- It was revised in 1995.
- The OSI model has seven layers. (Physical Layer, Data Link Layer, Network Layer, Transport Layer, Session Layer, Presentation Layer, Application Layer)

OSI Model


7
Application
6
Presentation
5
Session
4
Transport
3
Network
2
Data link
1
Physical

Some mnemonic phrases to help you remember the layers of the **OSI model**:

All People Seems To Need Double Power

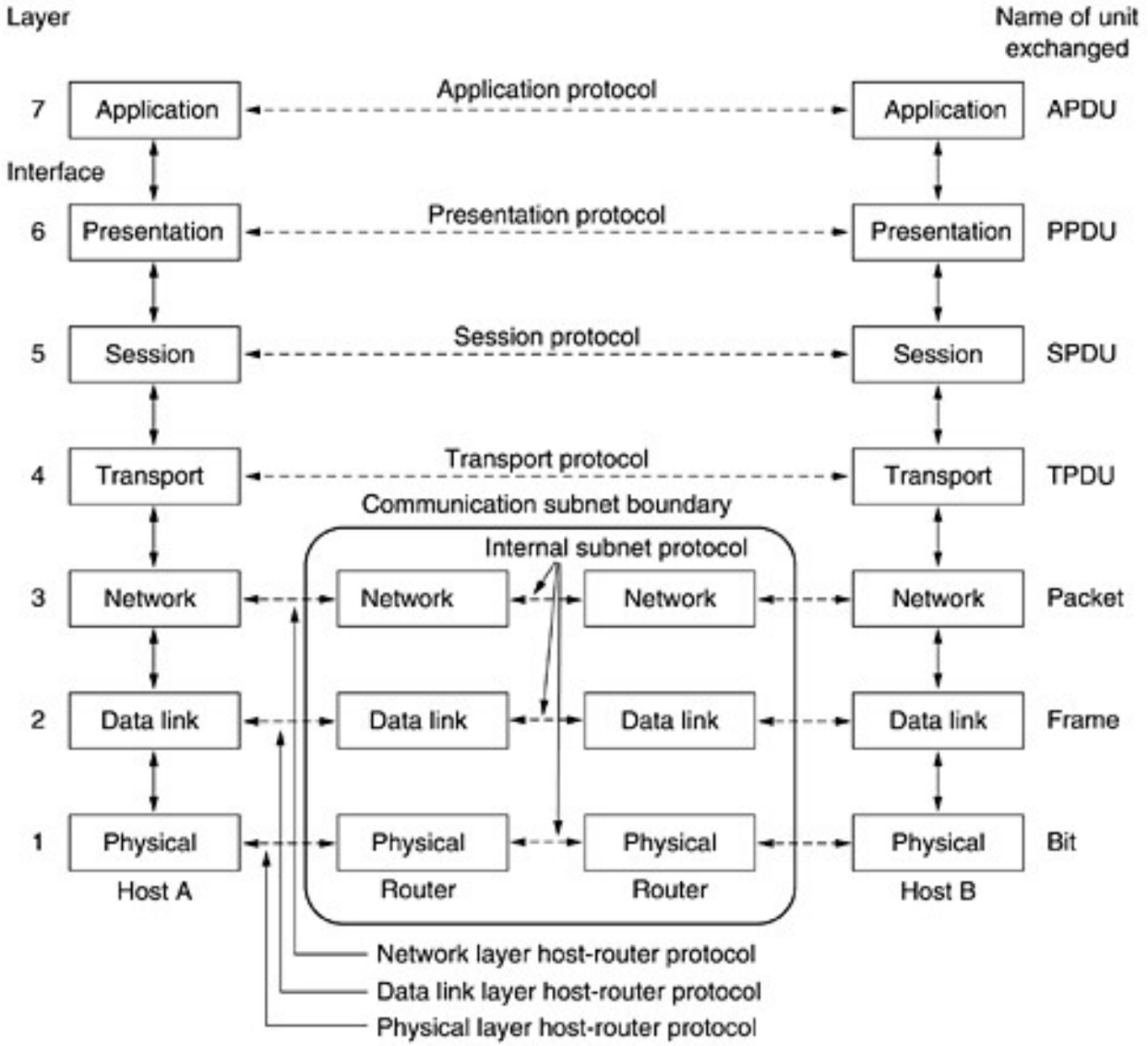
or

Please Do Not Take SPA

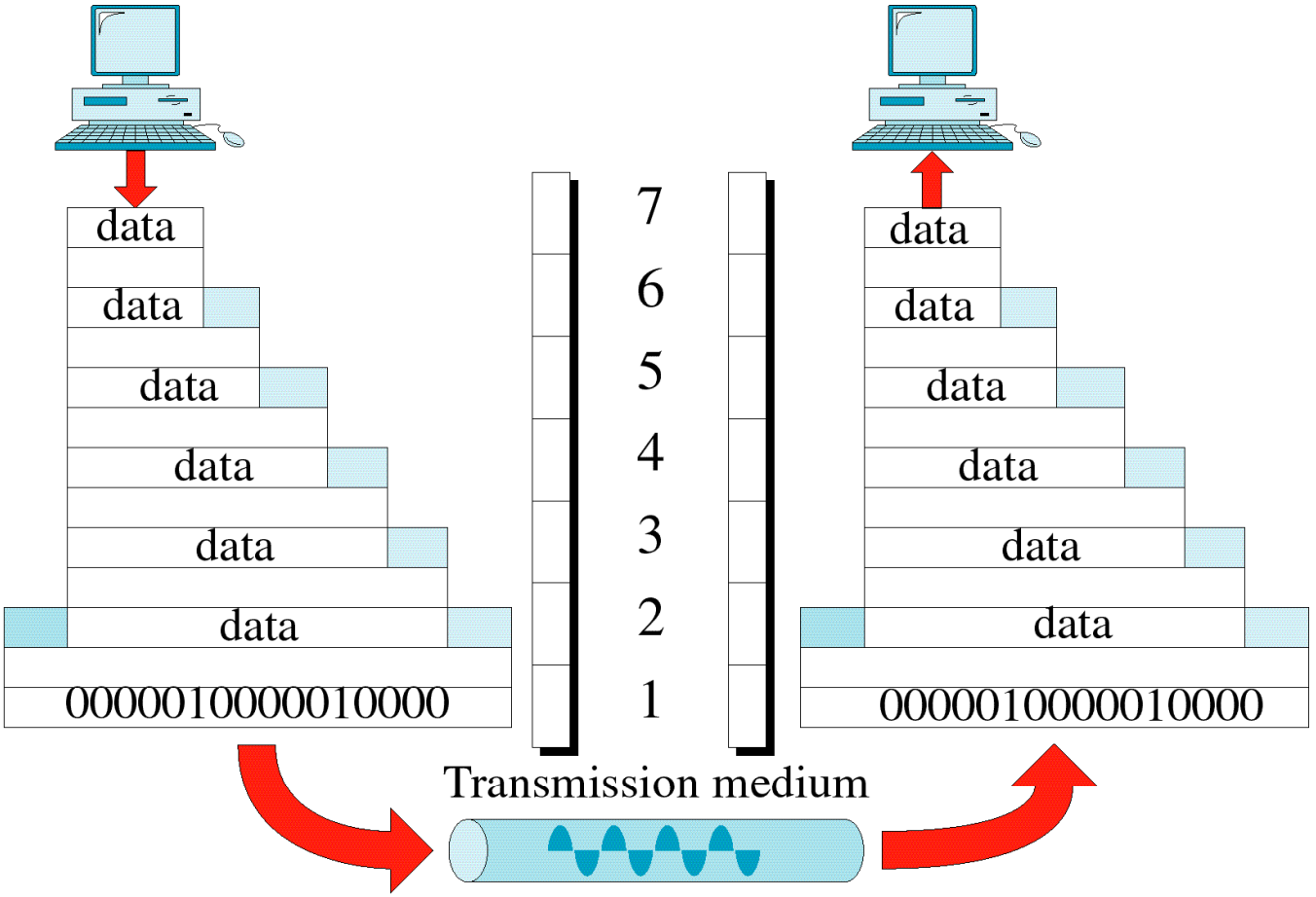
or

Aaj Phir Se Test Nahin Dena Padega

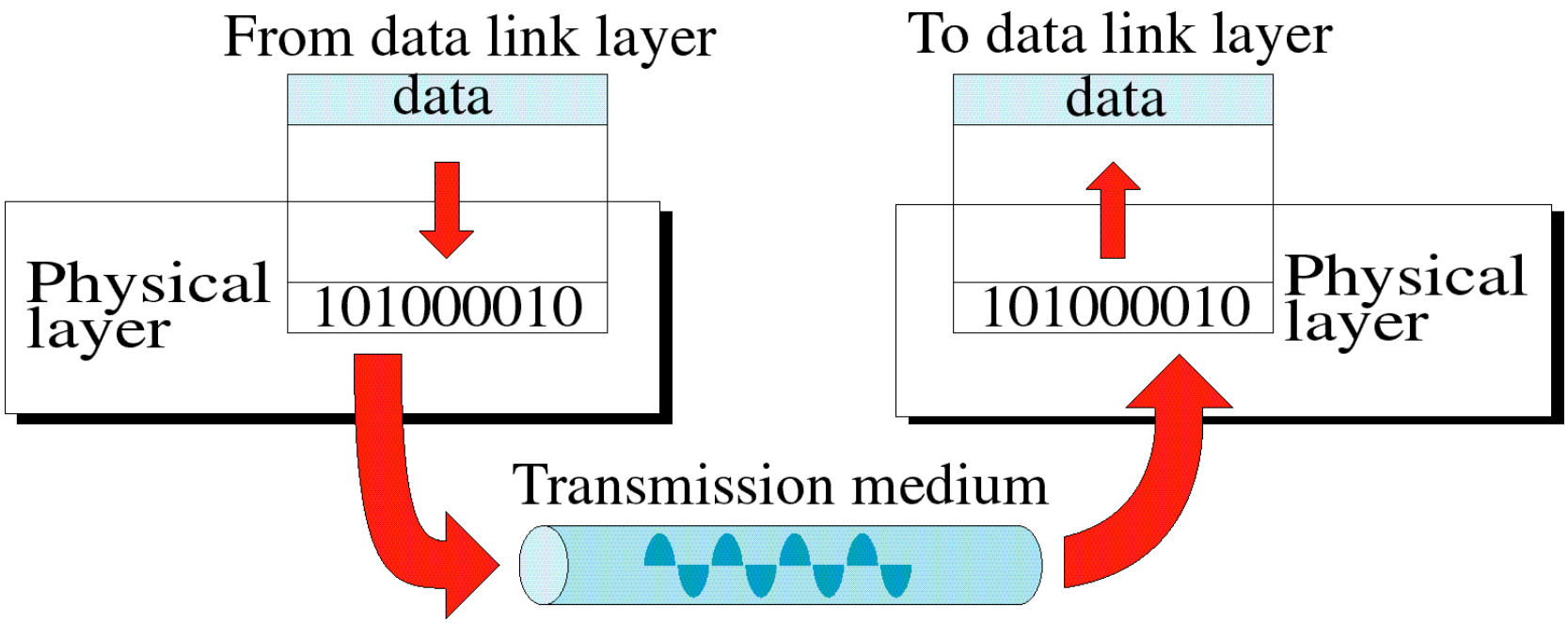
Figure The OSI reference model.



An Exchange Using the OSI Model



Physical Layer



The OSI Reference Model (The Physical Layer)

- The physical layer is concerned with **transmitting raw bits over a communication channel.** The design issues have to do with making sure that when one side sends a 1 bit, it is received by the other side as a 1 bit, not as a 0 bit.

- **Physical characteristics of interface and media**: It defines the characteristics of the interface between the devices and the transmission medium. It also defines the type of transmission medium.
- **Representation of bits**: The physical layer data consists of a stream of bits **without any interpretation.** For the transmission of bits over transmission channel, data are converted into signals using various types of encoding techniques.
- **Data Rate:** It is also defined by the physical layer.

The OSI Reference Model (The Physical Layer)

- **Synchronization of bits:** The sender and receiver must be synchronized at the bit level.

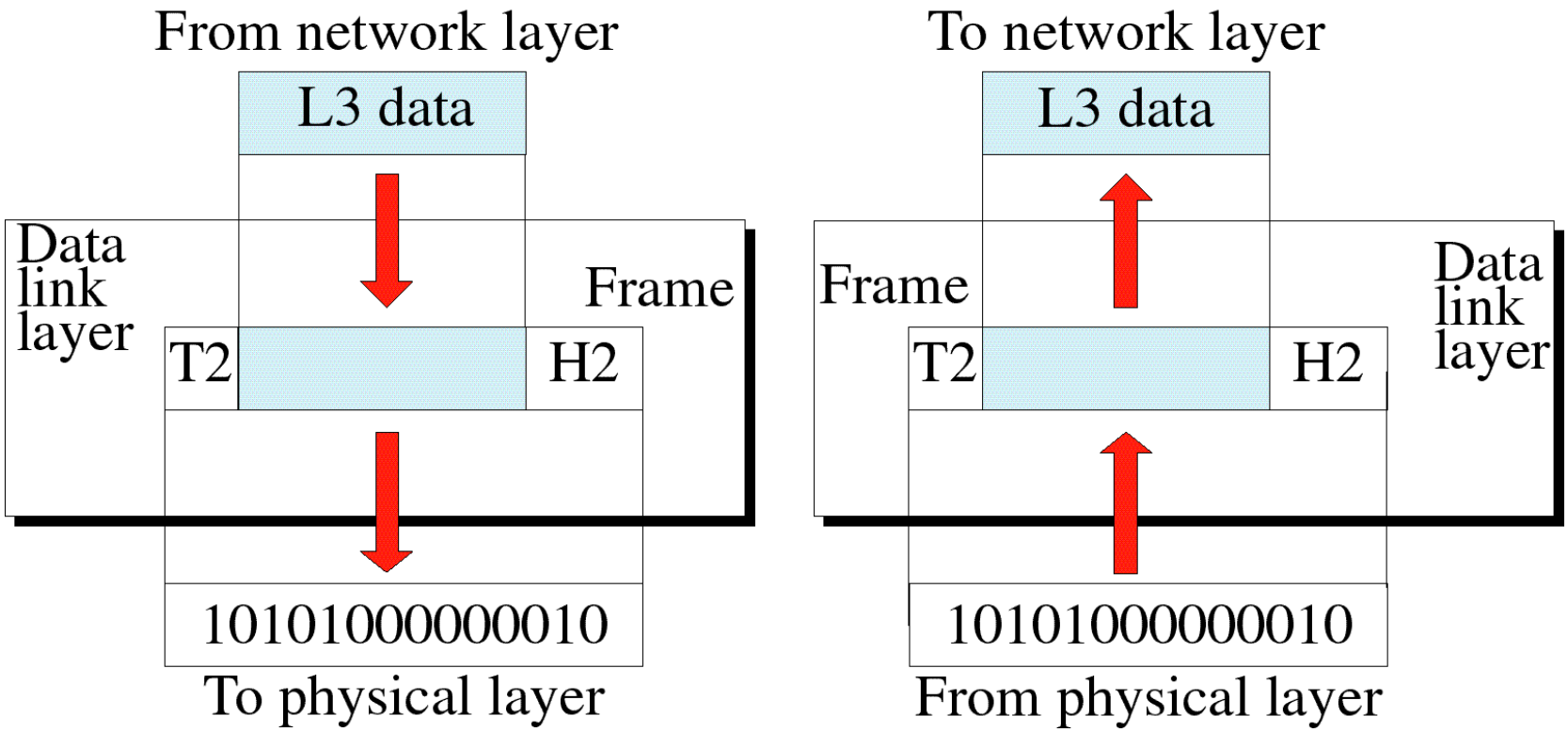
- **Line Configuration:** It defines the line configuration either point-to-point or multipoint line configurations.

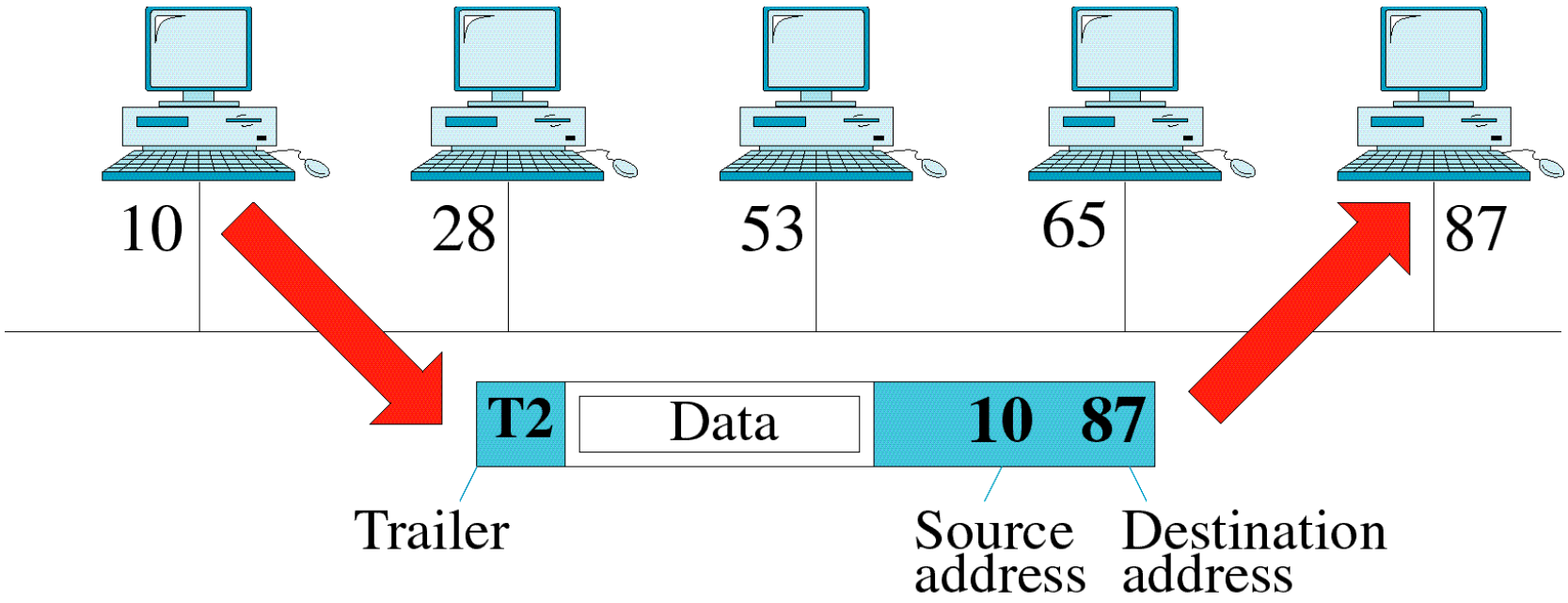
- **Physical Topology:** It defines how devices are connected to make a network. It may be *ring*, bus, tree, star, mesh topology.

- **Transmission mode:** The physical layer also defines the direction of transmission between two devices. It may be **simplex, half-duplex or full-duplex**.

Data Link Layer

- To organize **bits into frame**, to provide node-to-node delivery. It is also responsible for flow control, error control and access control.
- **Framing:** The data link layer divides the stream of bits received from the network layer into manageable data unit called frames.
- **Physical Addressing:** If frames are to be distributed to different systems on the network, the DLL adds a header to the frame to define the physical address of the sender and receiver of the frame.
- Trailer is added for **error control**.
- **Access Control:** When two or more devices are connected to the same link, DLL protocols are necessary to determine which device has control over the link at any given time.


From network layer
L3 data
Data link layer
Frame
T2
H2
10101000000010
To physical layer
To network layer
L3 data
Frame
Data link layer
T2
H2
10101000000010
From physical layer


10
28
53
65
87
T2
Data
10 87
Trailer
Source address
Destination address

Network Layer

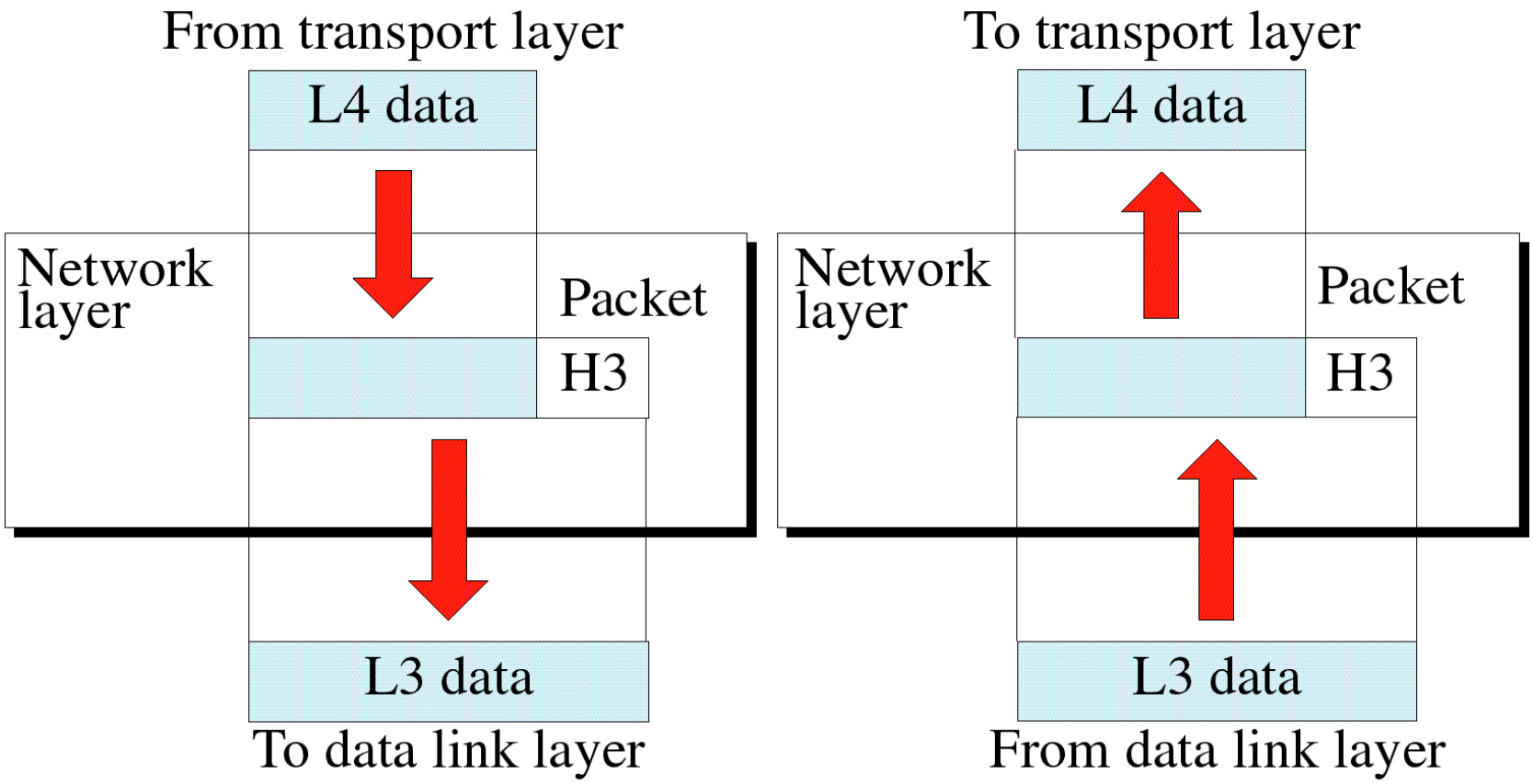
- To move **packets from source to destination**, provide **internetworking**.
- The **NL** is responsible for the **source-to-destination delivery of a packet** possibly across multiple networks, whereas the **DLL** oversees the **delivery of the packets between two systems** on the same network.
- If **two systems are connected to the same link**, there is usually **no need for a network layer**. However, if the **two systems are attached to different networks** with connecting devices between the networks, there is often a **need for the network layer to accomplish source to destination delivery**.

