Computer Networks

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Session Goals

- Introduction
- Applications of Computer Networks
- Network Hardware
- Network Software*
- Reference Models*

Introduction

- **Computer Network : " Collection of Autonomous computers interconnected by a single technology "**

- **Interconnected**
  - **Able exchange information**
- **Autonomous**
  - **Individuality in terms of h/w, s/w and services**
- **Single Technology**
  - **Structure , medium etc..**

Introduction

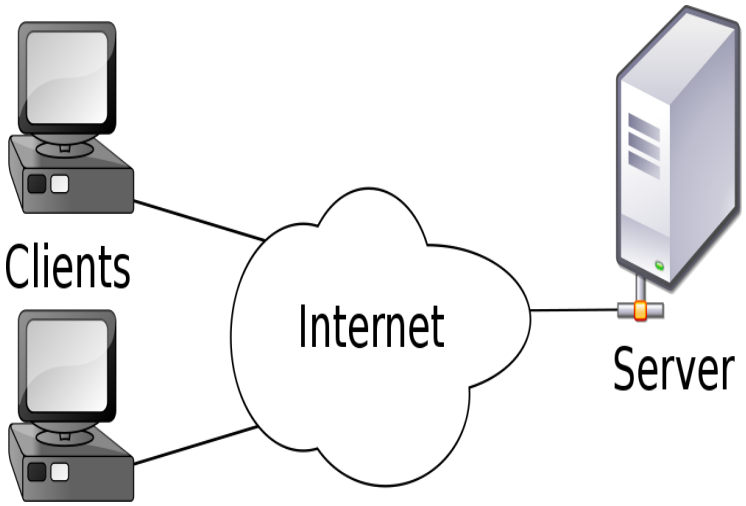
- **Need of Computer Networks**
  - **Single computer is serving to all computational needs in olden days.**
  - **Large number of separated but interconnected computers do that job.**
- **Fast**
- **Able to cop up the information processing grows, process and gather.**

Computer Networks Vs Distributed system

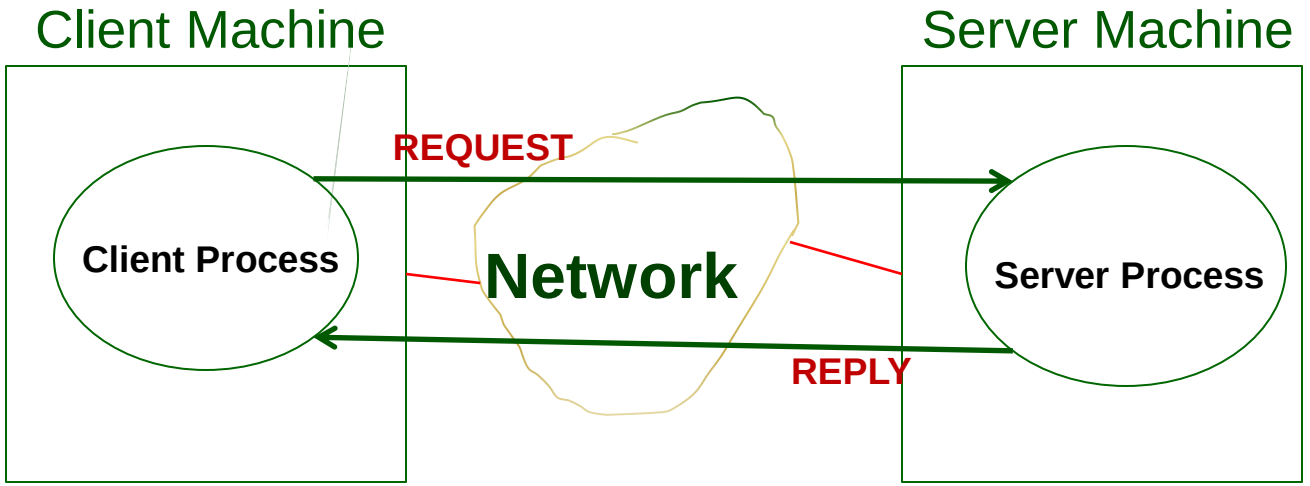
- **Distributed System**
  - **uses middleware, which is s/w built on OS.**
  - **Views as a single coherent system to user even though it is a collection of computers.**
  - **It's a model / paradigm**
  - **Example is WWW.**
- **Computer Networks**
  - **No Coherent, model and software**
  - **Exposed to work on actual machines**
- **Example :**
  - **Gmail (Distributed System)**
  - **Remote login (Computer Networks)**