Network Layer

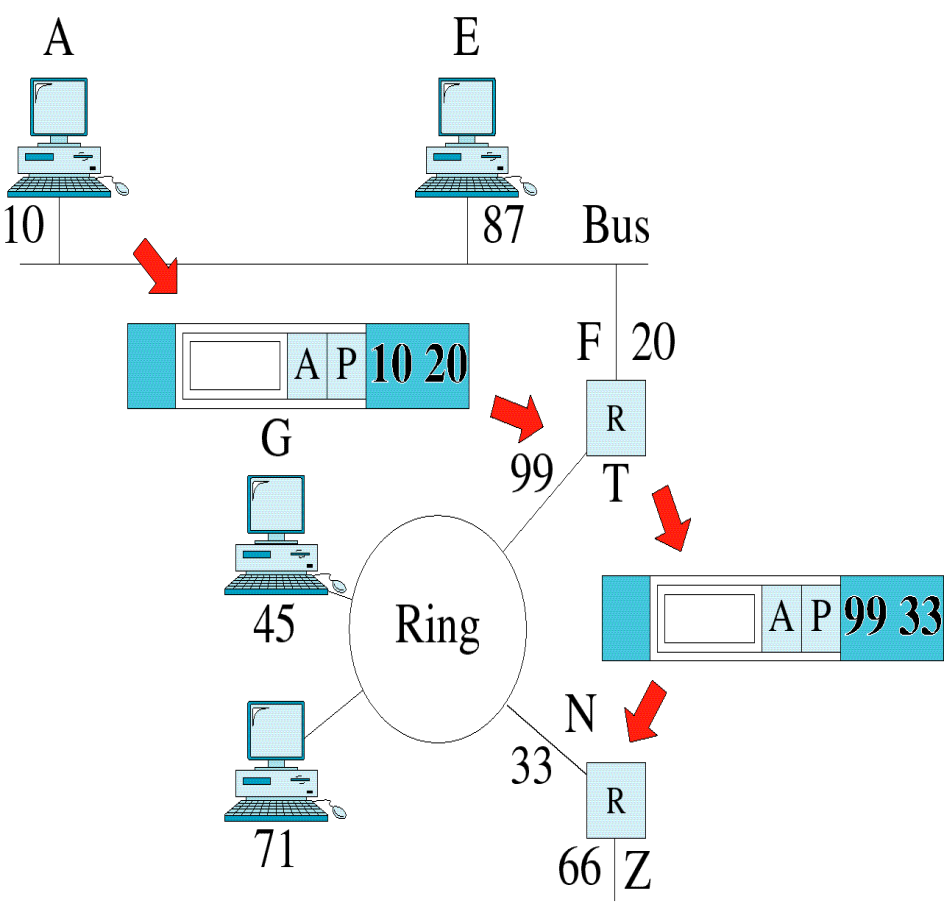
- **Logical Address:** The physical addressing implements by the DLL handles the addressing problem locally. If a packet passes the n/w boundary, we need another addressing system to help distinguish the source and destination systems. The NL adds a header to the packet coming from the upper layer that, among other things, includes the **logical address of the sender and receiver**.

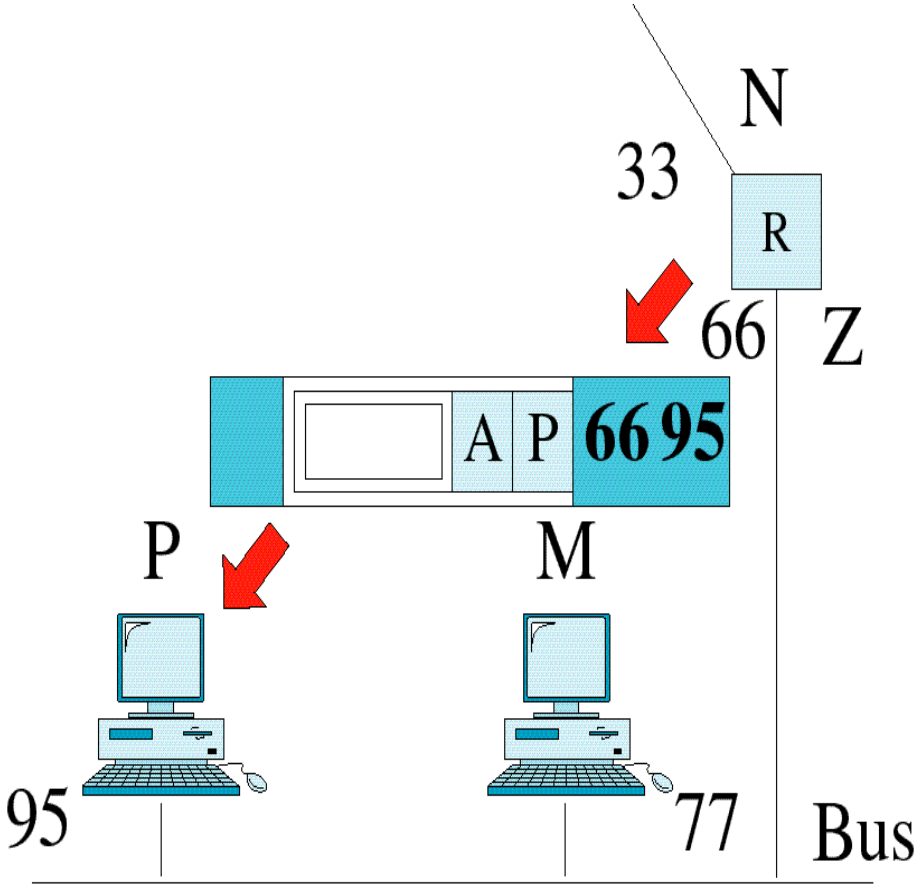
- **Routing:** When independent networks or links connected together to create an internetwork or a large network, the connecting devices (routers or gateways) **route the packets to their final destination**.

Network Layer



Network Layer

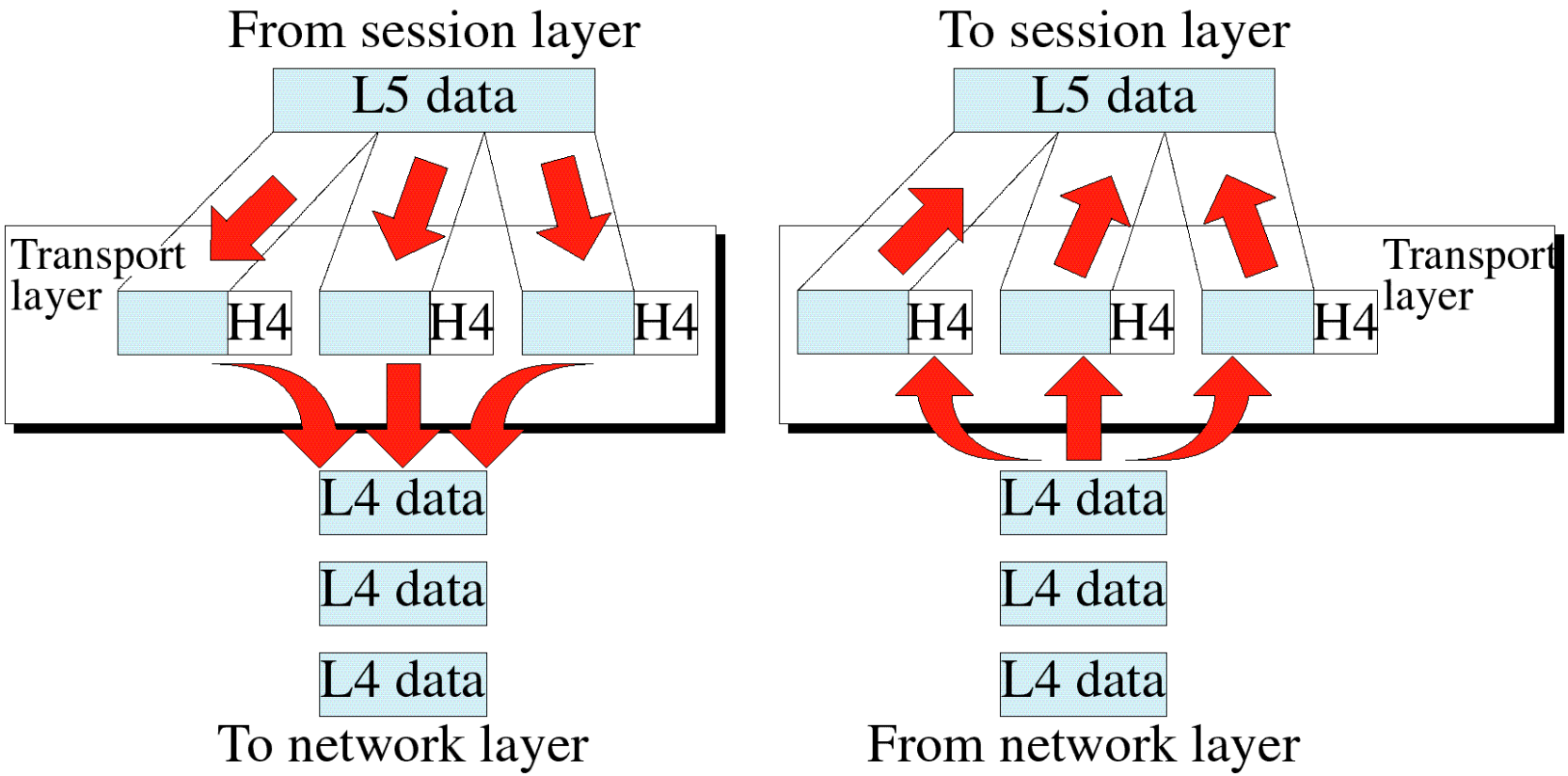




Transport Layer

- The Transport layer is responsible for source to destination (end-to-end) delivery of the **entire message** whereas the n/w layer oversees end-to-end delivery of **individual packets**, it doesn't recognize any relationship between those packets. But the TP Layer ensures that the whole message arrives intact and in order, overseeing both **error control** and **flow control** at the source-to-destination level.
- For security, the TL may create a **connection** between the two end ports. A connection is a single logical path between the source and destination that is associated with all packets in a message.
- This connection include three steps:
  1. Connection establishment
  2. Data Transfer
  3. Connection Release

Transport Layer



Transport Layer

- **Functions of Transport Layer:**
- **Service-point addressing**: Communication occurs not just from end machine to end machine but from end application to end application. Data generated by an application on one machine must be received not just by other machine but by the correct application on the other machine, so to ensure accurate delivery from access point to service access point, we need **another level of addressing** in addition to those at the DLL an NL levels.
- **E.g.s of services:**
- SMTP: Simple Mail Transfer Protocol
- FTP: File Transfer Protocol
- TELNET: Terminal Network
- SNMP: Simple Network Management Protocol
- HTTP: Hyper Text Transfer Protocol

Transport Layer

- According to **IANA (Internet Assigned No. Authority),** port numbers are divided into three ranges.

1. **Well-known Port**: **0 to 1023**. They all are assigned and controlled by IANA.
2. **Registered Port**: **1024 to 49,151.** Not assigned & controlled by IANA, but they can be registered with IANA to prevent duplication.
3. **Dynamic Port [Private]**: **49,152 to 65,535**. They are neither controlled nor registered. They can be used for any process.

Well-known Ports

- 20 & 21: File Transfer Protocol (FTP)
- 22: Secure Shell (SSH)
- 23: Telnet remote login service
- 25: Simple Mail Transfer Protocol (SMTP)
- 53: Domain Name System (DNS) service
- 80: Hypertext Transfer Protocol (HTTP) used in the World Wide Web
- 110: Post Office Protocol (POP3)
- 119: Network News Transfer Protocol (NNTP)
- 143: Internet Message Access Protocol (IMAP)
- 161: Simple Network Management Protocol (SNMP)
- 443: HTTP Secure (HTTPS)

Transport Layer

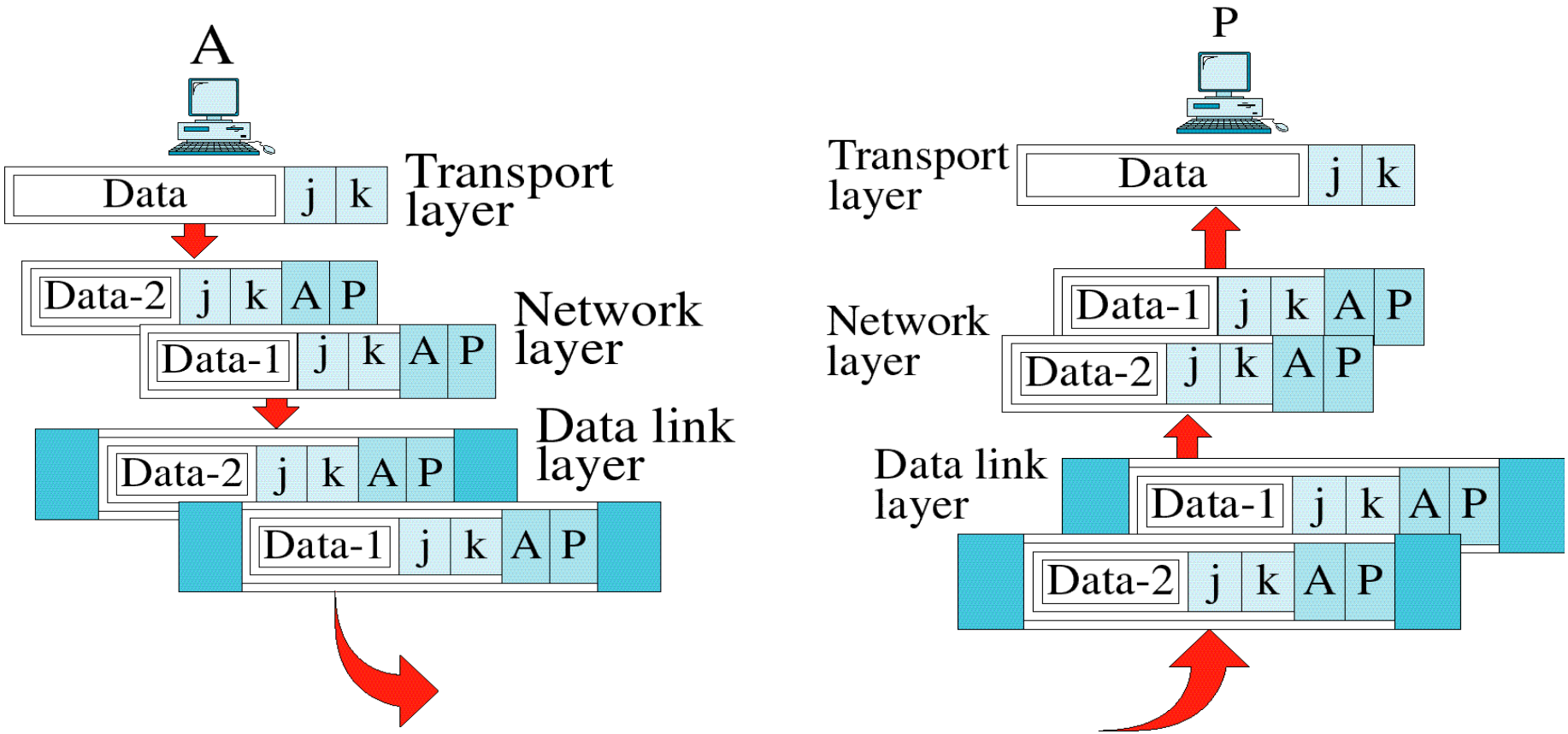
- **Segmentation and Reassembly:** A message is divided into transmittable segments (Packets), with each segment containing a sequence number.

- **Connection Control:** The transport layer can be either connectionless or connection-oriented.

- **Flow Control:** Like DLL, the TP is responsible for flow control, but flow control at this layer is performed end to end rather than across a single link.

- **Error Control:** Like DLL, the TP is responsible for error control, but flow control at this layer is performed end to end rather than across a single link.

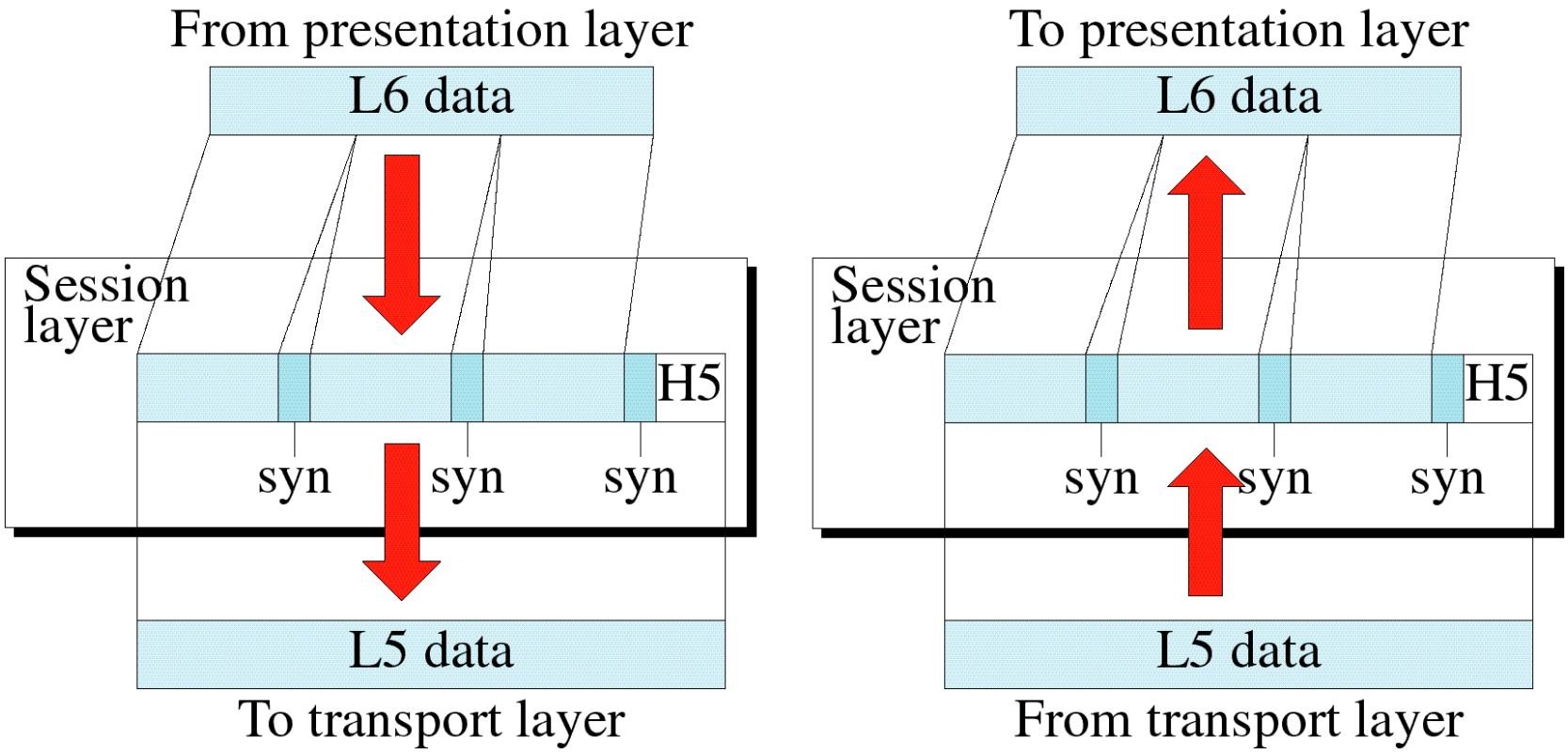
Transport Layer



Session layer

- The session layer is responsible fie **dialog control** and **synchronization**.
- It establishes, maintains, and synchronizes the interaction among communicating systems.
- **Functions of session layers:**
- **Dialog Control**: The session layer allows two systems to enter into a dialog.
- **Synchronization**: The session layer allows a process to add checkpoints to a stream of data. For e.g., if a system is sending a file of 2000 pages, it is advisable to **insert checkpoints** after every 100 pages to ensure that each 100 page unit is received and acknowledged independently.

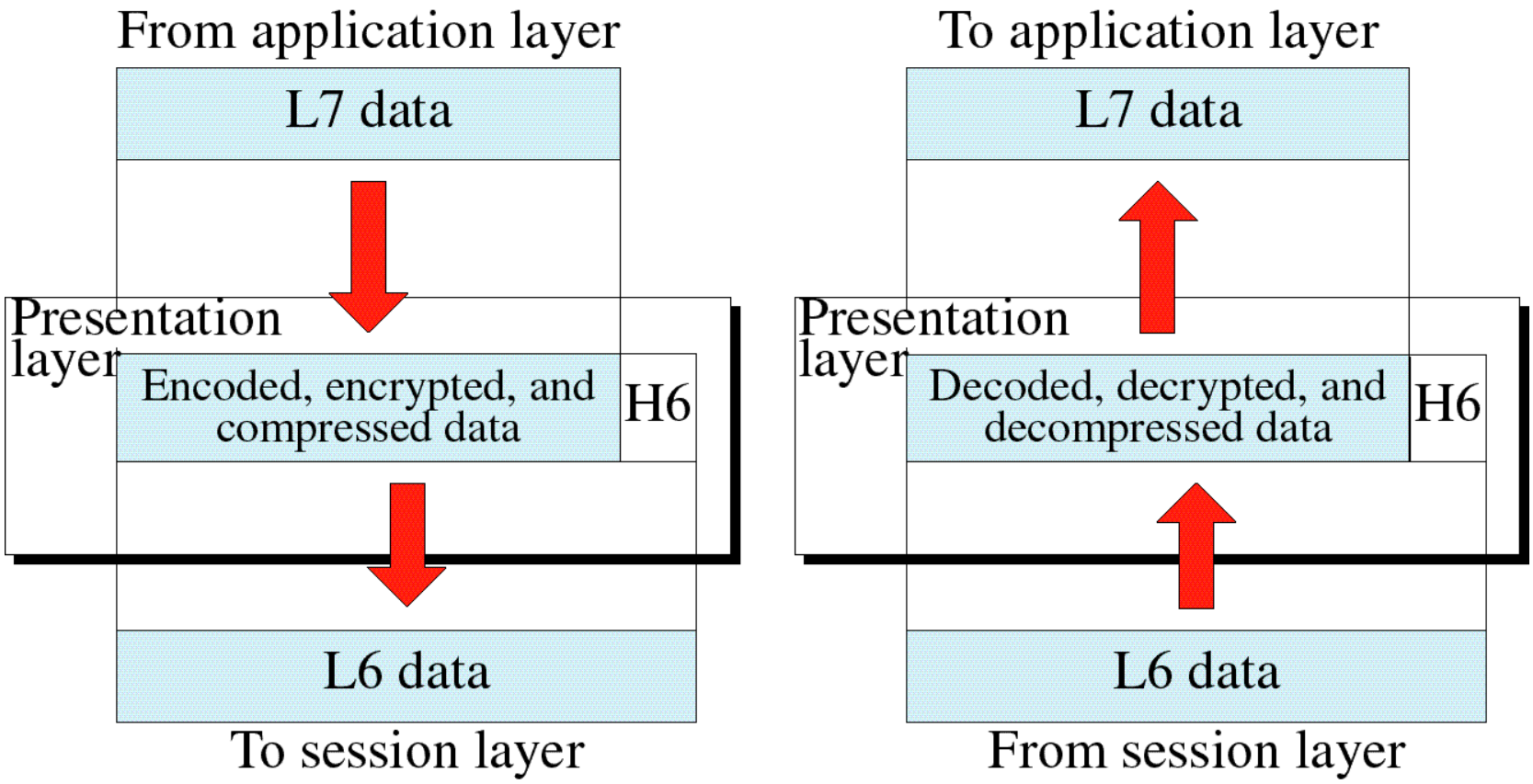
Session Layer



Presentation Layer

- The Presentation layer is responsible for translation, compression and encryption.
- **Translation:** The process (running program) in two systems are usually exchanging information in the form of **character strings, numbers** and so on. The information must be changed **to bit streams** before being transmitted. Because different computers use different encoding systems, the presentation layer at the sender changes the information from **its sender-dependent** format into **common format**. The presentation layer at the receiving machine changes the common format into its **receiver-dependen**t format.
- **Encryption:** To carry sensitive information, a system must be able to ensure privacy.
- **Compression:** Data compression reduces the number of bits contained in the information.

Presentation Layer



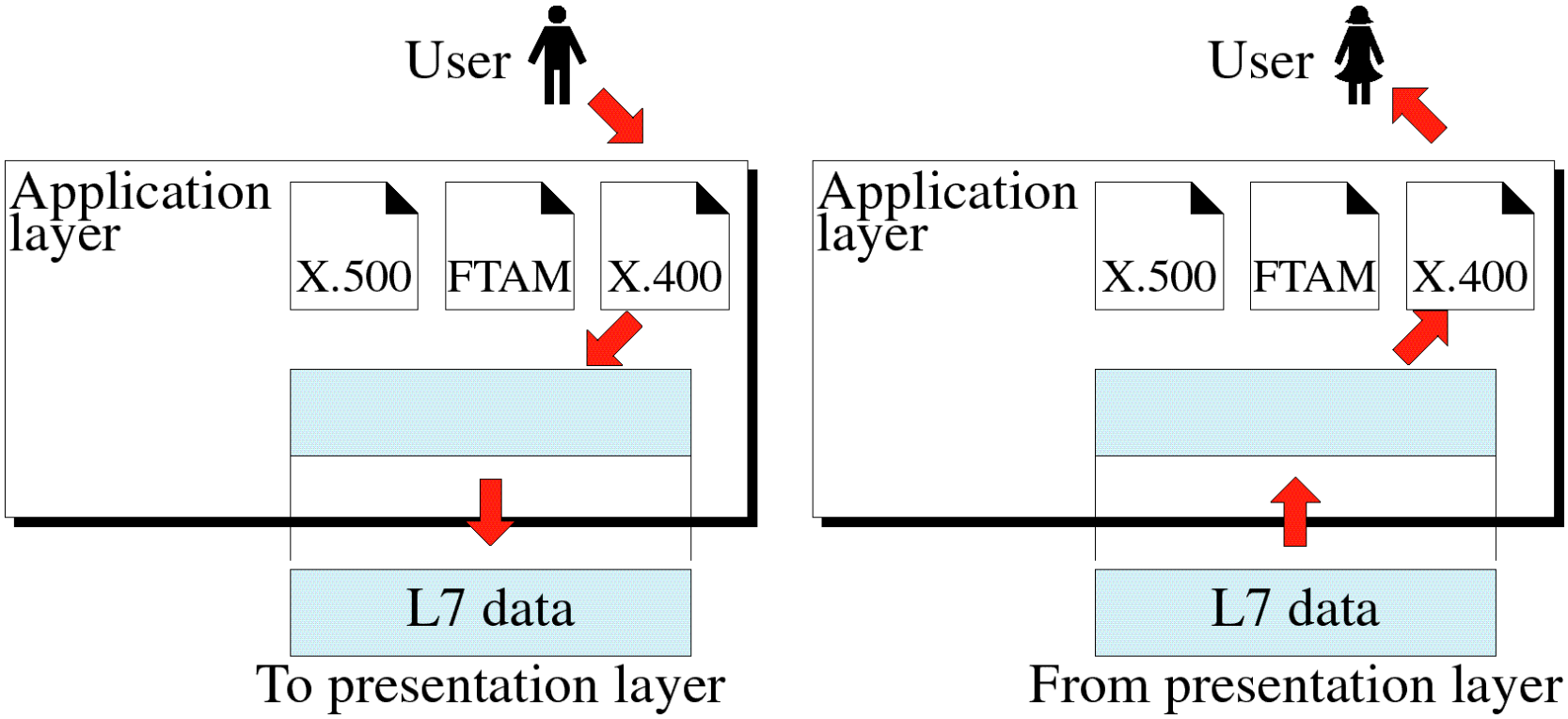
Application Layer

- The application layer is responsible **for providing services to the user.**
- Specific services provided by the application layer include following:

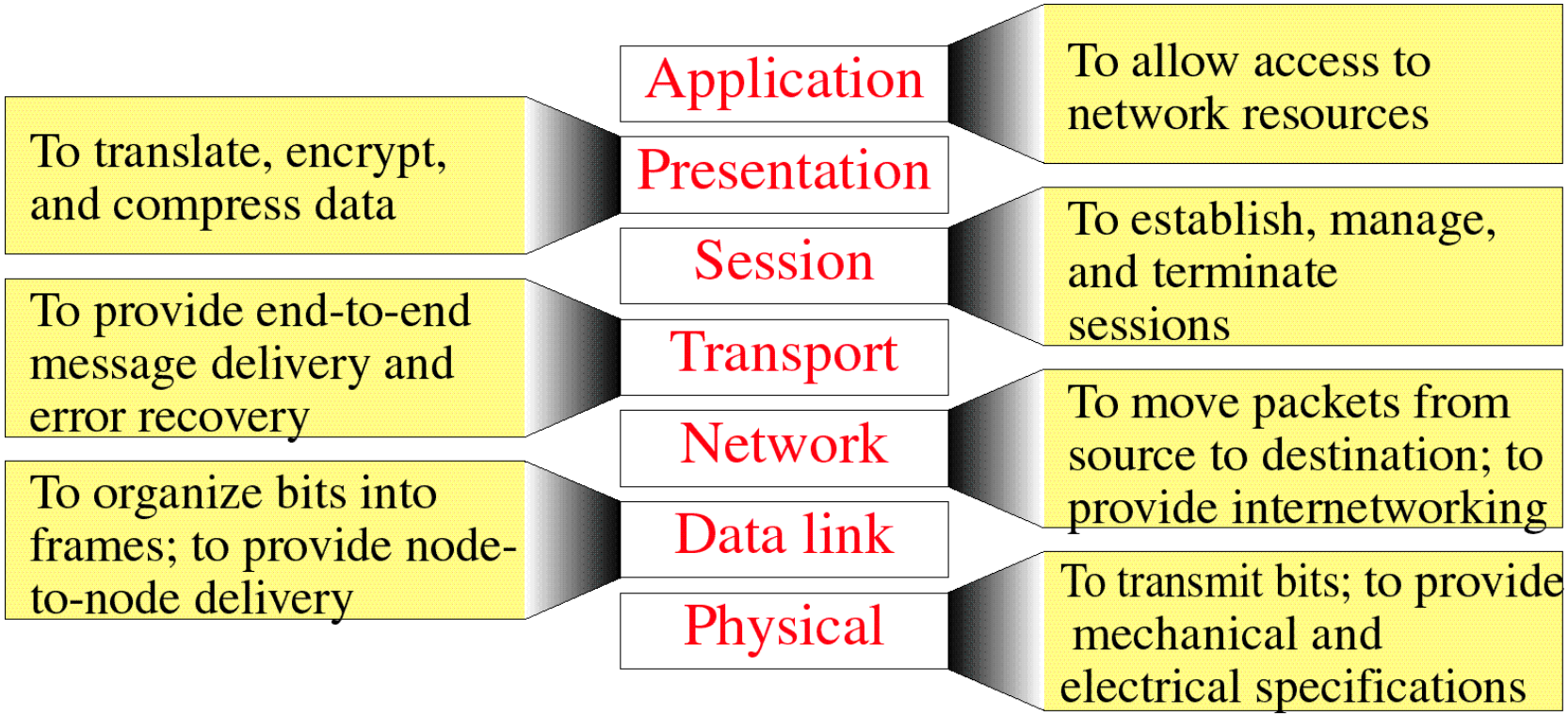
- **File transfer, access and management:** This application allows a user to access files in a remote host, to retrieve files from a remote computer for use in the local computer.

- **Mail server:** This application provides the basis for e-mail forwarding and storage.

Application Layer



Summary of Layer Functions



1.4.2 The TCP/IP Reference Model

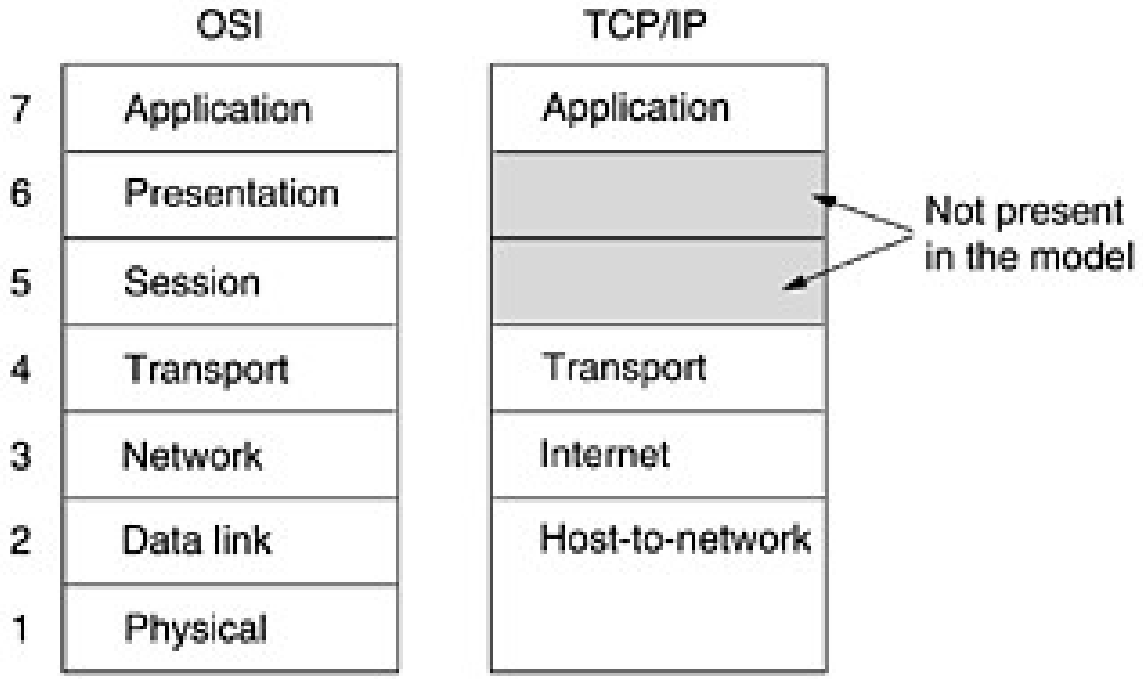
- The grandparent of all wide area networks, the ARPANET sponsored by DoD (Department of Defense) of US.

- It eventually connected **hundreds of universities and government installations,** using leased lines.

- When satellite and radio networks were added later, the existing protocols had trouble interworking with them, so a new reference architecture was needed.

1.4.2 The TCP/IP Reference Model

- The TCP/IP reference model has four layers: **host-to-network Layer, internet Layer, transport Layer, Application Layer**
- The Host-to-network layer of TCP/IP is equivalent to Data link and physical layer of OSI model.
- The Internet layer of TCP/IP is equivalent to Network layer of OSI model.
- The Application layer of TCP/IP is roughly doing the job of the session, presentation and application layer of OSI.



Differences between TCP & OSI

- **TCP/IP** is a standard **protocol** used for every network including the Internet, whereas,
- **OSI** is not a **protocol** but a reference **model** used for **understanding and designing** the system architecture.

- **TCP/IP** is a four-layered **model**, whereas, **OSI** has seven layers.

- **TCP/IP** is Tangible, whereas, **OSI** is not.

1.4.2 The TCP/IP Reference Model (The Internet Layer)

- The job of Internet Layer is to permit hosts **to inject packets into any network** and have them travel **independently** to the destination (potentially on a different network).
- They may **arrive in a different order** than they were sent, in which case it is the job of higher layers to rearrange them.
- The internet layer defines an official **packet format** and **protocol** called IP **(Internet Protocol).**

1.4.2 The TCP/IP Reference Model (The Transport Layer)

- First protocol of Transport layer is **TCP (Transmission Control Protocol)**:
- It is a **connection-oriented protocol** that allows a byte stream originating on one machine to be delivered without error on any other machine in the internet.
- It fragments the incoming byte stream into discrete messages and passes each one on to the internet layer.
- At the destination the receiving, the receiving TCP process **reassembles** the received messages into the output stream.
- TCP also handles **flow control**.

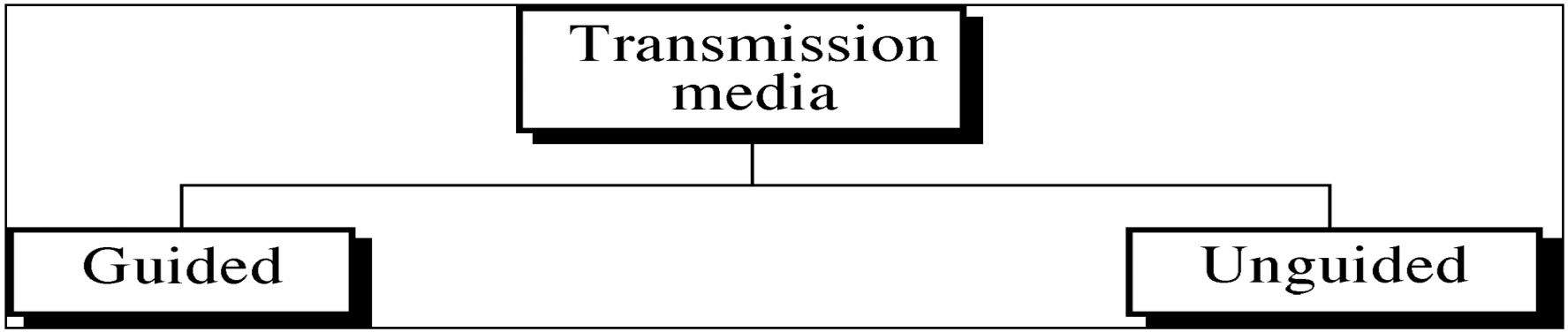
1.4.2 The TCP/IP Reference Model (The Transport Layer)

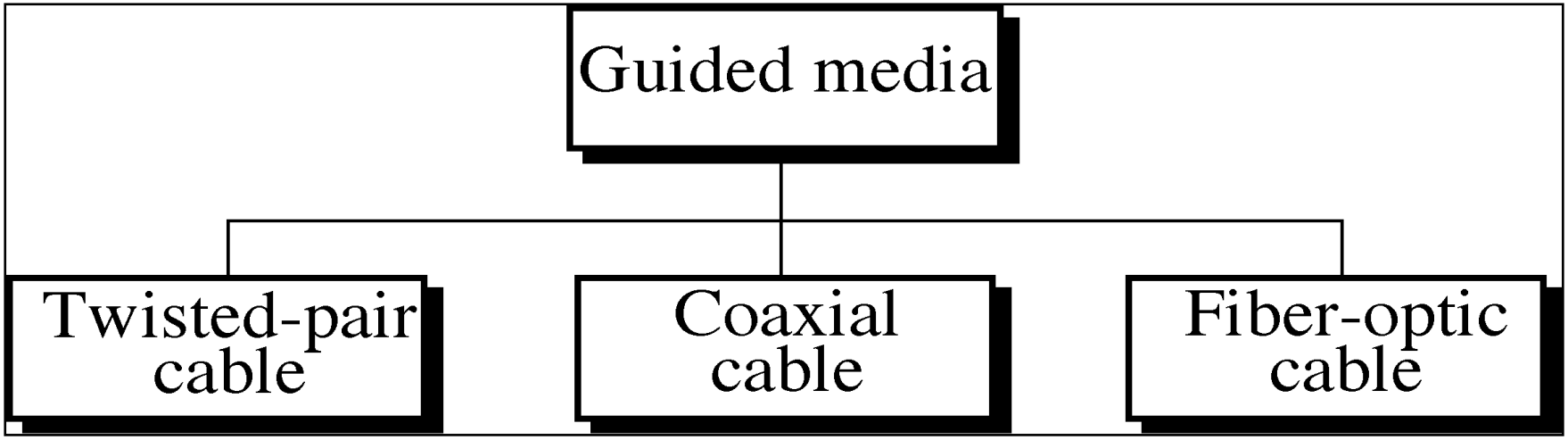
- The second protocol is **UDP** (User Datagram Protocol).
- It is an unreliable, connectionless protocol for applications.
- It is widely used for one, client-server-type, request-reply queries and applications in which **prompt delivery** is **more important than accurate delivery**, such as transmitting speech or video.

Chapter No. 02 The physical layer- I

- ✓Transmission media,
- ✓Magnetic media,
  - A. Twisted pair ,
  - B. coaxial cable,
  - C. Fiber optic ,
- ✓Wireless transmission,
- ✓Electromagnetic spectrum,
  - A. Radio transmission,
  - B. Microwave transmission,
  - C. Infrared,
  - D. light wave.

Transmission Media





2.2 Guided Transmission Media

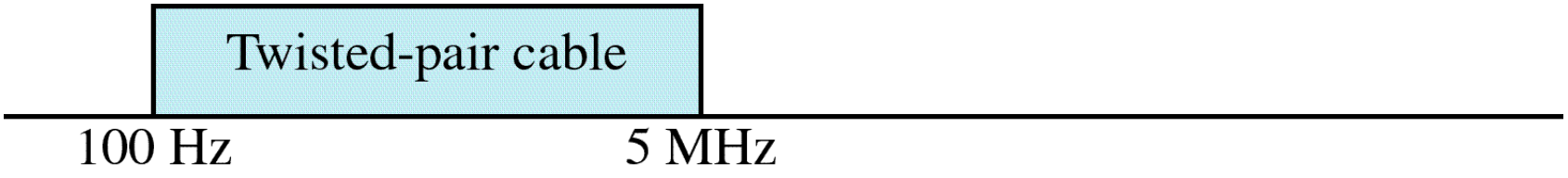
- **Transmission Media**: It is a physical path between transmitter and receiver in data communication system.
- Computers and telecommunication devices use **signals to represent data**. This signals are transmitted in the form of **electromagnetic energy**. Waves can travel through air, vacuum or wire etc.
- There are two types of transmission media: **Guided (Bounded)** and **Unguided (Unbounded)**
- In Guided media, waves are guided along solid medium such as Twisted Pair. Co-axial cable or fiber Optic cable.
- **TP and CC** use copper conductor that accept and transport signals in the form of electric current.
- Optic Fiber is glass or plastic cables that accept and transmit signals in the form of light.

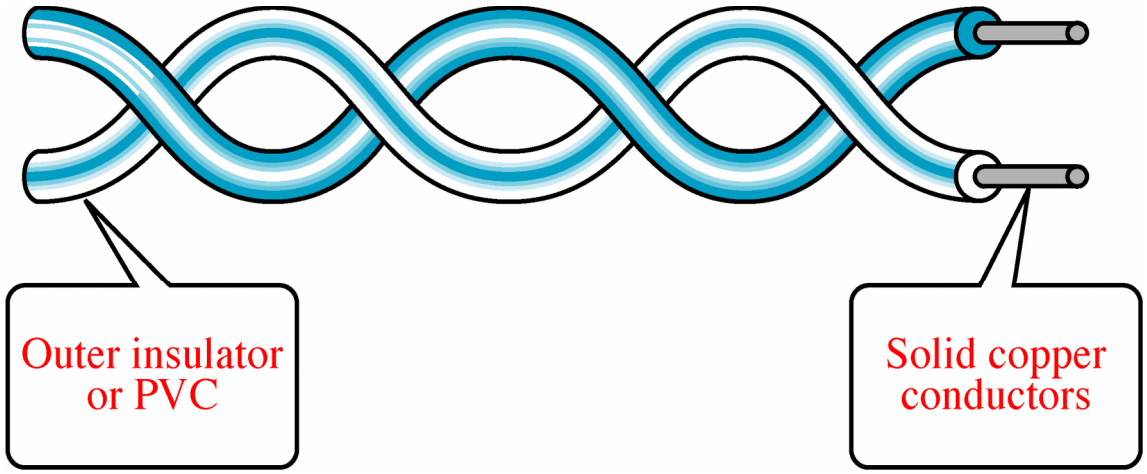
2.2 Guided Transmission Media

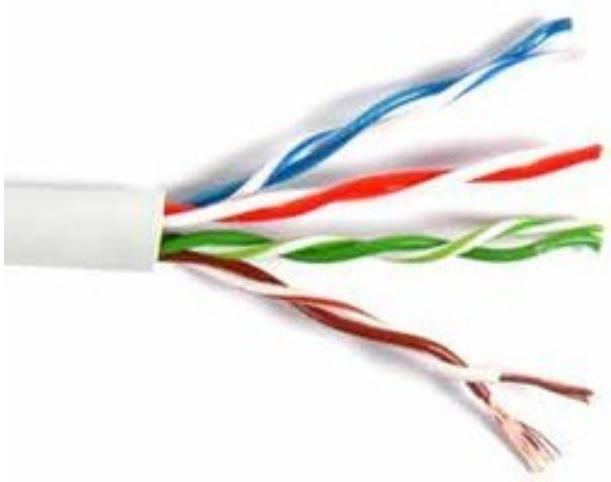
- In unguided media, electromagnetic waves transport without using any physical conductor.
- Atmosphere and outer space are the examples of unbounded media which provide transmitting waves but do not guided them so called **wireless transmission**.

- Here signals are broadcast through air, vacuum, sea water and thus are available to anyone who has device capable of receiving them.
- For e.g. Radio transmission, Satellite Transmission, Cellular Telephone.