Uses of Computer Networks

- **Business Applications**
  - **Resource Sharing**
    - **Client – Server Model**
  - **Communication Media**
    - **E – Mail**
    - **E – Commerce**
- **Home Applications**
  - **Person – Person Communication**
    - **Instant Messaging**
  - **Accessing Remote Information**
    - **New Paper, Digital Library**
  - **Interactive Entertainment**



Client Server Architecture



Network Hardware

- **Two Dimensions of Computer Networks**
  - **Transmission Technology**
  - **Scale**

- **Transmission**
  - **Broadcast link**
  - **Point-to-point link**

Network Hardware

- **Broadcast Networks:**
  - **" It has a single Communication CHANNEL, shared by all machines on the networks"**
  - **It uses intend address (receiver) in the data message and placed on channel.**
  - **All machines receives and examines the address.**
  - **If it is intended to that, it will process otherwise it ignores.**
  - **Usually in LAN's Only.**
- **Example : calling a person with his name in class.**
- **Broadcast Networks Transmission modes :**
  - **Broadcasting: " addressing a packet to all destinations by using special code in address field".**
    - **Receives and process all machines in a network.**
  - **Multicasting: " Transmit a packet to a subset of Machines in network "**
    - **Uses grouping.**

Network Hardware

- **Point-to-Point Networks:**
  - **" It has many connection between individual pairs of machines"**
  - **Data Packet may visit one or more intermediate machines , in network to reach destination.**
  - **Often multiple routes to destination.**
  - **Usually used in Large networks like WAN**
  - **Challenge:**
    - **Finding the best and good route between source to destination.**
- **Point-to-Point Networks Transmission Mode:**
  - **Unicasting: "It able to send data packets from one sender to one receiver only, by inserting destination address in address field"**