2.2 Guided Transmission Media (2.2.2 Twisted Pair)

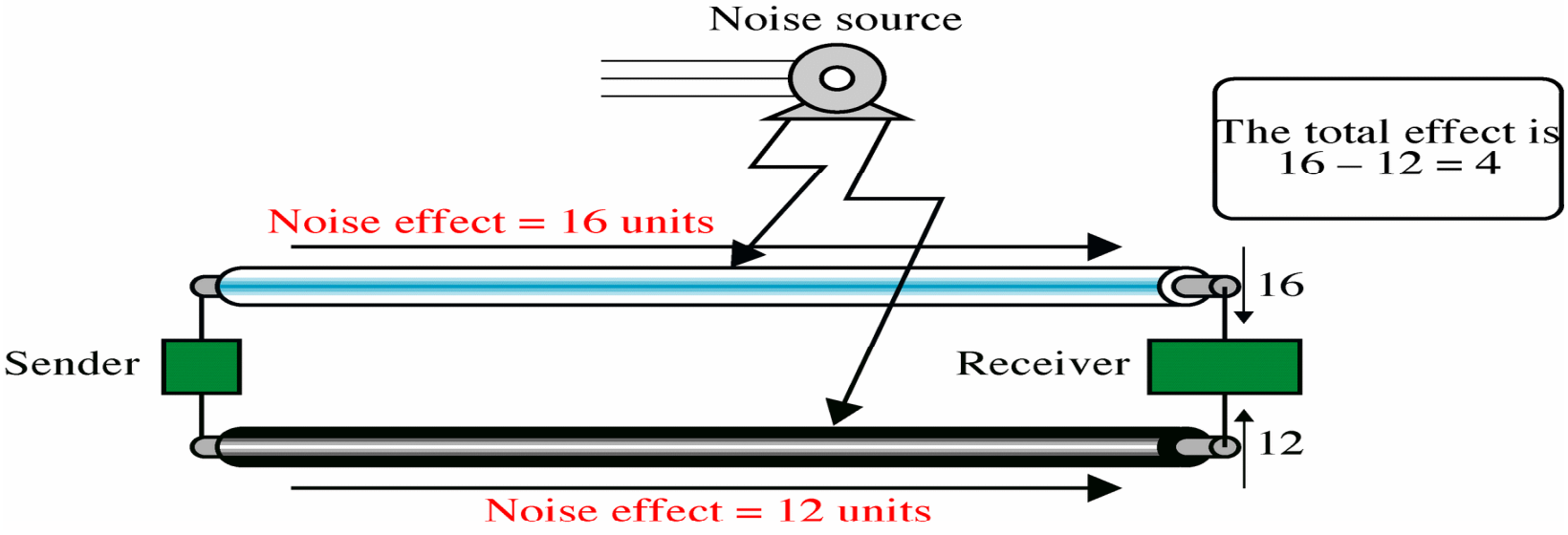


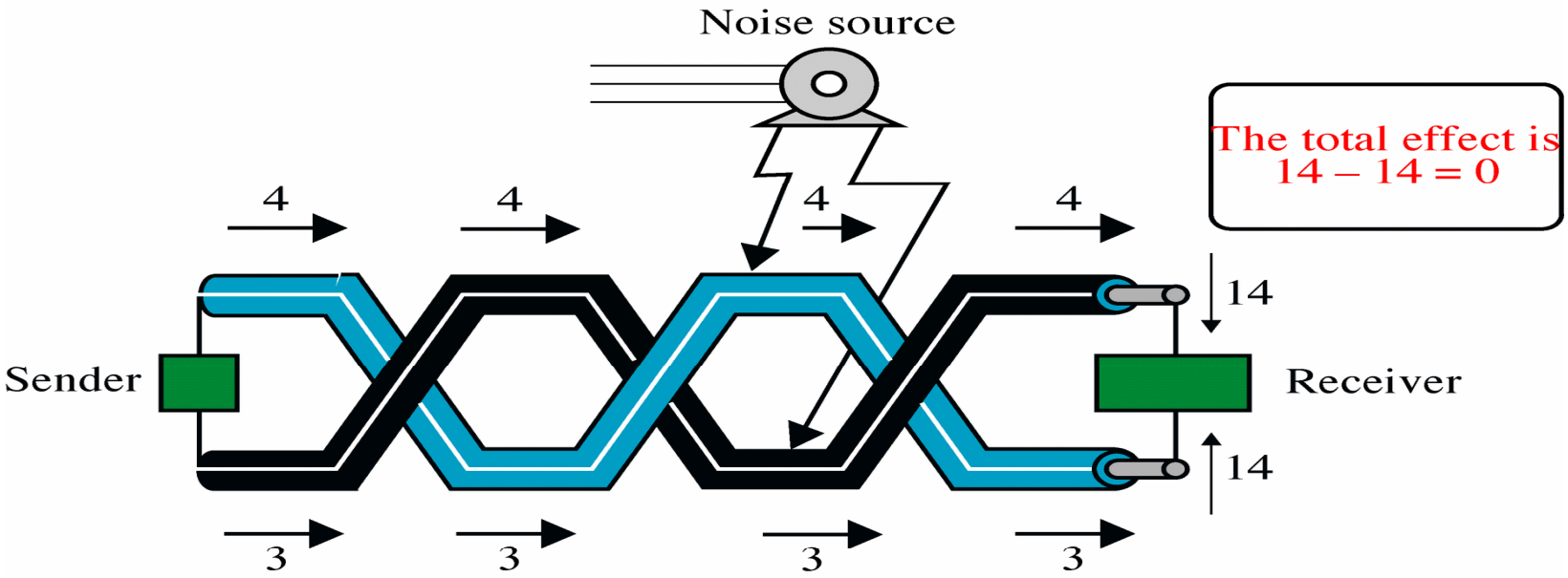




- It is most common type of telecommunication medium.
- Frequency range for TP cable is 100 Hz to 5 MHz, which is suitable for transmitting both data and voice.
- A TP is consists of two conductors, each with its own colored plastic insulation. The plastic insulation is color-banded for identification.

Effect of Noise on Parallel Lines

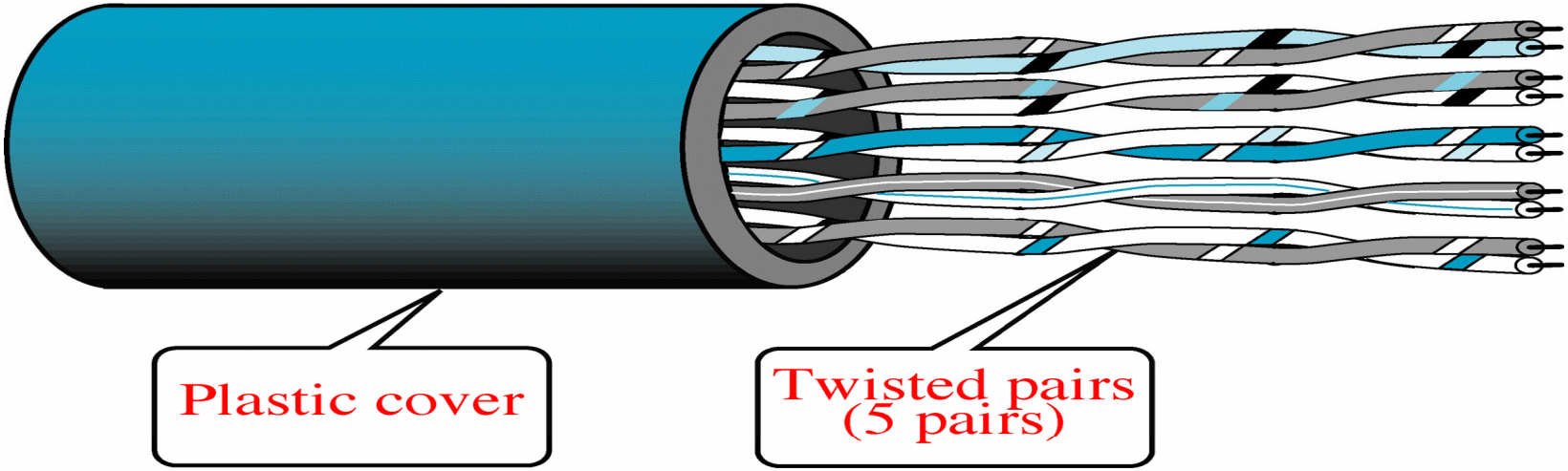




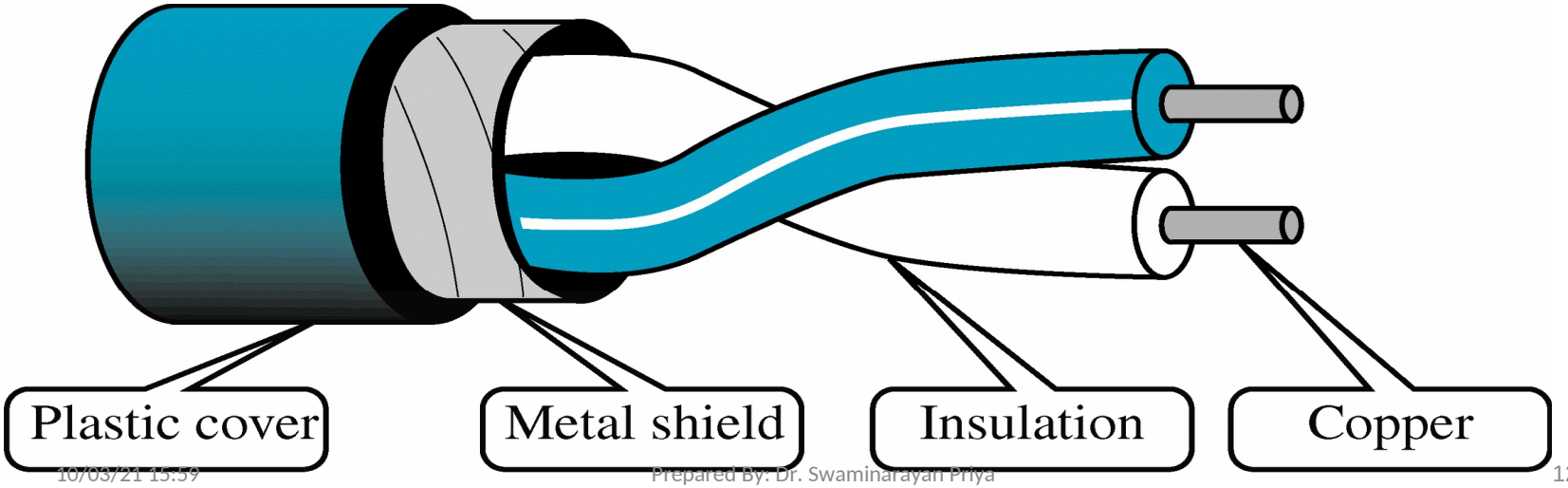
Noise on Twisted-Pair Lines

- In the past, two parallel flat wires were used for communication. The electromagnetic interference from devices such as motor can create noise over those wires. If two wires are parallel, the wire close to the source of the noise gets more interference and ends up with a higher voltage level than the wire farther away, which results in an uneven load and a damaged signal.
- It two wires are twisted around each other at regular intervals, each wire is closer to the noise regular intervals, each wire is closer to the noise source for half the time and farther away from for other half. At the receiving end, the cumulative effect of interference is same.
- Note: TP does not always eliminate the impact of noise, but it does significantly reduce it.

Unshielded Twisted-Pair Cable



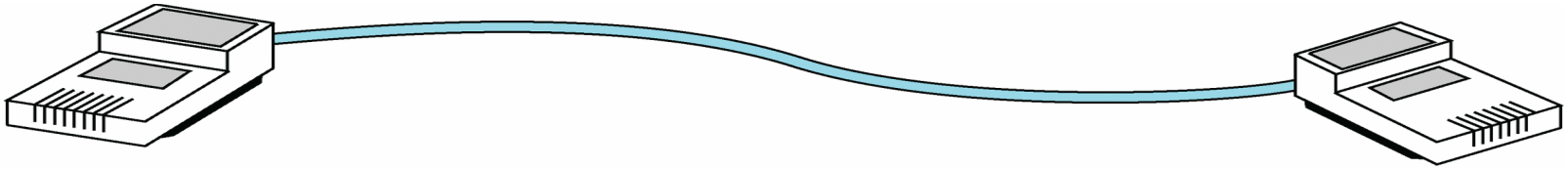
Shielded Twisted-Pair Cable

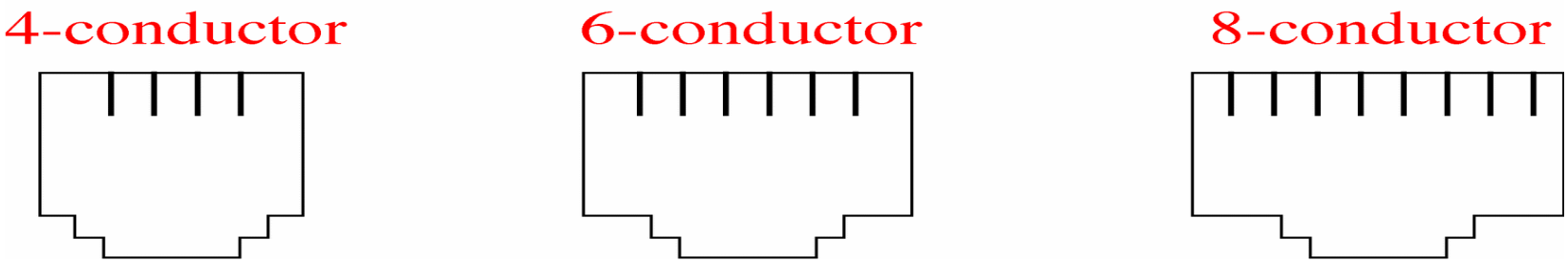


2.2 Guided Transmission Media (2.2.2 Twisted Pair)

- IBM has produced a version of TP-cable known as STP.
- STP cable has a metal foil that encases each pair of insulated conductors, so it improve the quality of cable by preventing the penetration of noise or crosstalk.
- But it is bulkier and more expensive.

UTP Connectors





•Conductors are either male (the plug) or female (the receptacle).
•Male connectors snap into female connector.
•Most common UTP connector is RJ-45 (Registered Jack – 45) with eight connectors, one for each wire of four twisted pair.

Twisted-Pair Cable

- **Standards for UTP cable**
- The EIA (Electronic Industries Association) had developed standards for UTP cables by quality.
- **CAT-1 (Category-1):** It is used in telephone system. It is good for voice but inadequate for all.
- **CAT-2:** It is suitable for voice and for data communication up to 4 Mbps.
- **CAT-3:** It requires at least three twists per foot. It is used for data transmission up to 10 Mbps. Now it is the standard cable for telephone systems.
- **CAT-4:** It is also requires at least three twists per foot. The possible transmission rate is 20 Mbps.
- **CAT-5** : it is used for data transmission up to 100 Mbps.

Standards for UTP cable

Category	Bandwidth	Data rate	Digital/Analog	Uses
CAT-1	Very row	< 100 kbps	Analog	Telephone
CAT-2	< 2 MHz.	4 Mbps	Analog/Digital	T-1 Lines
CAT-3	16 MHz.	10 Mbps	Digital	LANs
CAT-4	20 MHz.	20 Mbps	Digital	LANs
CAT-5	100 MHz.	100 Mbps	Digital	LANs
CAT-6	200 MHz.	200 Mbps	Digital	LANs
CAT-7	600 MHz.	600 Mbps	Digital	LANs

Advantages of UTP

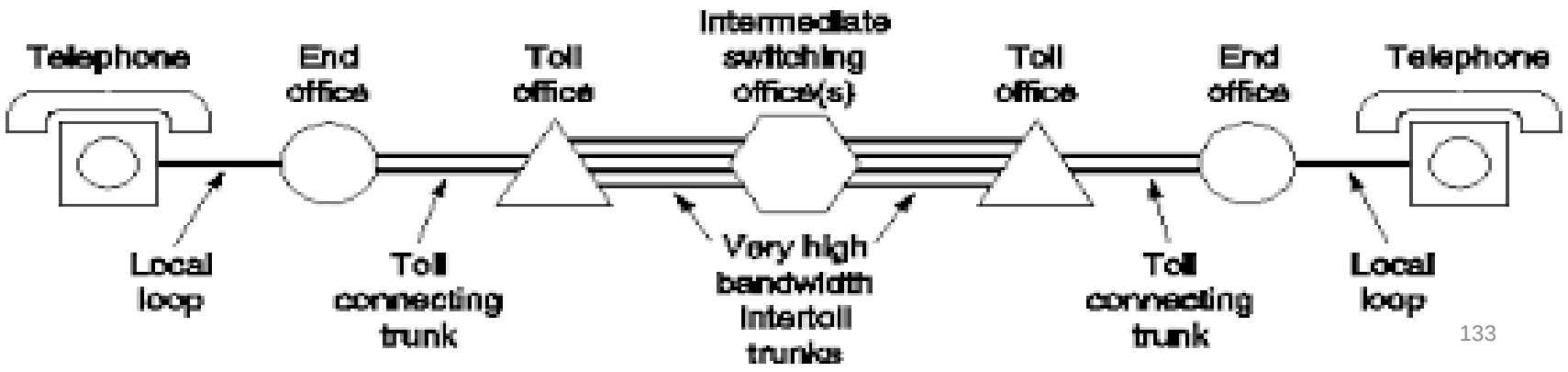
- UTP is cheap, flexible and easy to install.
- UTP are used in LAN technologies like Ethernet and Token Ring.

Applications of TP

- It is used in telephone lines to provide voice and data channels. The local loop – the line that connect subscribers to the central telephone office – is most commonly UTP cables.

- UTP is used in DSL (Digital Subscriber Line) technology. DSL provide high-speed access to the Internet. DSL also supports high-speed digital communication over the existing local loops.

- LANs such as 10-Base-T and 100-Base-T also uses TP cables.



formal name	Common name	Formal IEEE name	Speed	Cable and Max Length	Suitable Cable
10 BASE-T	Ethernet	802.3	10Mbps	Copper,100 m	category3, 5
100 BASE-T	Fast Ethernet	802.3u	100Mbps	Copper,100m	Category5
1000BASE-T	Gig Ethernet	802.3z	1000Mbps	Fiber,5000m	Category5e

- **Advantages of Twisted pair cable**

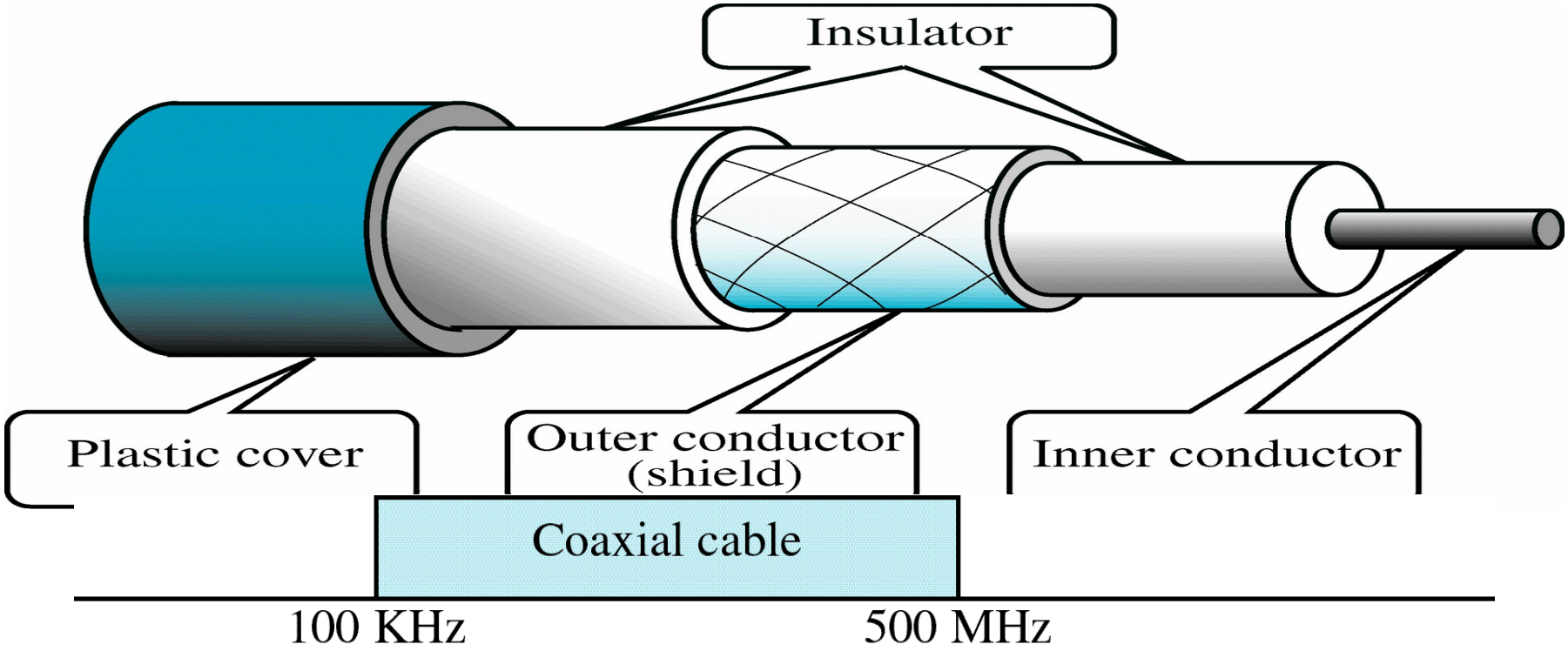
1.It can be used to carry both analog and digital data.

2.It is relatively easy to implement and terminate.

3.It is the least expensive media of transmission for short distances.

4.If portion of a twisted pair cable is damaged it does not effect the entire network.

2.2 Guided Transmission Media (2.2.3 Coaxial Cable)



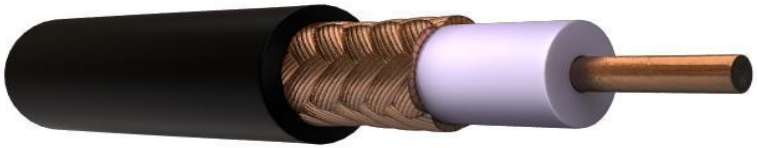
- One of the common transmission media. Usually called as **coax.**
- It has better shielding than twisted pairs, so it can span longer distances at higher speeds.
- Two kinds of coaxial cable are widely used.

2.2 Guided Transmission Media (2.2.3 Coaxial Cable)

- Instead of having two wires, coax has a central core conductor (Usually copper)enclosed in an insulating sheath, which is encased in an outer
- One kind, 50-ohm cable, is commonly used for digital transmission.
- The other, 70-ohm cable, is commonly used for analog transmission.
- A coaxial cable consists of a stiff copper wire as the core, surrounded by an insulating material. The insulator is encased by a cylindrical conductor, often as a closely woven braided mesh.
- The outer conductor is covered in a protective plastic sheath.
- The construction and shielding of the coaxial cable give it a good combination of high bandwidth and excellent noise immunity.

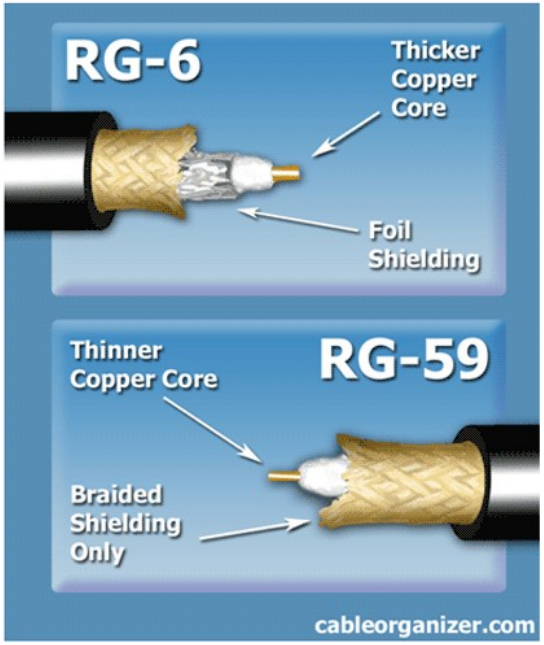
2.2 Guided Transmission Media (2.2.3 Coaxial Cable)

- Coaxial cables are categorized by their radio government (RG) ratings. Each RG no. denotes a unique set of physical specifications like,



- The wire gauge of the inner conductor
- The thickness and type of the inner insulator
- The size and type of outer casing.

1. RG-8, used in thick Ethernet
2. RG-9, used in thick Ethernet
3. RG-11, used in thick Ethernet
4. RG-58, used in thin Ethernet
5. RG-59, used for cable TV.

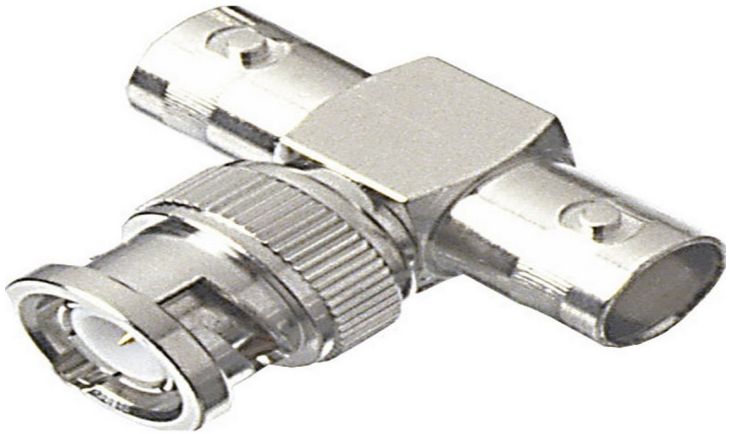


- **Coaxial cable connectors**: To connect coaxial cable to devices, coaxial connectors are needed.
- Most common types of connectors are as follows:

1. **BNC Connector (Bayonet N/W Connector):** It is used to connect the device at the end of the cable, such as a TV set.

Coaxial cable connectors

2. **BNC T Connector**: It is used in Ethernet n/w to branch out a cable for connection to a computer or other devices.
3. **BNC-Terminator**: It is used at the end of the cable to prevent the reflection of the signal.



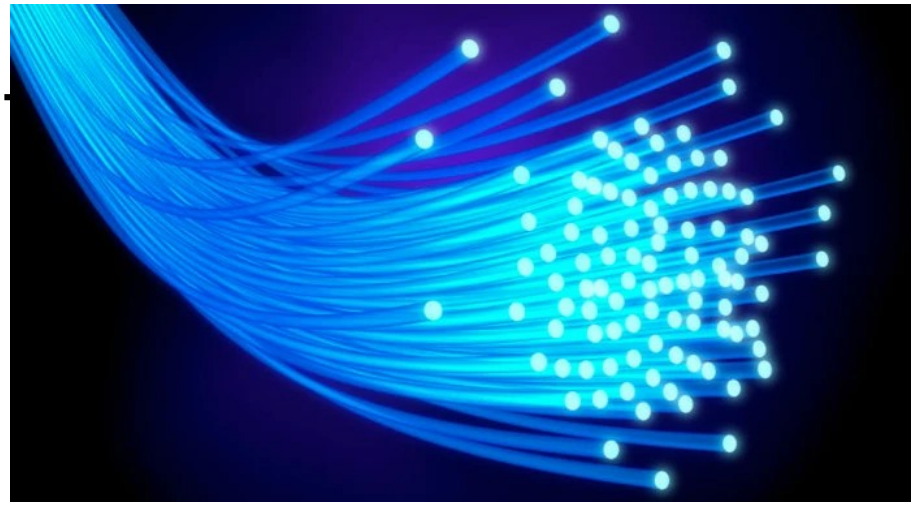
- **Applications:**
- Coaxial cable were used in **analog telephone networks** where a single coaxial n/w could carry 10,000 voice signals, but after that it was used in **digital telephone networks** where a single coaxial cable could carry digital data up to 600 Mbps.
- Cable TV networks also uses coaxial cables. In past, the entire cable n/w used coaxial cable but now cable service providers replace most of the n/w with fiber optic cable.
- It is also used in Ethernet LANs.

- TP, CC transmit signals in the form of current, while optic fiber optic cable transmits signals in the form of light.
- And second difference is the TP and CC consist of metal but OF cable consists of glass or plastic.

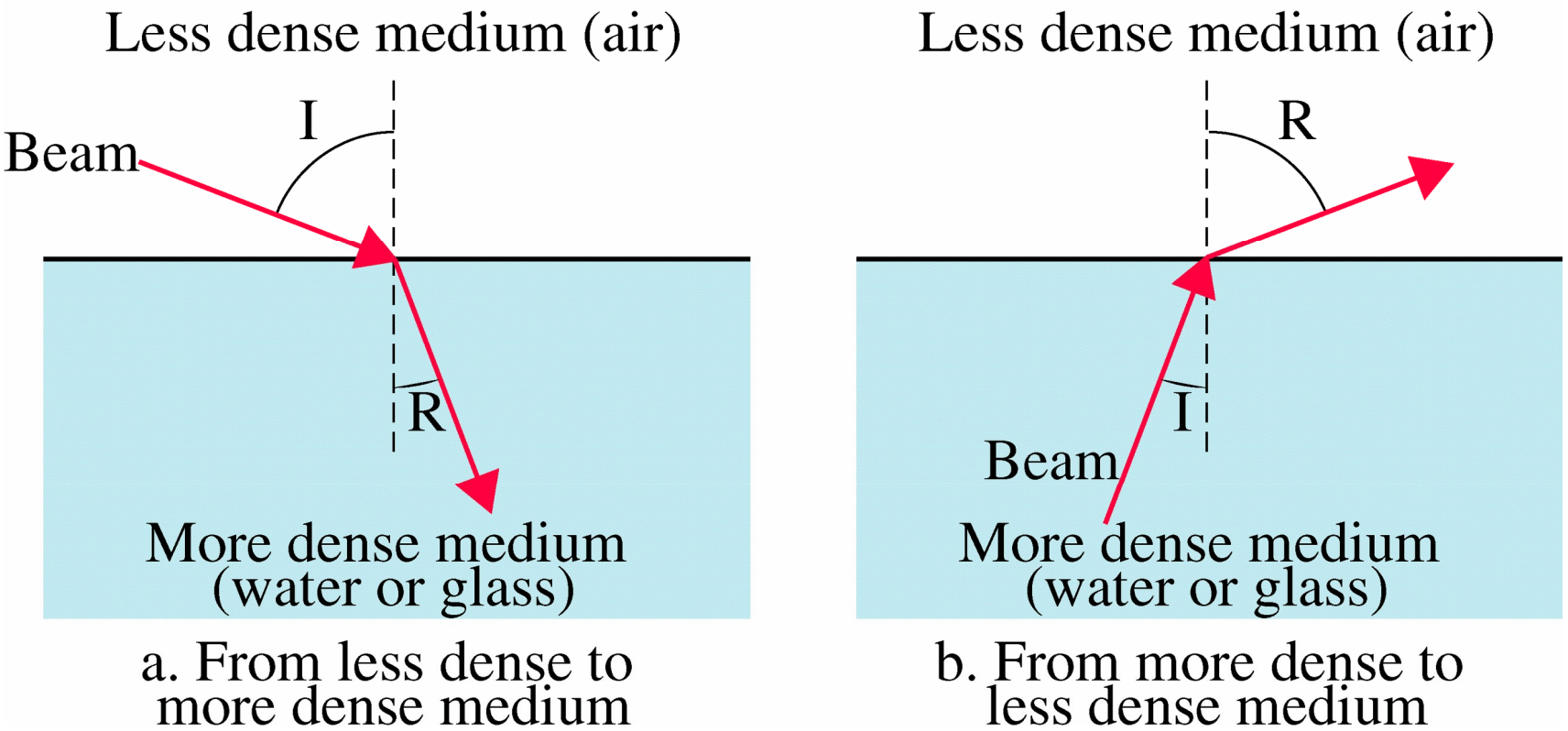
- With current fiber technology, the achievable bandwidth is certainly in excess of **50,000 Gbps (50 Tbps**).

- **Principle of Refraction:**
- Light, a form of electronic energy, travels at 3,00,000 kms/sec or 1,86,000 miles/second, in a vacuum. The speed of light depends on the density of the medium through which it is traveling (the higher the density, the slower the speed).

Principle of Refract

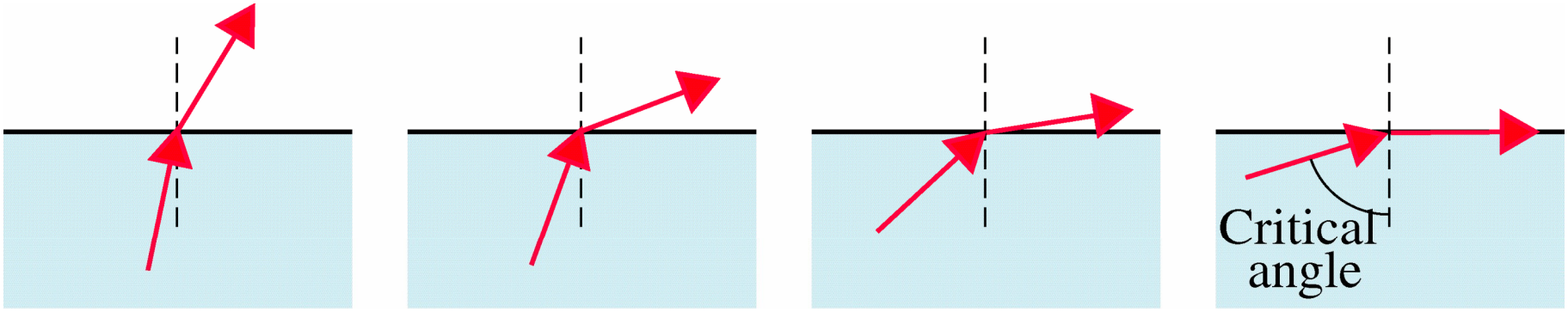


Refraction



- Light travels in a straight line as long as it moving through a single uniform substance. If a ray of light traveling through one substance suddenly enters another (more or less dense) substance, its speed changes, causing the ray to change direction.
- This change is called refraction.

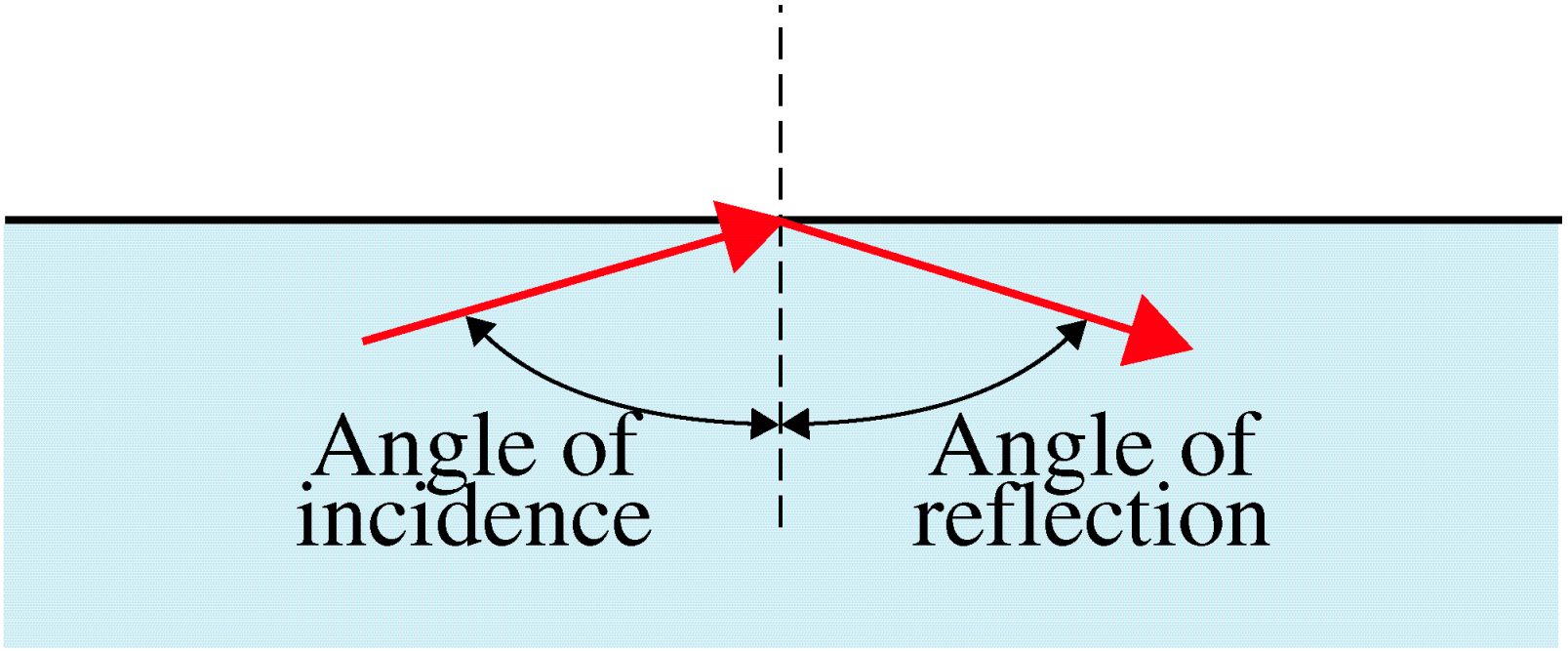
Critical Angle



- As shown in the above figure, as the angle of incidence increases, so does the angle of refraction. It moves away from the vertical and closer and closer to the horizontal.
- At some point, in this process, the change in the incident angle results in a refracted angle of 90 degrees, with the refracted beam now laying along the horizontal. The incident angle at this point is known as the critical angle.

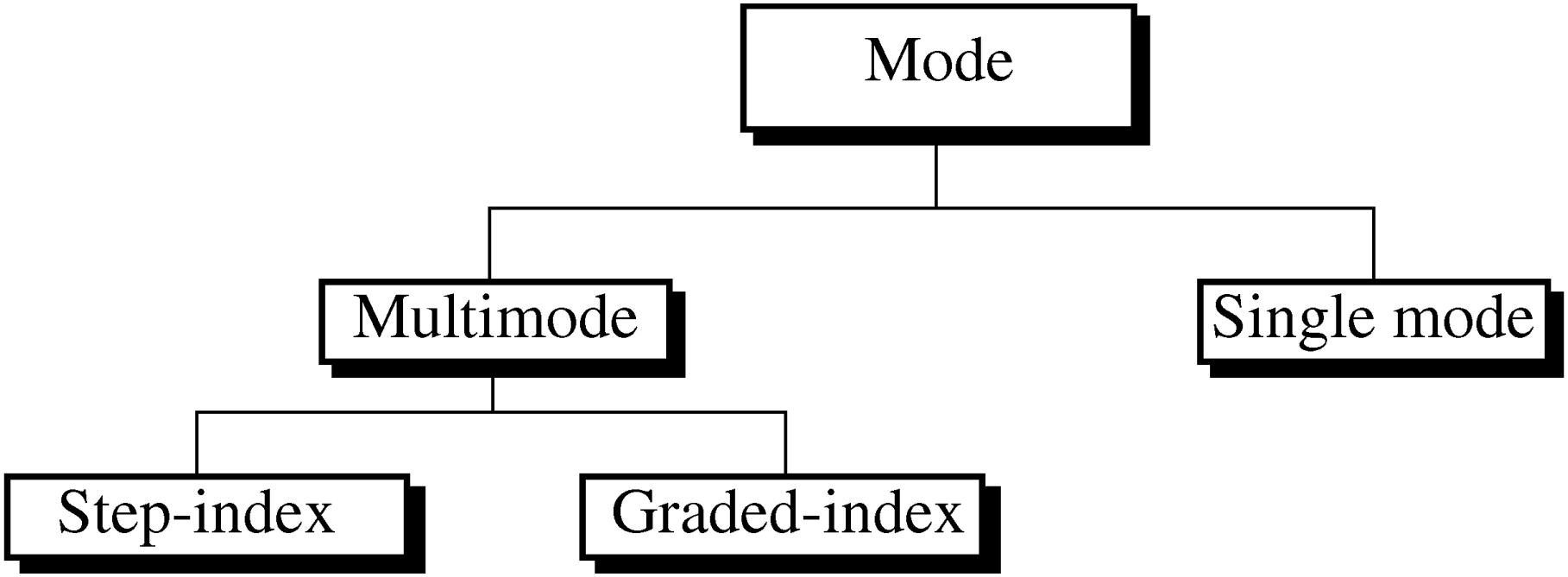
Figure 7-15

Reflection



- When the angle of incident becomes greater than the critical angle, a new phenomenon occurs called **reflection**.
- Light no longer passes into the less dense medium at all.
- In this case, the angle of incident is always equal to the angle of reflection.

Propagation Mode

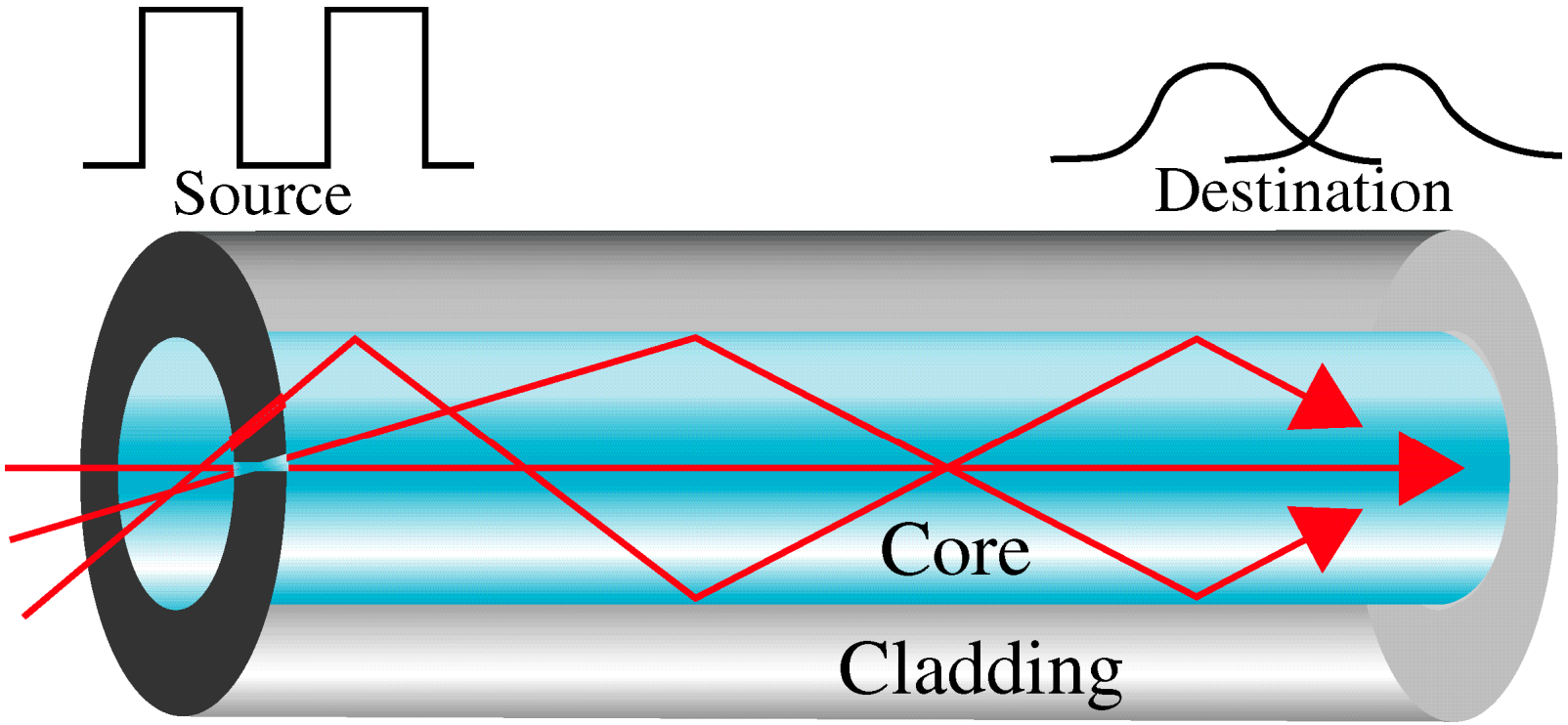


Current technology supports two modes for propagating light along optical channels.

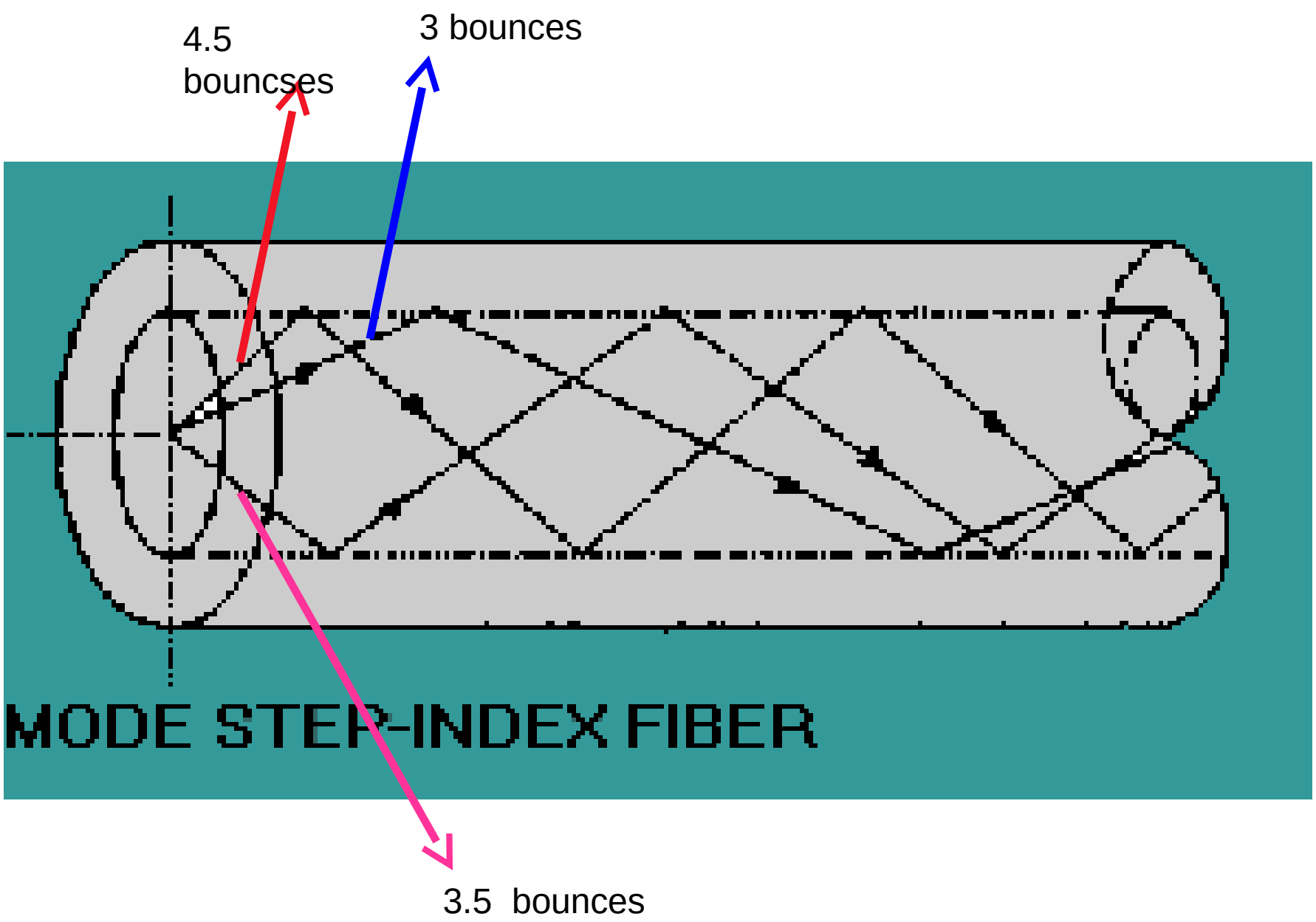
Multimode: Here multiple beams from a light source move through the core in different paths. Each ray is said to have a **different mode** so a fiber having this property is called a **multimode fiber.**

Figure 7-17

Multimode Step-Index



- In MMSI fiber, the density of the core remains constant from the center to the edges.
- A beam of light movers through this constant density in a **straight line** until it reaches the interface of the core and the cladding.