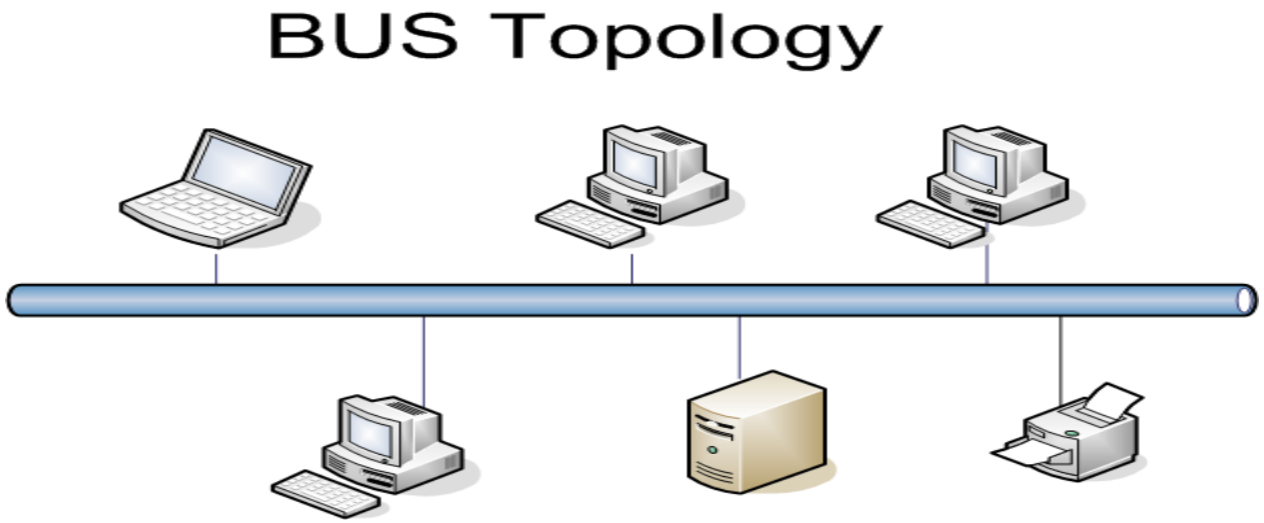
Network Hardware

- **Scale: Classification based on network size/scale**

Distance	Location	Example
1m	Square Meter	PAN
10m	Room	LAN
100m	Building	
1 km	Campus	
10km	City	MAN
100km	Country	WAN
1000km	Continent	
10000km	Planet	Internet

Local Area Networks (LAN)

- LAN: "Privately Owned Network with in a single building or Campus of up to a few kilometers in Size"
- Used for resource sharing.
- Example : Ethernet (IEEE 802.3, IEEE 802.5)
- LAN's are distinguish from other networks
  - Size (Worst case time known)
  - Transmission Technology(10Mbps-100Mbps, 10Gbps)
  - Topology (ring, star, bus etc)

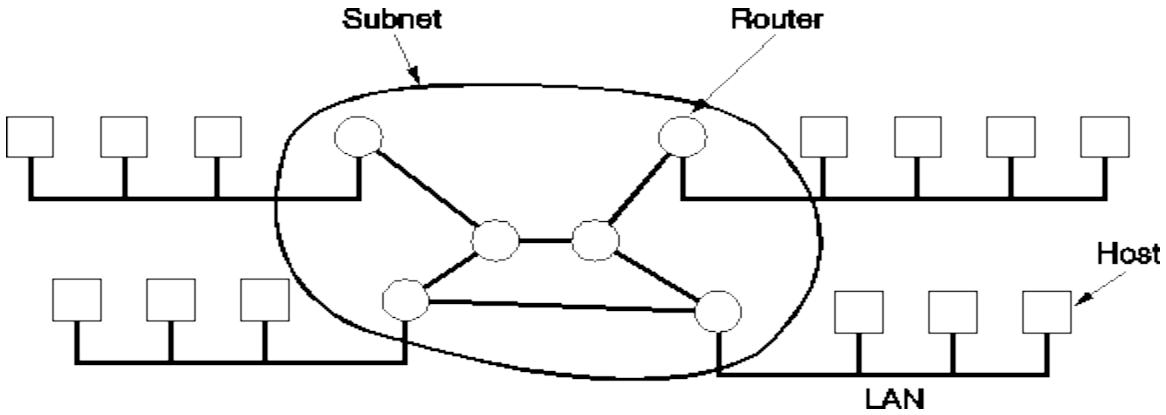


Metropolitan Area Network (MAN)

- Metropolitan Area Network (MAN) : it is a large computer networks span over a city.
- Owned and operated by single organization
- Inter networking of logical networks.
- Technologies used are ATM, FDDI
- Example : Cable TV, IEEE 802.6