4.5
bouncses
3 bounces
MODE STEP-INDEX FIBER
3.5 bounces

•Every beam reflects off the interface at an angle equal to its angle of incidence. The angle greater than the angle of incidence, the wider the angle of reflection.

•A beam with a smaller angle of incidence will require more bounces to travel the same distance than a beam with a larger of incidence.

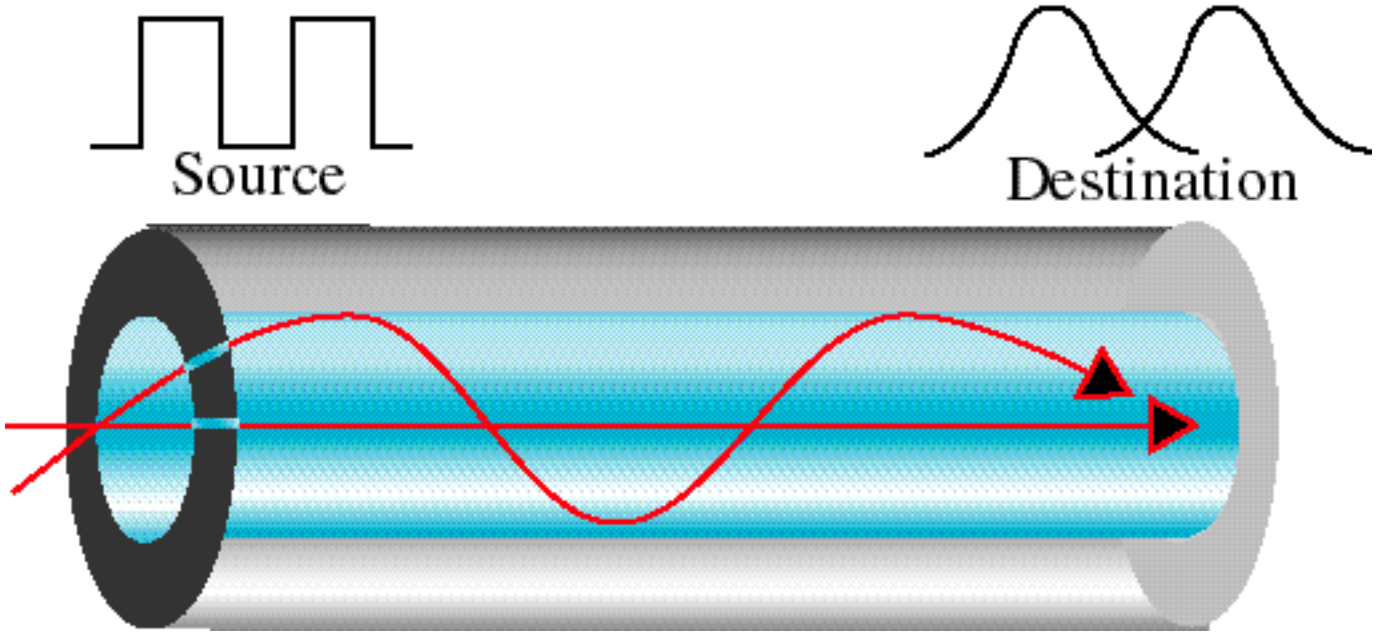
•It means that the beam with smaller incident angle must travel farther to reach the destination. Means this difference path length means that different beams arrives at the destination at different times.

•At these different beams are recombined at the receiver, they result in a signal that is no longer an exact replica of the signal that was transmitted. Such a signal has been destroyed by **propagation delay**.

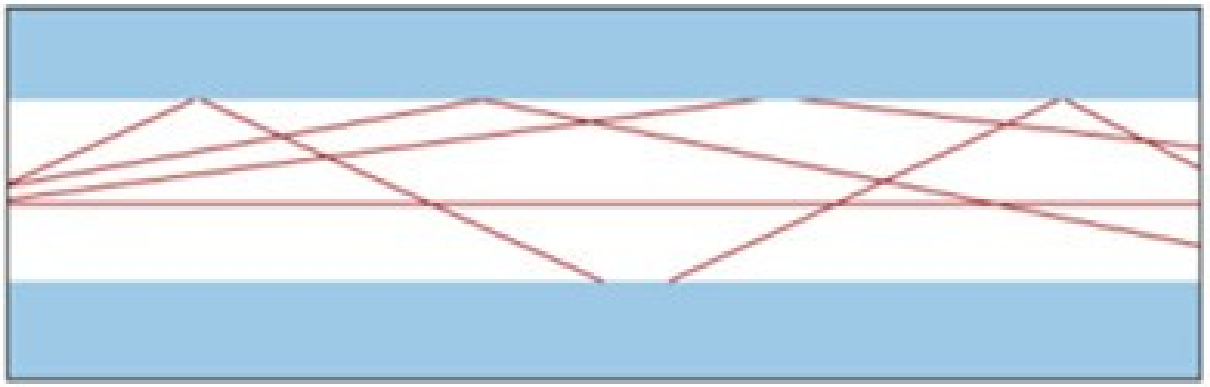
•This **distortion limits** the available **data rate** and makes multimode step-index cable inadequate for **certain precise application**.

Figure 7-18

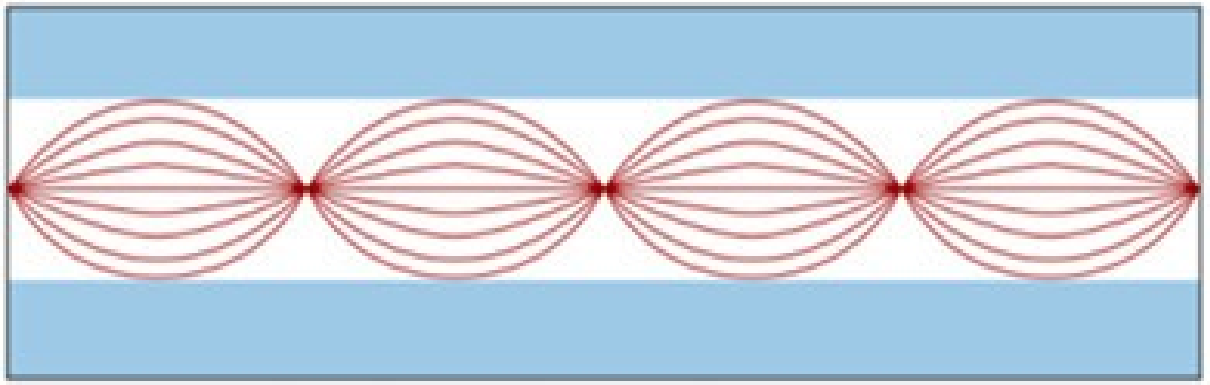
Multimode Graded-Index



- MMGI fiber optics **decreases this distortion** of the signal through the cable.
- A graded-index is one with varying densities. Density is highest at the center of the core and decreases gradually to its lowest at the edge.
- The signal is introduced at the center of the core, from this point, only horizontal beam moves in a straight line through the constant density at the centre.



Multimode, Step-Index



Multimode, Graded Index

Multimode Graded-Index

- Beams at other angles move through a series of constantly changing densities.
- Each density difference causes each beam to refract into a **curve**.
- In addition, varying the refraction varies the distance each beam travels in a given period of time, resulting in different intervals, careful placement of the receiver at one of these intersections allows the signal to be reconstructed with for greater precision.

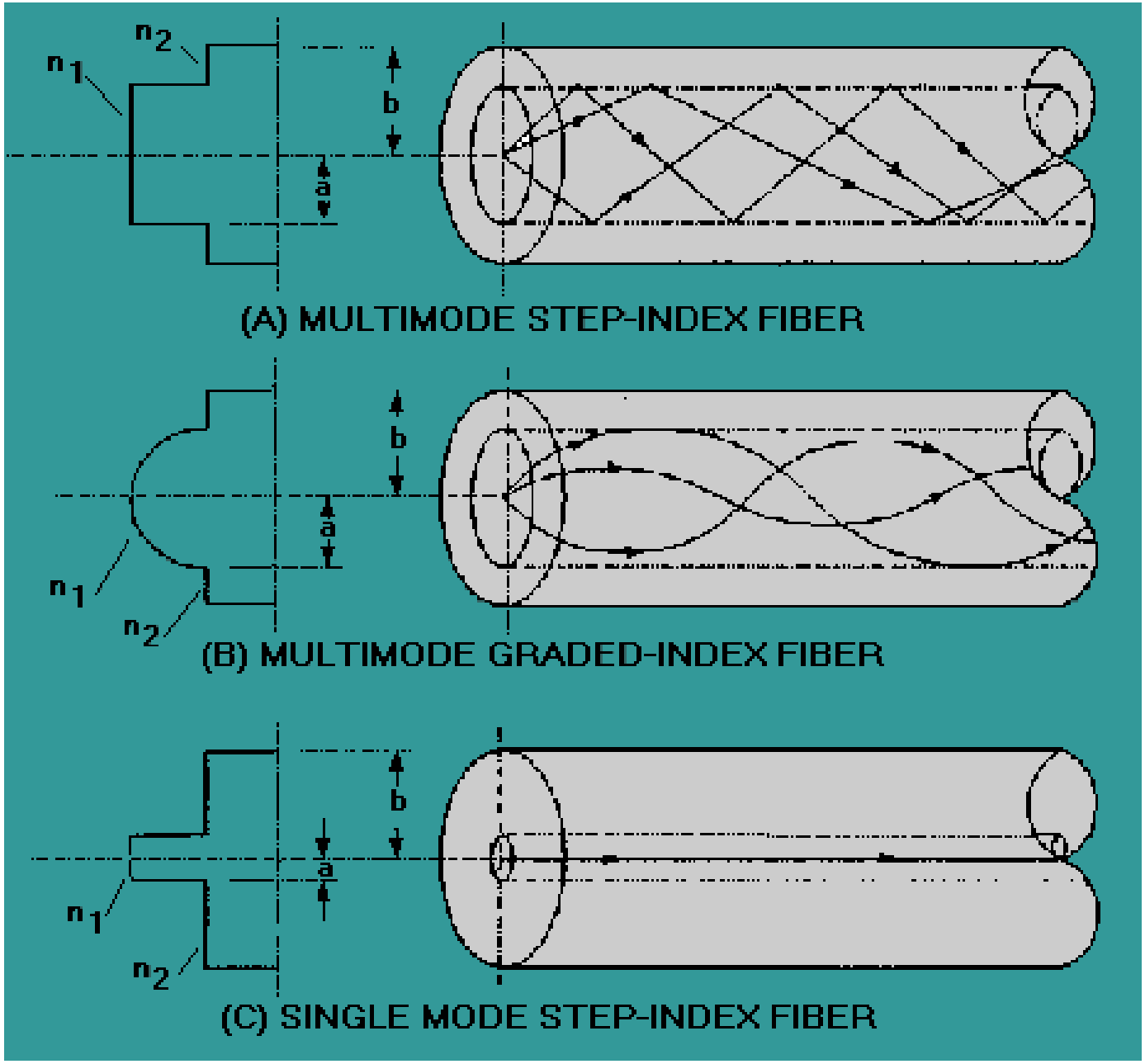
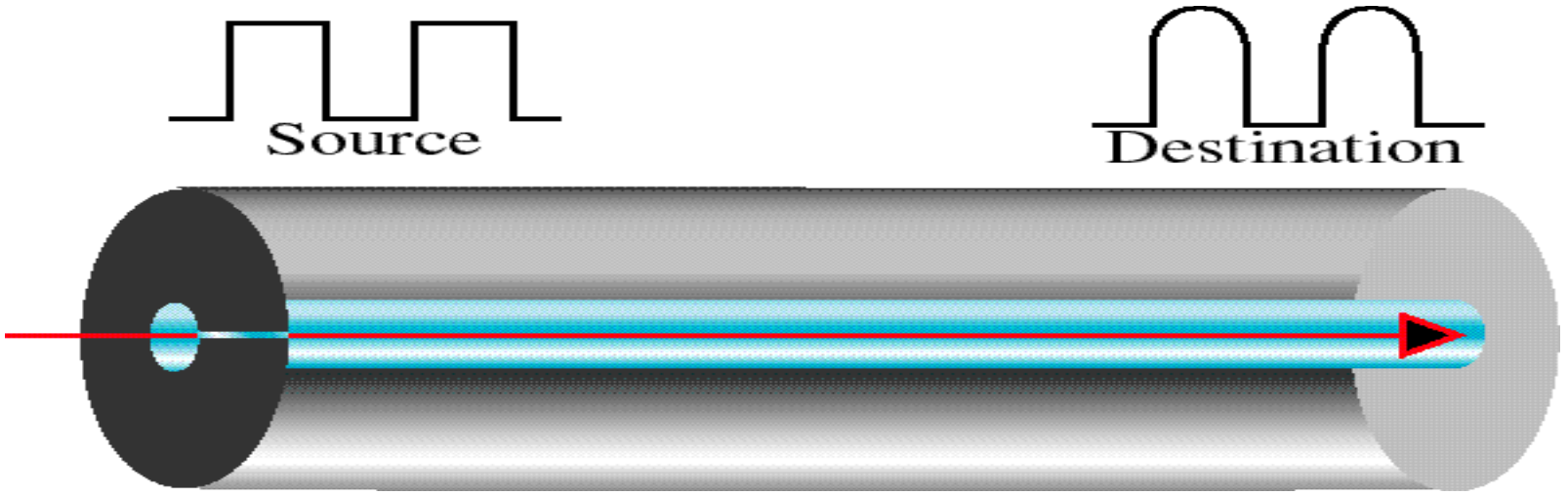

n2
n1
b
a
(A) MULTIMODE STEP-INDEX FIBER
b
a
n1
n2
(B) MULTIMODE GRADED-INDEX FIBER
b
a
n1
n2
(C) SINGLE MODE STEP-INDEX FIBER

Figure 7-19

Single Mode



1. The single mode fiber is manufactured with a **much smaller diameter than** that of multimode fibers, with substantially lower density.
2. Here by reducing diameter, we can get the light beam in nearly straight line. Here the propagation of different beams is almost identical and delays are negligible.
3. All the beams arrive at the destination together and can be reconstructed without distortion to the signal.

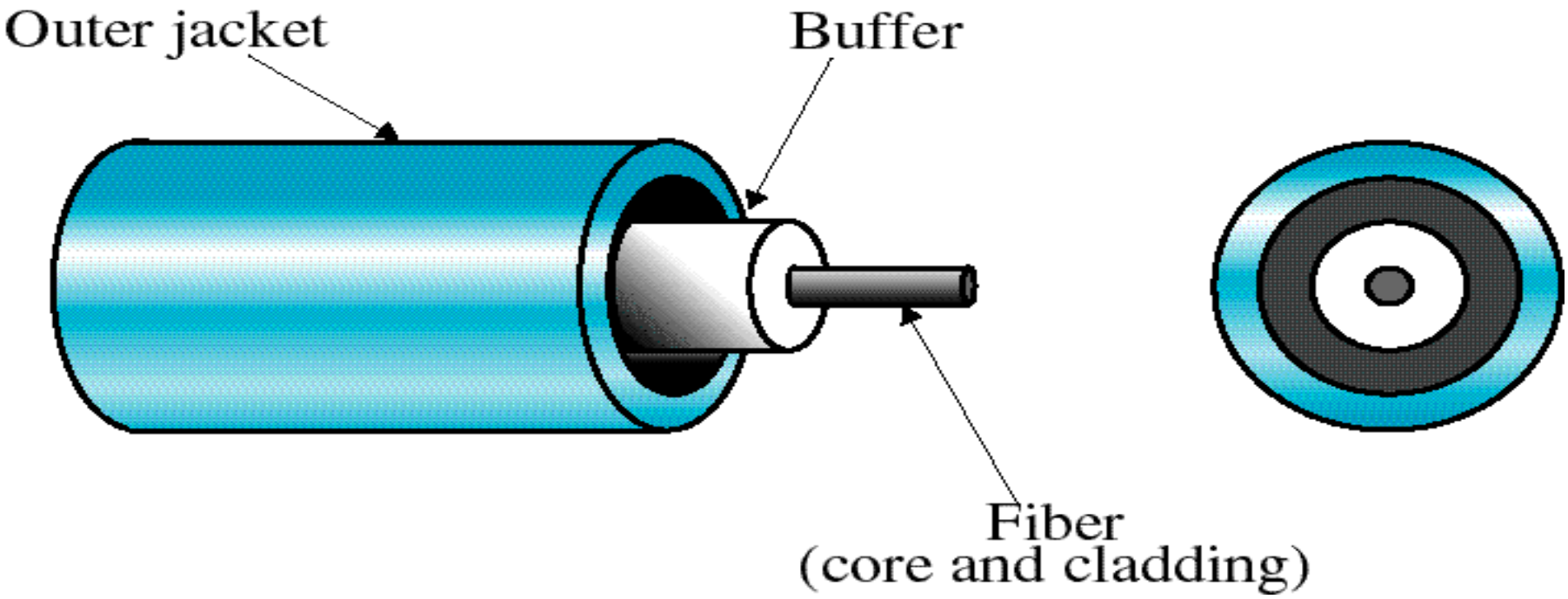
Fiber Size

- Fiber Optics are defined by the **ratio** of the diameter of their **core** to the diameter of their **cladding**. (it's measure in terms of Microns)

Sr. No.	Type	Core	Cladding	Mode
1	50/125	50	125	MMGI
2	62.5/125	62.5	125	MMGI
3	100/125	100	125	MMGI
4	7/125	7	125	Single Mode

Figure 7-20

Fiber Construction



An optical fiber transmission has three components:
1.Transmission Medium
2.Light source
3.Detector

A pulse of light indicates a 1 bit and the absence of light indicates a zero bit.

(1)Transmission Media: A core is surrounded by cladding, forming the fiber. The fiber is covered by a buffer layer that **protect it from moisture.** Finally. The entire cable is encased in an outer jacket.

(2)Both the core and cladding can be made of either glass or plastic but must be of different densities. In addition, the inner core must be ultrapure and completely regular in size and shape.

(3)The outer jacket can be made of several materials, including Teflon coating, plastic coating, fibrous plastic, metal tubing. Mostly the **plastic are light weight and inexpensive** but do not **provide structural strength**.

(4)Metal tubing provides **strength but raises cost**.

(5)Teflon is **light weight** and can be used **in open air**, but it is **expensive** and does not **increases cable strength**.

1. **Light Source:** Two kinds of light sources can be used to do the signaling. **LEDs (Light Emitting Diodes)** & **Semiconductor lasers**.

2. The sending device equipped with a light source and the receiving end with a photosensitive cell (photodiode) capable of translating the receiving light into current usable by a computer.

Item	LED	Semiconductor laser
Data rate	Low	High
Fiber type	Multimode	Multimode or single mode
Distance	Short	Long
Lifetime	Long life	Short life
Temperature sensitivity	Minor	Substantial
Cost	Low cost	Expensive

Fiber optic cable connectors

- **Subscriber channel connector (SC) Connector**: It is used in **cable TV**. It uses a push/pull locking system.
- **Straight-tip (ST) Connector**: It is used for connecting cable to networking devices. It uses a bayonet locking system and is more reliable than SC.
- **MT-RJ** is a now connector with the same size as RJ-45.

Fiber Optics (Advantages)

- Fiber-optics cable has several advantages over metallic cable(twisted-pair or coaxial)
- **Higher bandwidth**: Fiber-optic cable can support dramatically higher bandwidths than either twisted-pair or coaxial cable.
- **Less signal attenuation** : Fiber-optic transmission distance is significantly greater than that of other guided media. A signal can run for 50 km without requiring regeneration. We need repeaters every 5 km for coaxial or twisted-pair cable.

Fiber optics (advantages)

- **Immunity to electromagnetic interference** : FO transmission uses light rather than electricity, noise is not a factor. External light is blocked from the channel by the outer jacket.
- **Resistance to corrosive materials** : Glass is more resistant to corrosive materials than copper.
- **Light Weight** : Fiber-optic cables are much lighter than copper cables.

Fiber optics(disadvantages)

- There are some disadvantages in the use of optical fiber.
- **Installation/maintenance** : Fiber-optic cable is a relatively new technology. Installation and maintenance need expertise that is not yet available everywhere.
- **Unidirectional** : Propagation of light is unidirectional. If we need bidirectional communication, two fibers are needed.
- **Cost** : The cable and interfaces are relatively more expensive than those of other guided media. If the demand for bandwidth is not high, often the use of optical fiber cannot be justified.

Comparison of Fiber Optics and Copper Wire (UTP)

- it is **thin and lightweight**. Fiber is much lighter than copper. One thousand twisted pairs 1 km long weigh 8000 kg. Two fibers have more capacity and weigh only 100 kg, which greatly reduces the need for expensive mechanical support systems that must be maintained. Approximate thick ness of Multimode fiber is one-sixth of human hair.
- Fiber also has the advantage of not being affected by power surges, electromagnetic interference, or power failures. Nor is it affected by corrosive chemicals in the air, making it ideal for harsh factory environments.
- Due to the **low attenuation**, repeaters are needed only about every 50 km on long lines, versus about every 5 km for copper, a substantial cost saving
- Fiber can handle much **higher bandwidths** than copper.

Comparison of Fiber Optics and Copper Wire

- Finally, fibers do not leak light and are quite difficult to tap. These properties gives fiber excellent security.
- On the downside, fiber is a less familiar technology requiring skills not all engineers have, and fibers can be damaged easily by being bent too much.
- Since optical transmission is inherently **unidirectional**, two-way communication requires either two fibers or two frequency bands on one fiber.
- Finally, **fiber interfaces cost more than electrical interfaces**. Nevertheless, the future of all fixed data communication for distances of more than a few meters is clearly with fiber.

Applications

- In SONET (Synchronous Optical Network), the fiber optic cable is used as a backbone, which supports data transmission rate up to 1600 Gbps.
- Some cable TV companies use a combination of Optical fiber and Coaxial Cable. They use optical fiber as backbone cable TV network and coaxial cable provide connection between backbone to user.
- Fiber is also used in Local Area Networks like 100BaseFx (Fast Ethernet) Network and 1000BaseX Network.

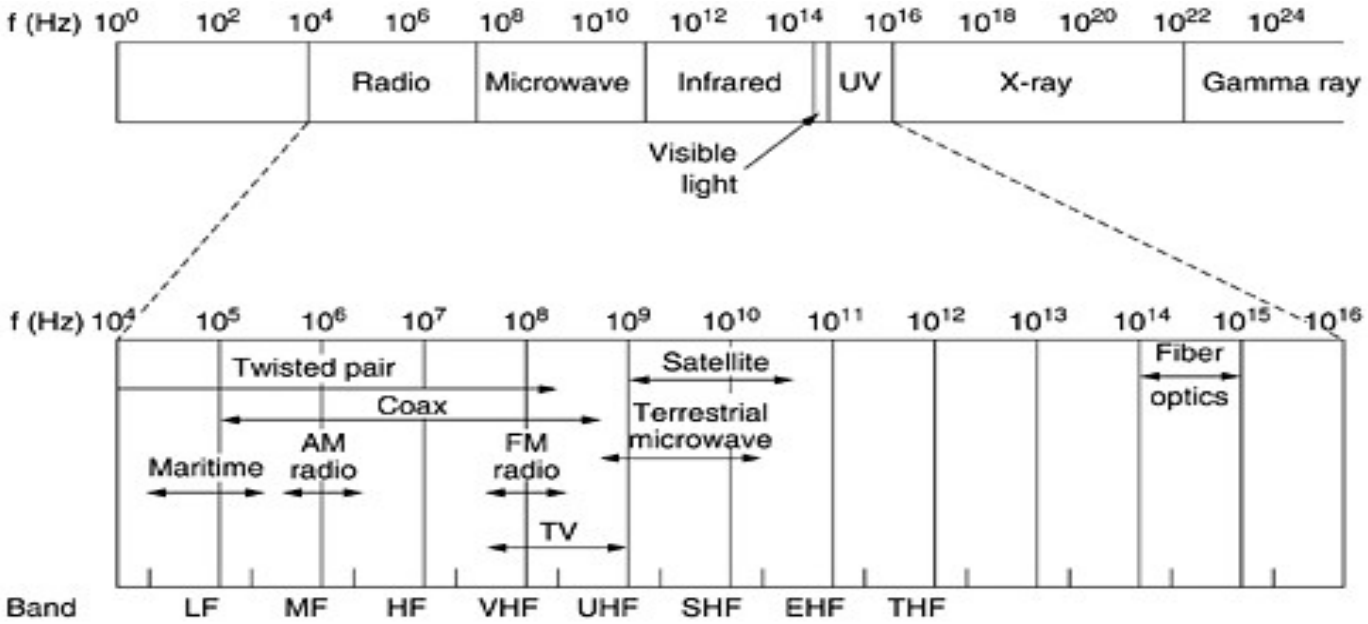
2.3 Wireless Transmission

- Unguided media transport electromagnetic waves without using a physical conductor.
- This type of communication is often referred to as wireless communication.
- Signals are normally broadcast through air and thus are available to anyone who has a device capable of receiving them.

- Wireless has advantages for even fixed devices in some circumstances. For example, if running a fiber to a building is difficult due to the terrain (mountains, jungles, swamps, etc.), wireless may be better.

- It is noteworthy that modern wireless digital communication began in the Hawaiian Islands, where large chunks of Pacific Ocean separated the users and the telephone system was inadequate.

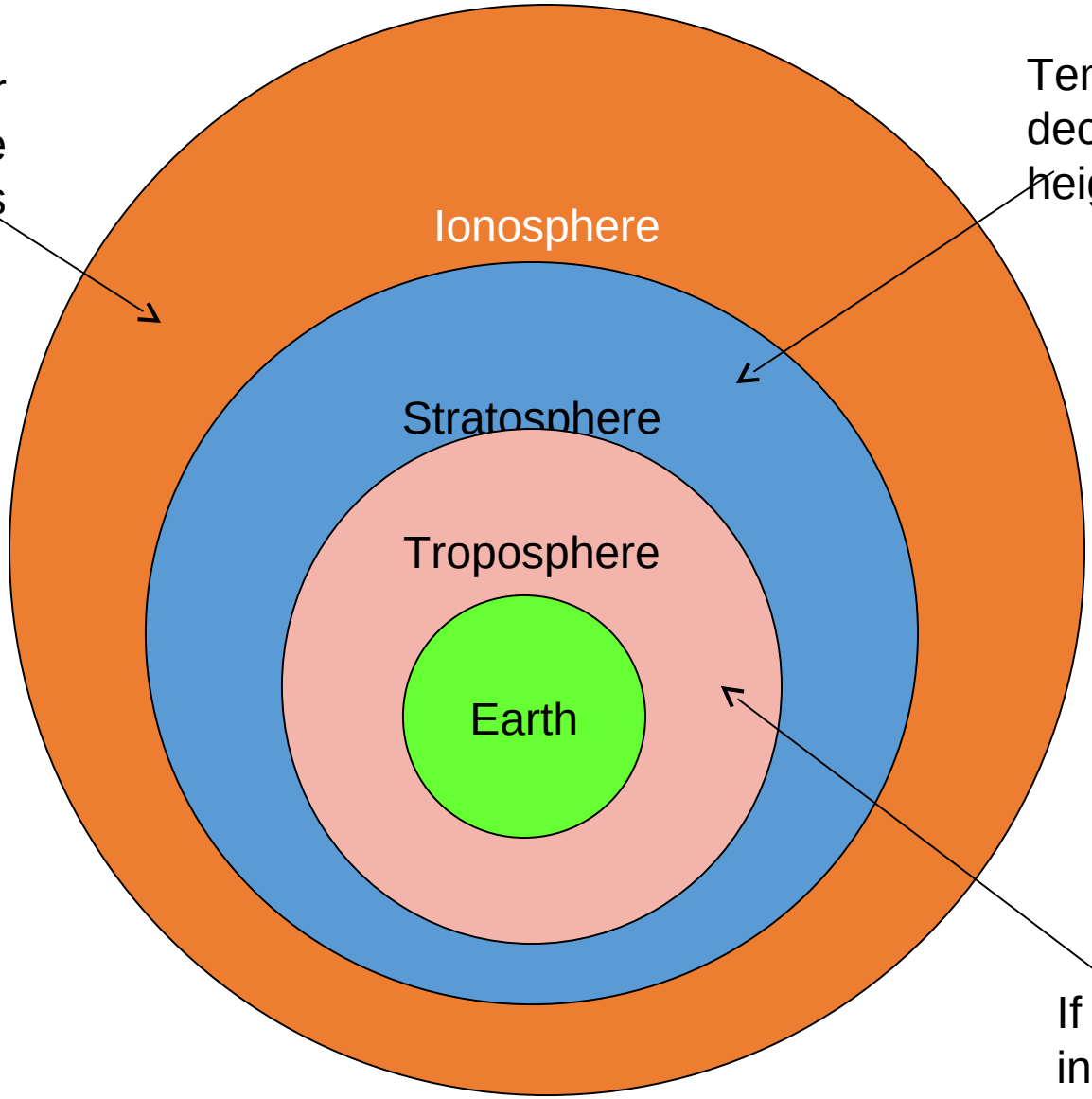
Figure 2-11. The electromagnetic spectrum and its uses for communication.



- The radio, microwave, infrared, and visible light portions of the spectrum can all be used for **transmitting information** by **modulating the amplitude, frequency, or phase of the waves**. Ultraviolet light, X-rays, and gamma rays would be **even better**, due to their higher **frequencies**, but they are **hard to produce and modulate**, **do not propagate** well through buildings, and are **dangerous to living things**.

- The bands listed at the bottom of Fig. 2-11 are the **official ITU (International Telecommunication Union) names** and are **based on the wavelengths**.
- **LF** : Low Frequency band
- **MF**: Medium Frequency band
- **HF** : High frequency band
- **VHF**: Very High Frequency band
- **UHF**: Ultra High Frequency band
- **SHF**: Super High Frequency band
- **EHF**: Extremely High Frequency band
- **THF**: Tremendously High Frequency bands.
- Beyond that there are no names, but **Incredibly**, **Astonishingly**, and **Prodigiously** high frequency (IHF, AHF, and PHF) would sound nice.

It is outer layer from where signal reflects back



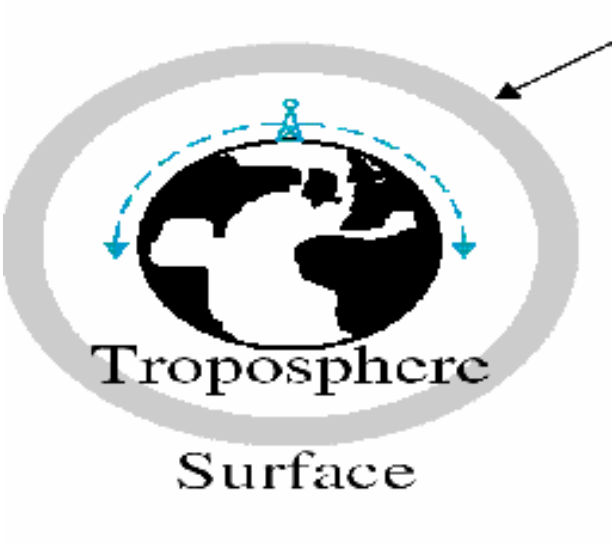
Temperature is not decreased with height

If the height is increased then temperature is decreased.
It's height is 7 miles

Propagation Types (Ground Propagation)

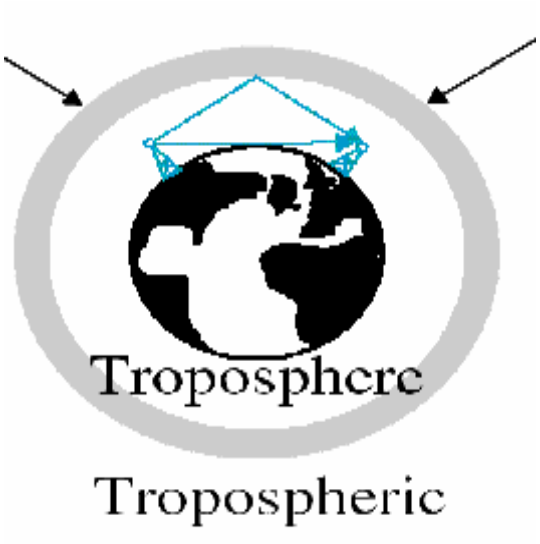
Ground Propagation (Surface Propagation): (below 2 Mhz)

- In ground propagation, low-frequency signals travel in all directions from the transmitting antenna and follow the curvature of the planet.
- Distance covered by signal depends on the strength of the signal.
- Eg. of surface propagation are submarine communication, long-range radio navigation



Propagation Types (Sky Propagation)

- In sky propagation, higher frequency radio waves travel upward into the ionosphere where they are reflected back to the earth.
- It covers long distance.



Propagation Types (Line of sight Propagation)

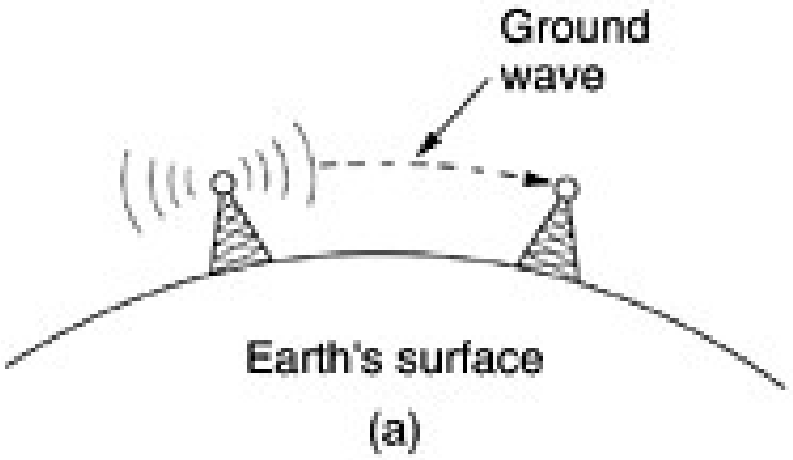
- In light-of-sight propagation, very high frequency signals are transmitted in straight lines directly from antenna to antenna.

- Receiving antenna and transmitting antenna must be aligned.

2.3.2 Radio Transmission

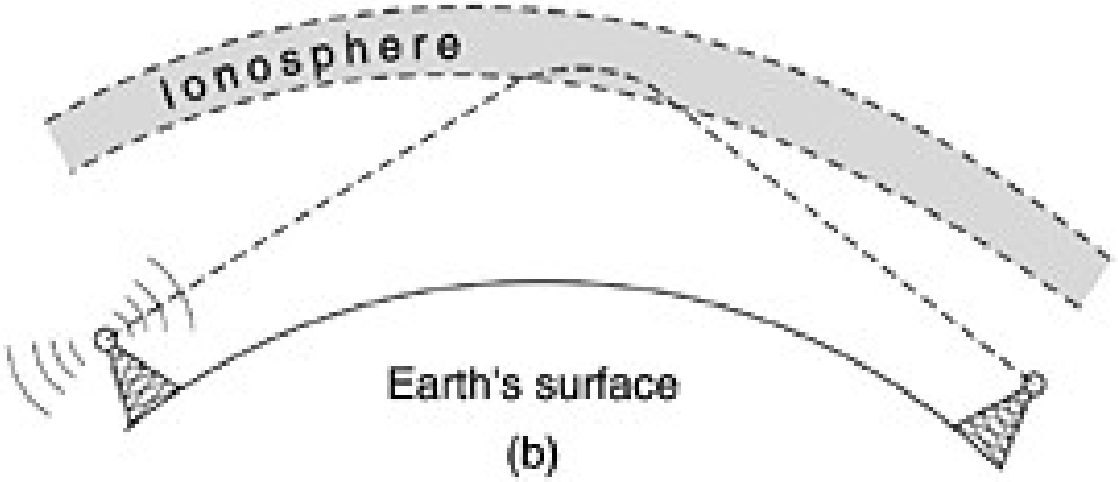
- Radio waves are easy to generate, can travel long distances, and can penetrate buildings easily, so they are widely used for communication, both indoors and outdoors.
- Radio waves also are **omnidirectional**, meaning that they travel in all directions from the source, so the transmitter and receiver do not have to be carefully aligned physically.
- The properties of radio waves are **frequency dependent**.
- At **low frequencies,** radio waves pass through obstacles well, but the power falls off sharply with distance from the source.
- At **high frequencies**, radio waves tend to travel in straight lines and bounce off obstacles. They are also absorbed by rain.
- At **all frequencies**, radio waves are subject to interference from motors and other electrical equipment.

2.3.2 Radio Transmission



- The radio wave range is divided into bands like VLF, LF, MF and VHF.
- The VLF, LF, and MF bands, radio waves are known as ground waves as they **follow the ground**, as illustrated in Fig. 2-12(a).
- These waves are capable of **moving anywhere without reflection**.
- These waves can be **detected for perhaps 1000 km at the lower frequencies**, **less at the higher ones**.
- Radio waves in these bands **pass through buildings easily**, which is why portable radios work indoors.

2.3.2 Radio Transmission



- The waves that belong to HF and VHF travel in straight line.
- In **the HF and VHF bands**, the **ground waves tend to be absorbed by the earth.**
- The waves that reach the **ionosphere,** a **layer of charged particles** circling the earth at a **height of 100 to 500 km**, are refracted by it and sent back to earth, as shown in Fig. 2-12(b).
- Under certain atmospheric conditions, the signals can **bounce several times, so it covers long distance.**
- The **military** also communicate in the HF and VHF bands.

2.3.2 Radio Transmission

- Unfortunately, the radio waves are poor candidate for **data communication** as they have lower frequency and thus low capacity to encode data.

2.3.3 Microwave Transmission

- Range for Microwave transmission in the electromagnetic spectrum is 10^8 to 10^{11} Hz. i.e. they are above 100 MHz and come in the gigahertz range.
- Electromagnetic waves having frequencies between **1 and 300 GHz** are called microwaves.
- It is a very popular way of **transmitting data.**
- When the waves reduce in length, they tend to **travel straighter** and not in all directions.
- It doesn't require the expense of **laying cables** because it is wireless communication.
- Microwaves are **unidirectional.**
- When antenna transmits microwave waves, they can be narrowly focused.
- This means that the sending and receiving antennas need to be aligned.
- Microwave propagation **is line-of-sight**.
- **Repeaters** are often needed for **long-distance communication**.
- **Very high-frequency** microwaves **cannot penetrate walls.**
- This characteristic can be a disadvantage if receivers are inside buildings.

2.3.3 Microwave Transmission

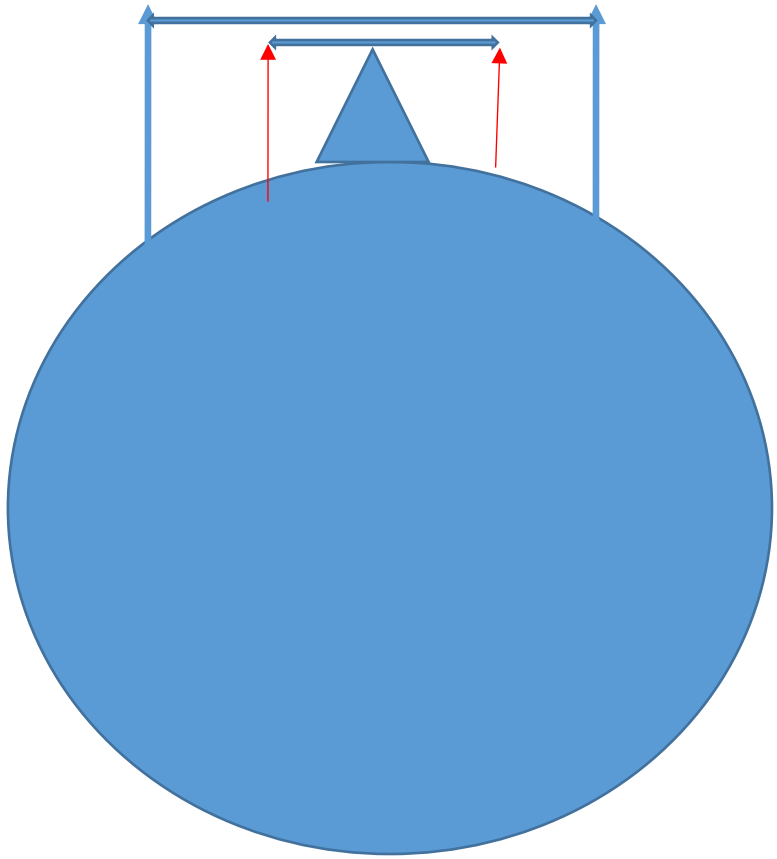
- Therefore wider sub bands can be assigned, and a high data rate is possible.
- Use of certain portions of the band requires permission **from authorities**.
- Microwaves need unidirectional antennas that send out signals in one direction.
- The unidirectional property has an obvious **advantage**.
- A pair of antennas can be aligned **without interfering with another pair of aligned antennas.**
- Microwave propagation is **line-of-sight propagation**, so the antennas are **installed on tower so it covers large distance**. There should not be any obstacle between two antennas.
- The **curvature of the earth** as well as other blocking obstacles do not allow two short towers to communicate using microwaves.
- The distance coverable by the line-or-sight signal depends on the height of the antenna. Max distance between two antennas is

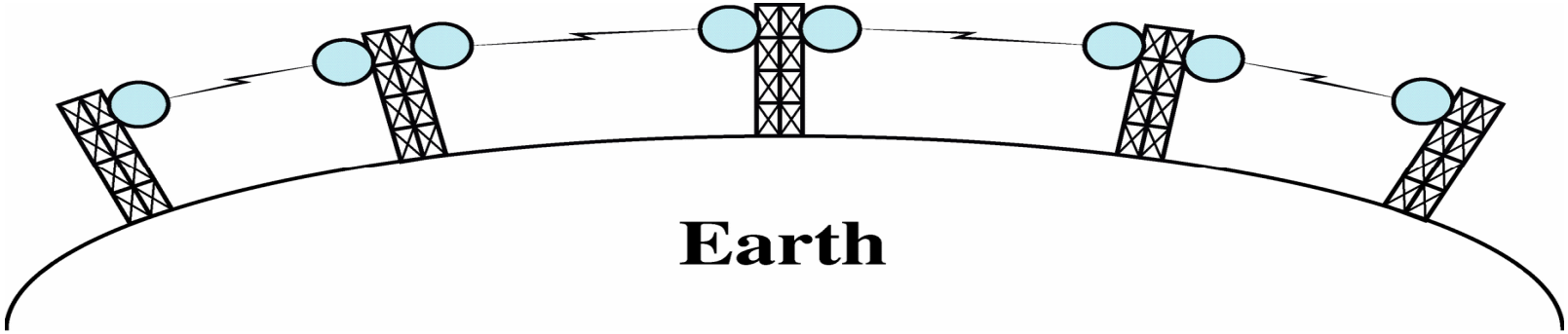
$$d = 7.14\sqrt{Kh}$$

where h is antenna height and K is an adjustment factor to account for the bend in microwave due to earth's curvature, enabling it to travel further than the line of sight; typically $K = \frac{4}{3}$

* Two microwave antennae at a height of 100m may be as far as

$$7.14 \times \sqrt{133} = 82km$$





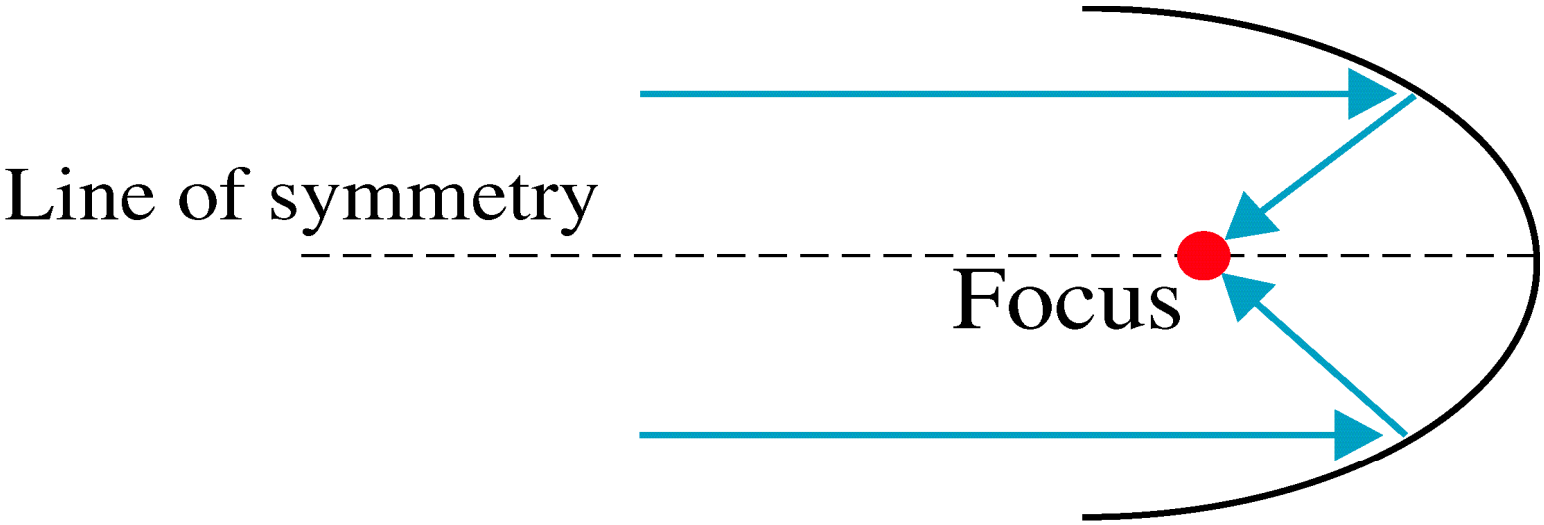
- Microwave signals propagate in one direction at a time, which means that two frequencies are necessary for two-way communication such as a telephone conversation, so one frequency is reserved for microwave transmission in one direction and the other for transmission in the other direction.
- Each frequency **requires its own transmitter and receiver** but now both pieces of equipment are combined in a single piece of equipment, called **Transceiver**, which allows a single antenna to serve both frequencies and functions.
- Repeaters: To increase the distance covered by terrestrial microwave, a system of repeaters can be installed with each antenna. A signal received by one antenna can be converted back into transmittable form and relayed to the next antenna.
- A repeater may broadcast the regenerated signal either at the original frequency or at a new frequency, depending on the system.