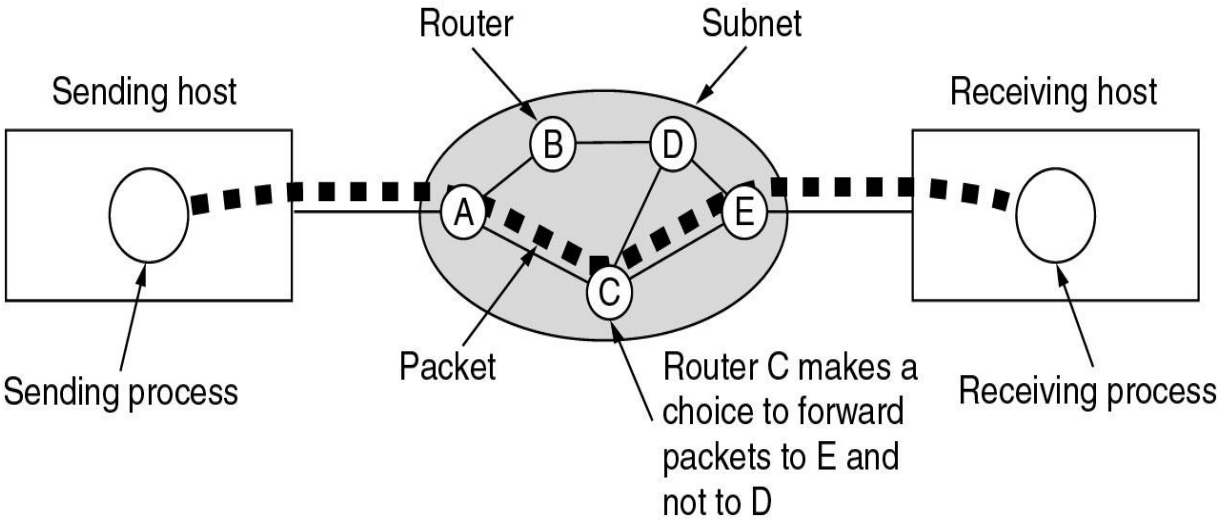
Wide Area Network (WAN)

- **Wide Area Network (WAN) : it spans a large geographical area, often country or continent.**
- **Host/End System: The WAN contains machine , which are intend to run user or application programs.**
- **Communication Subnet: which interconnected hosts.**
  - **it is owned by ISP or Telephone company**
- **WAN subnet consists of**
  - **Transmission lines (moves the bits)**
  - **Switching elements (connects 2 / 3 transmission lines)**



Wide Area Network (WAN)

- **Communication Subnet Uses a principle**
- **Store-and-forward or packet-switched**
  - **Message divided into packets with sequence numbers**
  - **Packets are injected into network**
  - **Packets uses different paths to reach destination**
  - **Resembles at destination with the help of sequence number**

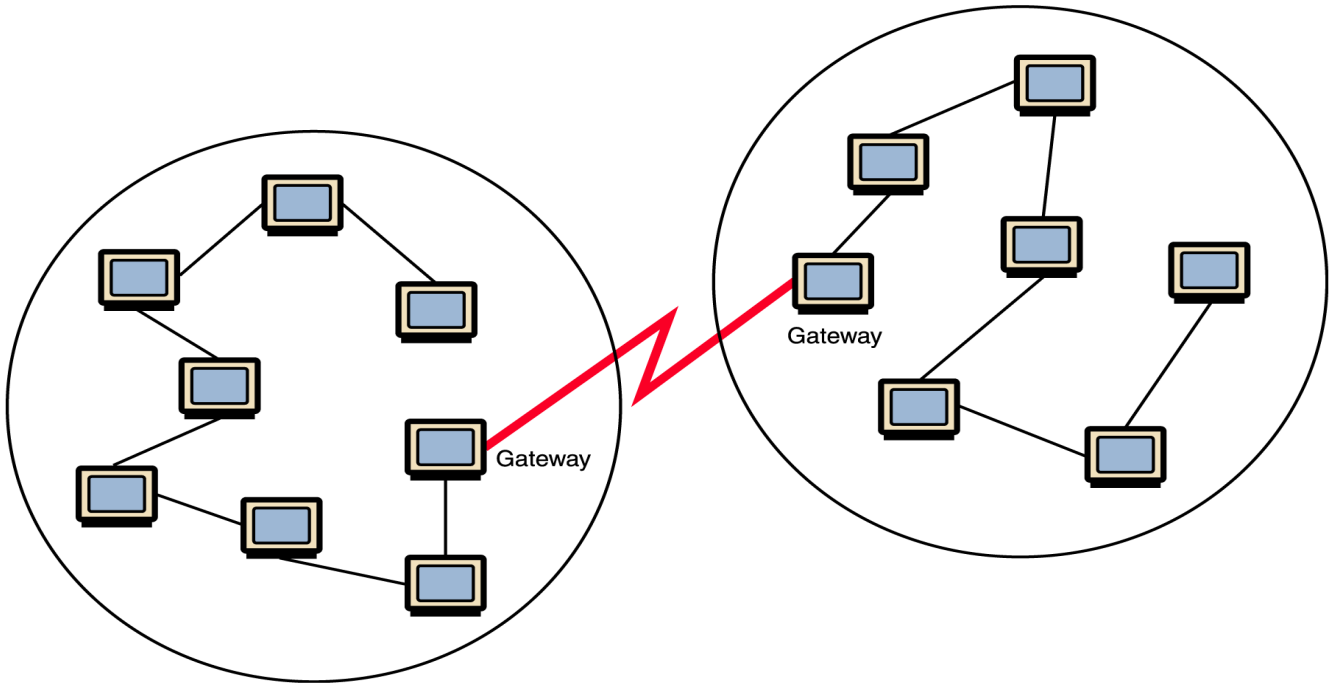


Wireless Networks

- It is one type of Computer networks, that are not connected by physically visible medium like cable.
- It uses air for transmission.
- Speed is some what slow
- High Error rate
- High Interference
- 3 categories based on size and technology
  - System Interconnection (Bluetooth)
  - Wireless LANs (uses radio and antenna to communicate, IEEE 802.11)
  - Wireless WANs (Cellular Networks)

Internetworks

- Collection of interconnected networks is called an Internetworks or internet.
- Gateway used to connect one network to other networks.
- Simply internet → LAN + WAN



Network Software

- Initially computer networks depends on Hardware.
- Now it depends on Software
- To reduce Design Complexity, networks are organized as stack of layers or levels, each one built upon one below it.
- No of Layers
- Name of the layer
- Content of layer
- Function of layer

Network to network

- Each Layer offers some services to layer above it.