Mobile Antenna

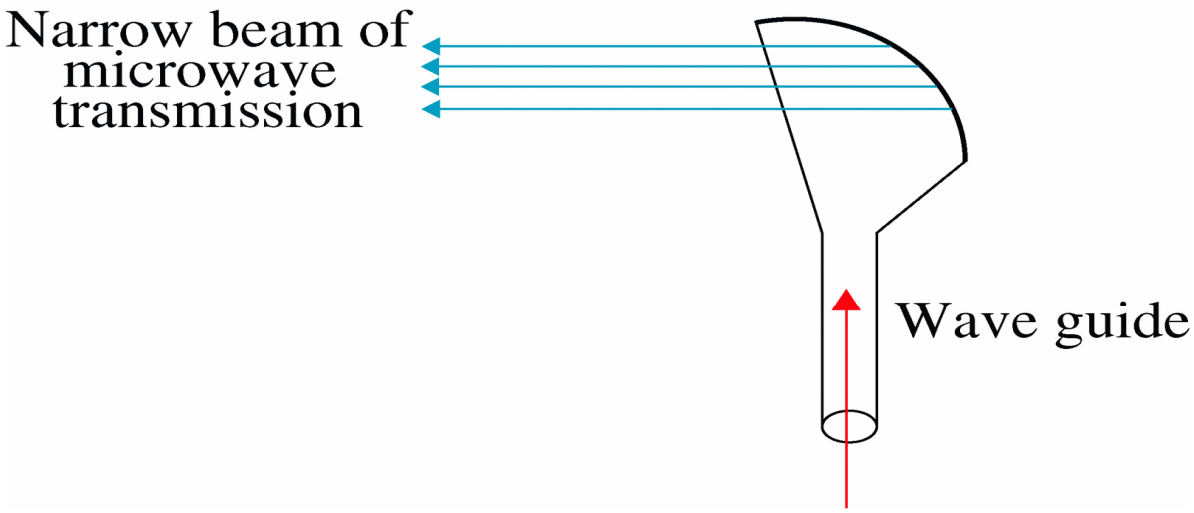
2.3.3 Microwave Transmission

- Two types of antennas are used for microwave communications
  1. **The parabolic dish**
  2. **The horn**
- In parabola dish, every line parallel to the **line of symmetry (line-of-sight**) reflects off the curve at angles such that they intersect in a common point called the focus, so more no. of the signal is received that would be possible with a **single-point receiver**.

Parabolic Dish Antenna



The horn dish



- A horn antenna looks like a gigantic scoop.
- Outgoing transmissions are broadcast up a stem and deflected outward in a series of narrow parallel beams by a curved head.
- Received transmissions are collected by the scooped shape of the horn and are deflected down into the stem.

2.3.3 Microwave Transmission

- Like the radio waves, microwaves are also highly in demand, some government body controls the use of microwave bands by licensing a specific portion to a specific party.
- In the US, the FCC (Federal Communications Commission) does this job.

- In India, this is done by DoT (Department of Telecommunication).

2.3.3 Microwave Transmission

- **Advantages:**
- It supports 16 GBPS data rate.
- It can carry 2,50,000 voice channels simultaneously, when FO were not available MWs were used in long distance telephone transmission system.
- It requires less no. of amplifiers/repeaters than CC for the same distance.
- It provide good performance in digital transmission in small region (radius < 10 km). This concept is known as "**Local Data Distribution**"
- **Disadvantages:**
- The capital investment needed for installment of antennas.
- The waves having a higher frequency than 4 GHz become so short they get absorbed by raindrops. If the transmission passes through a region that is prone to heavy rainfalls, the receiver may not get any signal.
- **Application:**
- It is useful in unicasting (One-to-one communication).
- They are used in cellular phones, satellite n/w and wireless LANs.

2.3.4 Infrared and Millimeter Waves

- Unguided infrared and millimeter waves are widely used for short-range communication.
- The remote controls used on televisions, VCRs, and stereos all use infrared communication.
- They are relatively **directional**, **cheap**, and **easy to build**.
- **Drawback:** They **do not pass through solid objects**
- On the other hand, the fact that infrared waves do not pass through solid walls well is also a plus. It means that an infrared system in one room of a **building will not interfere with a similar system in adjacent rooms or buildings**: you cannot control your neighbor's television with your remote control.
- Furthermore, security of infrared systems against eavesdropping is better than that of radio systems precisely for this reason.
- Therefore, **no government license is needed to operate an infrared system**, in contrast to radio systems, which must be licensed outside the ISM(industrial, scientific and medical) bands.
- Infrared communication has a limited use on the desktop, for example, connecting notebook computers and printers.

2.4 Communication Satellites

- Microwave is collection of nodes where node may be earth station antenna, mobile, computer, telephone handset etc.
- In satellite, there must be at least one node is satellite antenna.
- Satellite communication covers long distance than Microwave communication.
- It can cover remote area (undeveloped parts of the earth because it just require installation of earth station in that area.
- Both use line-of-sight transmission.

2.4 Communication Satellites

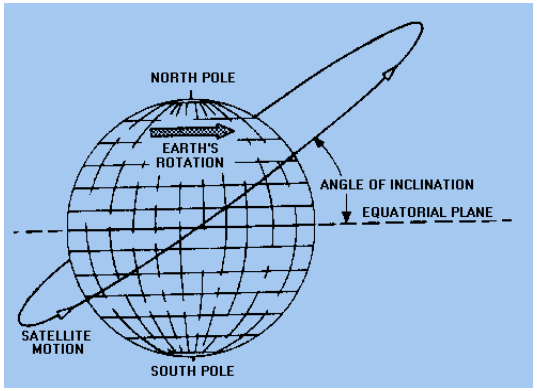
- Satellite transmission is much like line-of-sight microwave transmission in which one of the station is a satellite orbiting the earth.
- A satellite is acting as a super tall antenna and repeater.
- In satellite communication signals travel in straight lines, but it covers continents and oceans with a single bounce.

- We can use a real satellite, such as moon but the use of artificial satellites is preferred because,

1. We can install electronic equipment on the satellite to regenerate the signals that has lost its energy during travel.
2. Second restriction is the distance from the earth, which create a long delay in communication.

2.4 Communication Satellites

- **Satellite Orbits**: Orbit is the path in which the artificial satellite travels around the earth.
- The orbit can be (1) equatorial (2) Inclined (3) Polar



2.4 Communication Satellites

- Seventeenth century **German astronomer Johannes Kepler** proved that the satellite takes more time to move round the earth when it is farther from the earth.
- **Kepler's Law (Period of a satellite)**
- **The period of a satellite, the time required for a satellite to complete a round around the earth.**
- Kepler's law is used to find out the period of any satellite.
- Period = C * distance$^{1.5}$
- where C is a constant = 1/100, The period is in seconds, The distance is in kilometers.
- **What is the period of a satellite that is located at an orbit approximately 35,786 km above the earth?**
- Period = (1/100) * (35,786 + 6378) $^{1.5}$
- = (1/100) * (42464) $^{1.5}$
- = 86,579 Seconds
- = 24 Hr.
- **Sir Arthur C. Clark** proved that at the distance of 35800 km, the satellite moves exactly at the same speed as the revolution of earth.

2.4 Communication Satellites

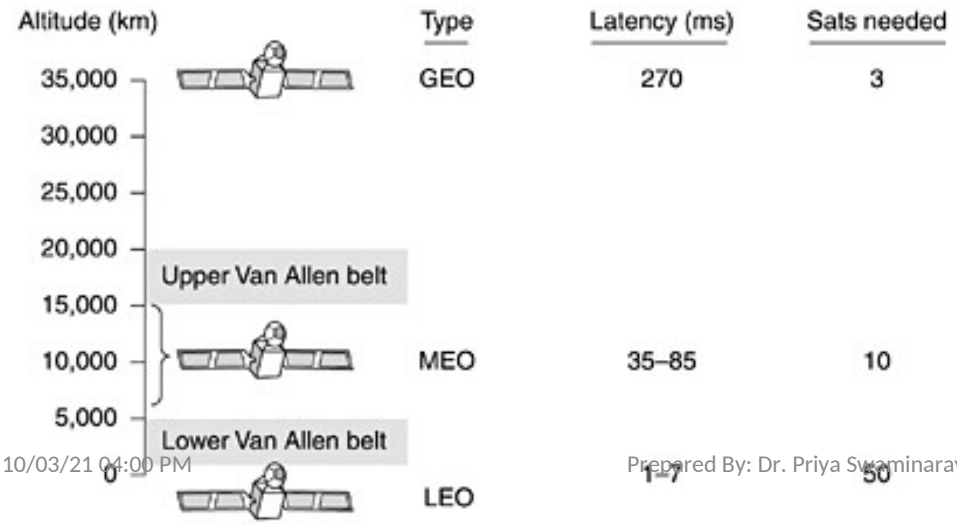
- **Bent Pipe:** A communication satellite can be thought of as a big microwave repeater in the sky. It contains several **transponders**, each of which listens to some portion of the spectrum, amplifies the incoming signal, and then rebroadcasts it at another frequency to avoid interference with the incoming signal.

- The downward beams can be **broad**, covering a substantial fraction of the earth's surface, or **narrow,** covering an area only hundreds of kilometers in diameter.

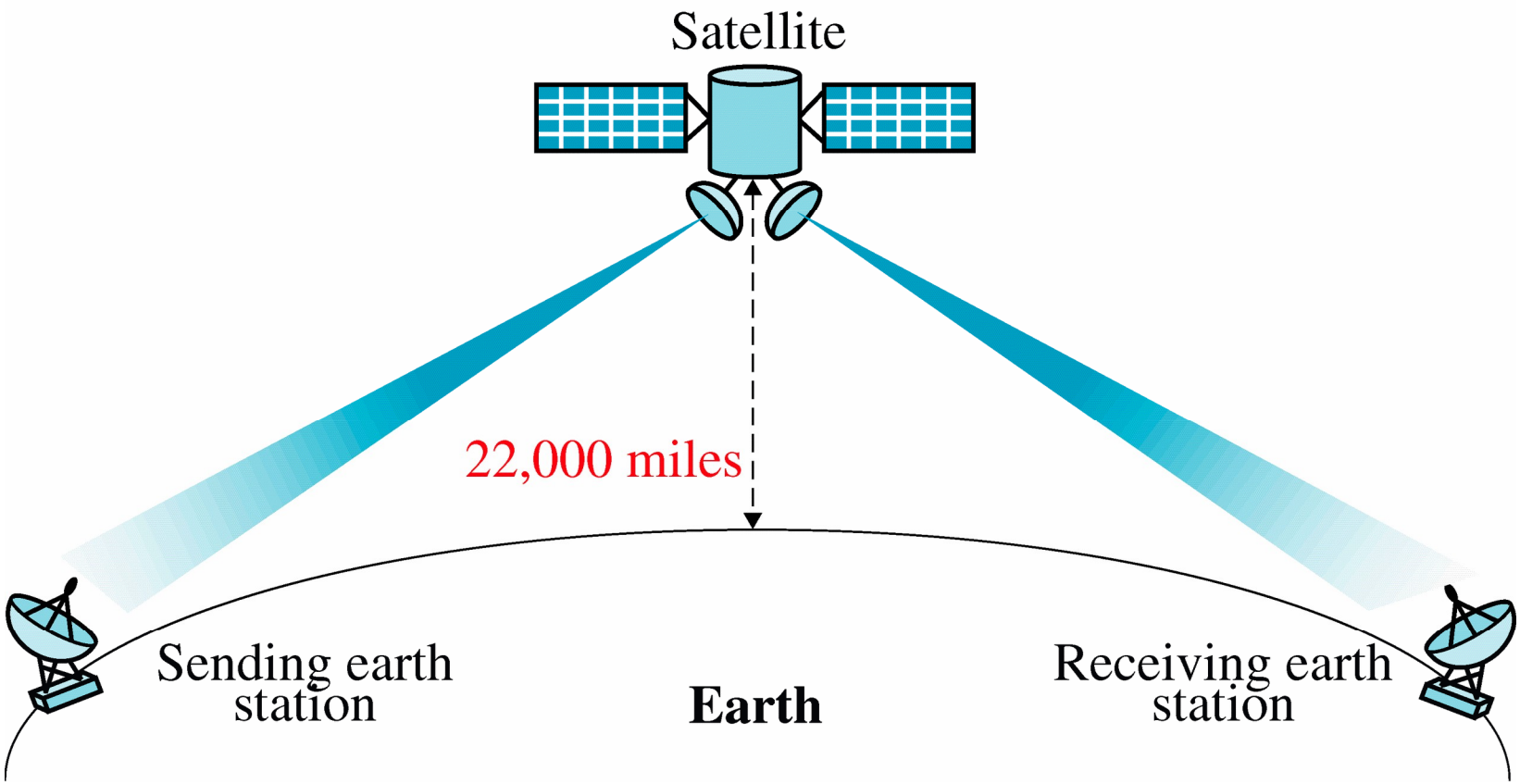
- This mode of operation is known as a bent pipe.

2.4 Communication Satellites

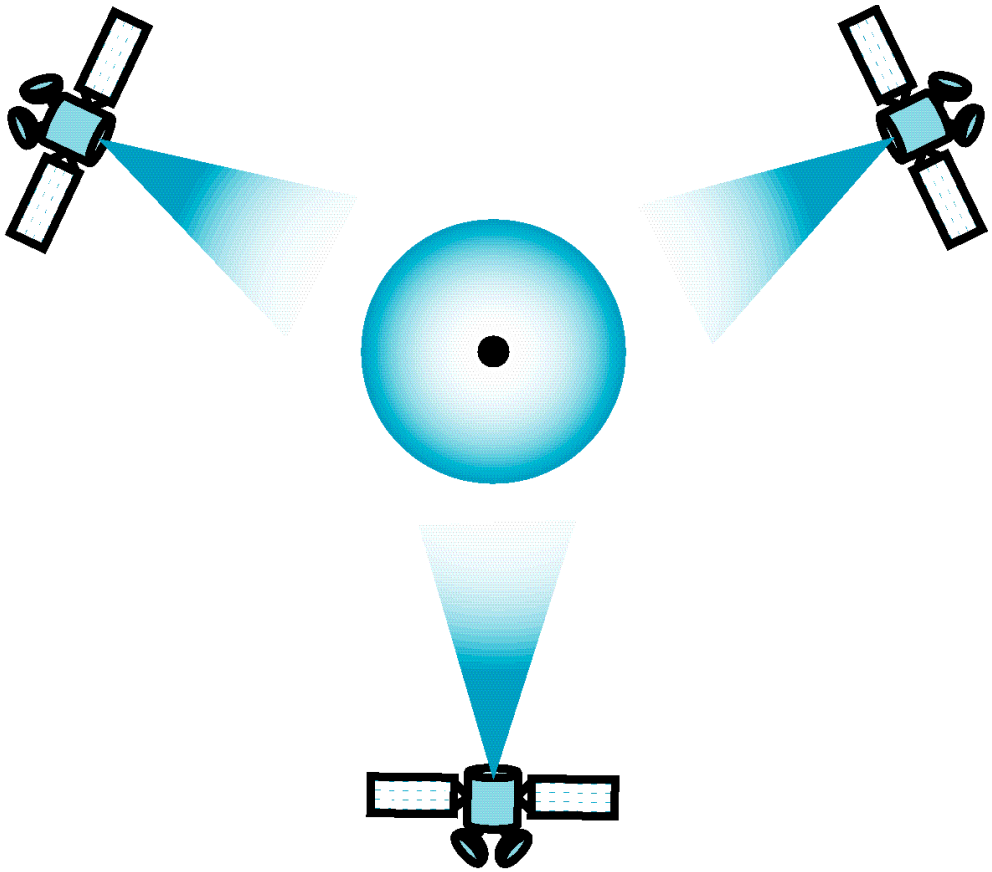
- **Footprint:** The signal from a satellite focused at a specific area called a footprint. The signal power at the center is maximum. The power decreases as we move from the footprint center.
- **Three Categories of satellite:**
- One issue is the presence of the **Van Allen belts**, layers of highly charged particles trapped by the earth's magnetic field. Any satellite flying within them would be **destroyed fairly quickly by the highly-energetic charged particles** trapped there by the earth's magnetic field. These factors lead to three regions in which satellites can be placed safely.
- Three categories of satellite: Based on the location of the orbit, satellites can divided into three categories,



GEO: Geostationary Satellites
MEO: Medium-Earth Orbit
LEO: Low-Earth Orbit


Satellite
22,000 miles
Sending earth station
Earth
Receiving earth station

Geosynchronous Orbit



The advantage of GEO (geo-synchronous earth orbit) satellite is that it can cover almost one-third of the earth's surface, so we need only **three satellites** to cover the entire earth.

The GEO footprint is very large.

As the satellite orbit comes nearer to the earth, the footprint gets smaller. At lower altitude, we need more satellites to cover the entire surface of earth.

For MEO, around **ten satellites** are needed and

for LEO, the figure goes to

2.4.1 Geostationary Satellites

- The most important point to note here is that the time to get the response back from a satellite located at this distance is really large; almost 270 milliseconds (msecs) to and fro. This is not **encouraging for all interactive applications like Telnet** and **real-time applications like audio and video conferencing.**
- The other reason for using other orbits is that the **geosynchronous orbit is heavily crowded** (full almost to its limit). This orbit is a circle around the earth exactly above the equator, and has 360° like all other circles in the world. Plus, there has to be a gap of 2° between adjacent satellites to avoid interference. Thus 180 msec stands for milliseconds (i.e., 360/2) is the upper limit for the number of satellites one can put in the geosynchronous orbit.
- The orbit is already crowded as all the satellites which transmit the TV channels are already stationed there. Some of the government and military satellites are also there to add to the crowd.

2.4.1 Geostationary Satellites

- The first artificial communication satellite, **Telstar**, was launched in July 1962.
- To prevent total chaos in the sky, orbit slot allocation is done by ITU (International Telecommunications Union).
- Modern satellites can be quite large, **weighing up to 4000 kg** and consuming several kilowatts of electric power produced by the solar panels.

- **Station Keeping** :The effects of solar, lunar, and planetary gravity tend to move them away from their assigned orbit slots and orientations, an effect countered by **on-board rocket motors**. This fine-tuning activity is called station keeping.

2.4.1 Geostationary Satellites

- When the fuel for the motors has been exhausted, typically in about 10 years, the satellite drifts and tumbles helplessly, so it has to be turned off.
- Eventually, the orbit decays and the satellite reenters the atmosphere and burns up or occasionally crashes to earth.
- ITU has allocated certain frequency bands to satellite users. The main ones are listed in Fig. 2-16.
- The C band was the first to be designated for commercial satellite traffic. Two frequency ranges are assigned in it, the lower one for downlink traffic (from the satellite) and the upper one for uplink traffic (to the satellite). To allow traffic to go both ways at the same time, two channels are required, one going each way. These **bands are already overcrowded** because they are also used by the common carriers for terrestrial microwave links.
- The L and S bands were added by international agreement in 2000. However, they are narrow and crowded.

Band	Downlink	Uplink	Bandwidth	Problems
L	1.5 GHz	1.6 GHz	15 MHz	Low bandwidth; crowded
S	1.9 GHz	2.2 GHz	70 MHz	Low bandwidth; crowded
C	4.0 GHz	6.0 GHz	500 MHz	Terrestrial interference
Ku	11 GHz	14 GHz	500 MHz	Rain
Ka	20 GHz	30 GHz	3500 MHz	Rain, equipment cost

LEO for data communication

- LEO need 50 satellites to cover entire earth.

- Even though we need such a large number of satellites to cover the earth, LEO is attractive for the following reasons:

1. We have already seen that GEO is almost full.
2. The LEO is near to earth, so transmitters don't need to have powerful signals to send. It is ideal for using satellite mobile phones which emit only a few miliwatts of power. That leads to smaller mobile devices with long-lasting batteries.
3. For the same reason, the time for the signal to reach the satellite and back is much lesser, nearly 1 to 7 msec, which is not bad for interactive applications.

4. LEO satellites are less expensive to launch and though they are near to the ground, they do not require signals as strong as GEO. Signal strength falls down as the square of the distance from the source.

   Hence, if the distance is reduced to half, the required signal strength reduces four times. The LEOs are placed around 400 km above the earth's surface (almost 1000 times nearer) and thus need much less power than GEO.

- GSAT-16 satellite launched by ISRO on 6 December 2014
- Weight : With a lift-off mass of 3,181 kg,
- No. of transponders: total of 48 communication transponder
- it became the 18th satellite to be launched by Ariane space for ISRO.
- Purpose: communication services

- Orbiting Carbon Observatory-2 satellite (OCO-2) launched by NASA on 2nd July 2014
- Purpose: To monitoring atmospheric carbon dioxide, the heat-trapping gas thought to be responsible for much of Earth's recent warming trend.

2.4 Communication Satellites

Advantages:

- For broadcast communication, satellite is cheaper than fiber optics.
- Mobile communication is possible only through satellite or microwave but not by the fiber optic.

Disadvantages:

- Installation of satellite is expensive.

Applications:

- Global Communication
- Mobile Communication
- Military Communication