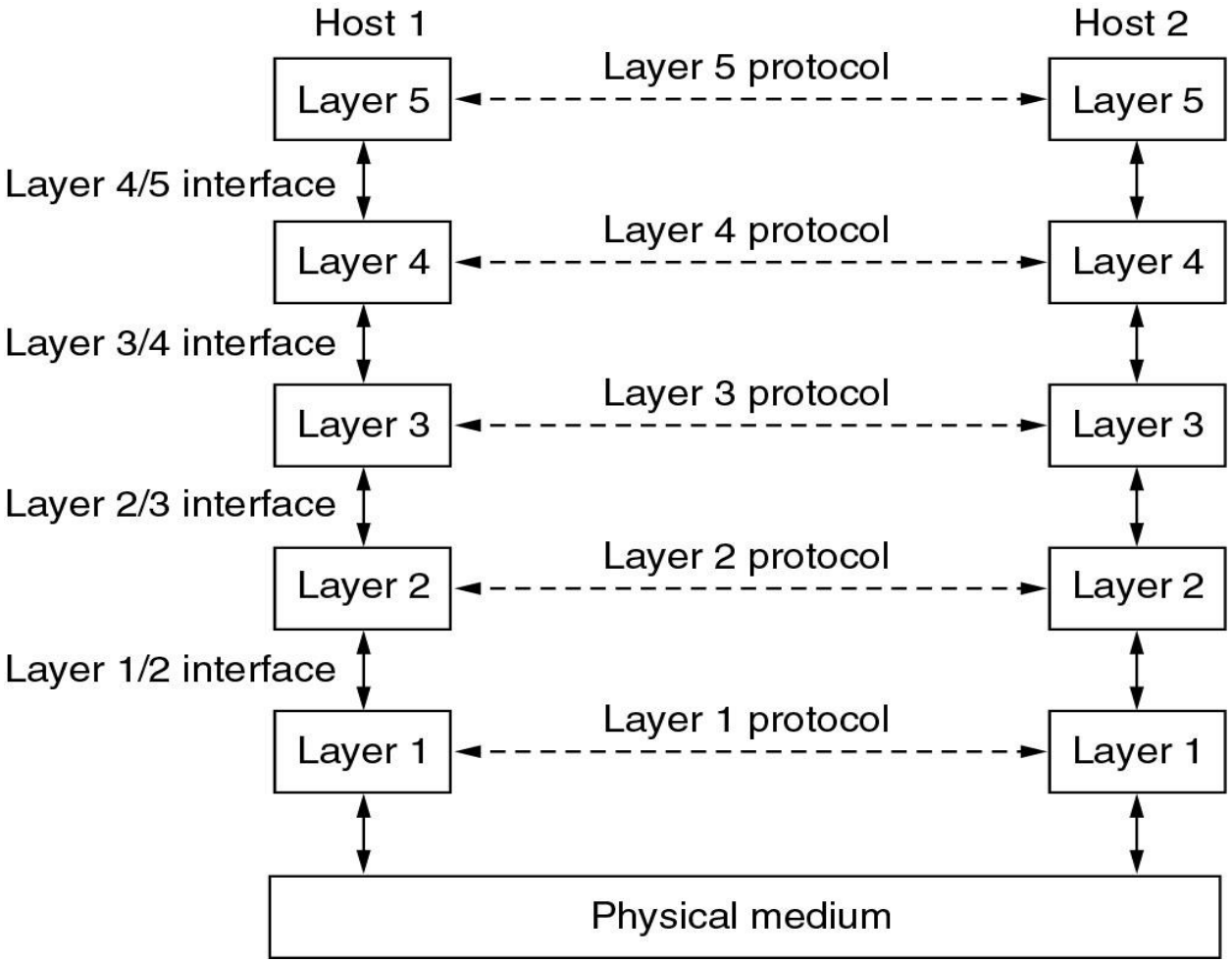
Network Software

- A entity of layer on one host talks to the same layer entity on another host (its peer).
- The entities of layers on different machines are termed peers.
- The rules and conventions used in that conversation is called Protocol.
- Protocol is an agreement and rules between the communication parties, on which the communication can takes place.
- Interface defines the primitive operations and services offer to the above layer. Clearly defined Interfaces are needed to avoid unnecessary data transmission.

Network Software

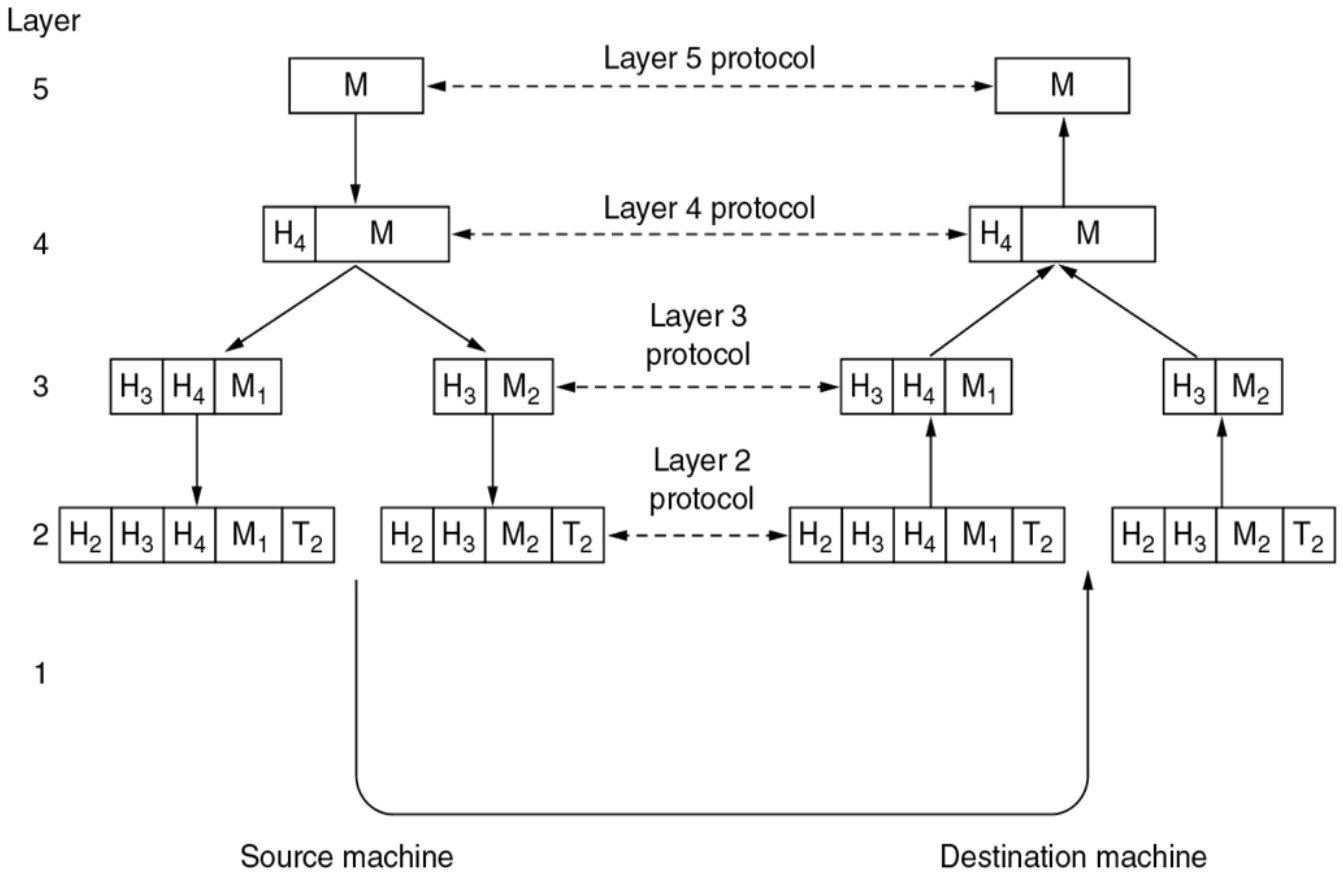
- **Network Designer decides,**
  - **number of layers**
  - **Functionalities of layers**
  - **Interfaces between layers.**
- **Network Architecture : A set of Layers and Protocols is called network architecture.**
- **Protocol Stack : List of Protocols used by a system, i.e one protocol per layer.**

Network Software



Network Software

- Protocol Hierarchies
- **Protocols of Lower Layer in hierarchy are implemented in hardware**



Design issues of Layers

- Addressing (Each needs to identify sender and receiver)
- Data Transfer
  - simplex
  - Half duplex
  - Full duplex
  - Two logical channels (urgent and normal)
- Error Control (agreement)
- Packets arrived out of order(protocol)
- Flow Control
- Message Breaking, Reassemble @ Receiver
- Multiplexing and Demultiplexing.
- Routing

Layer's Services

- Two different services to the layer above on it.
  - Connection Oriented Services
  - Connection Less Services
- **Connection Oriented Services**
  - Its like a Telephone System.
  - It has 3 phases
  - Connection Establishment
  - Data Transfer
  - Connection Termination
  - Its like a tube after connection setup.
  - Negotiations
    - **QoS, Maximum Message Size…**

Layer's Services

- Two different services to the layer above on it.
  - Connection Oriented Services
  - Connection Less Services
- **Connection Less Services**
  - Its like a Postal System.
  - Message has destination address.
  - May Use different routes to reach destinations.

Layer's Services

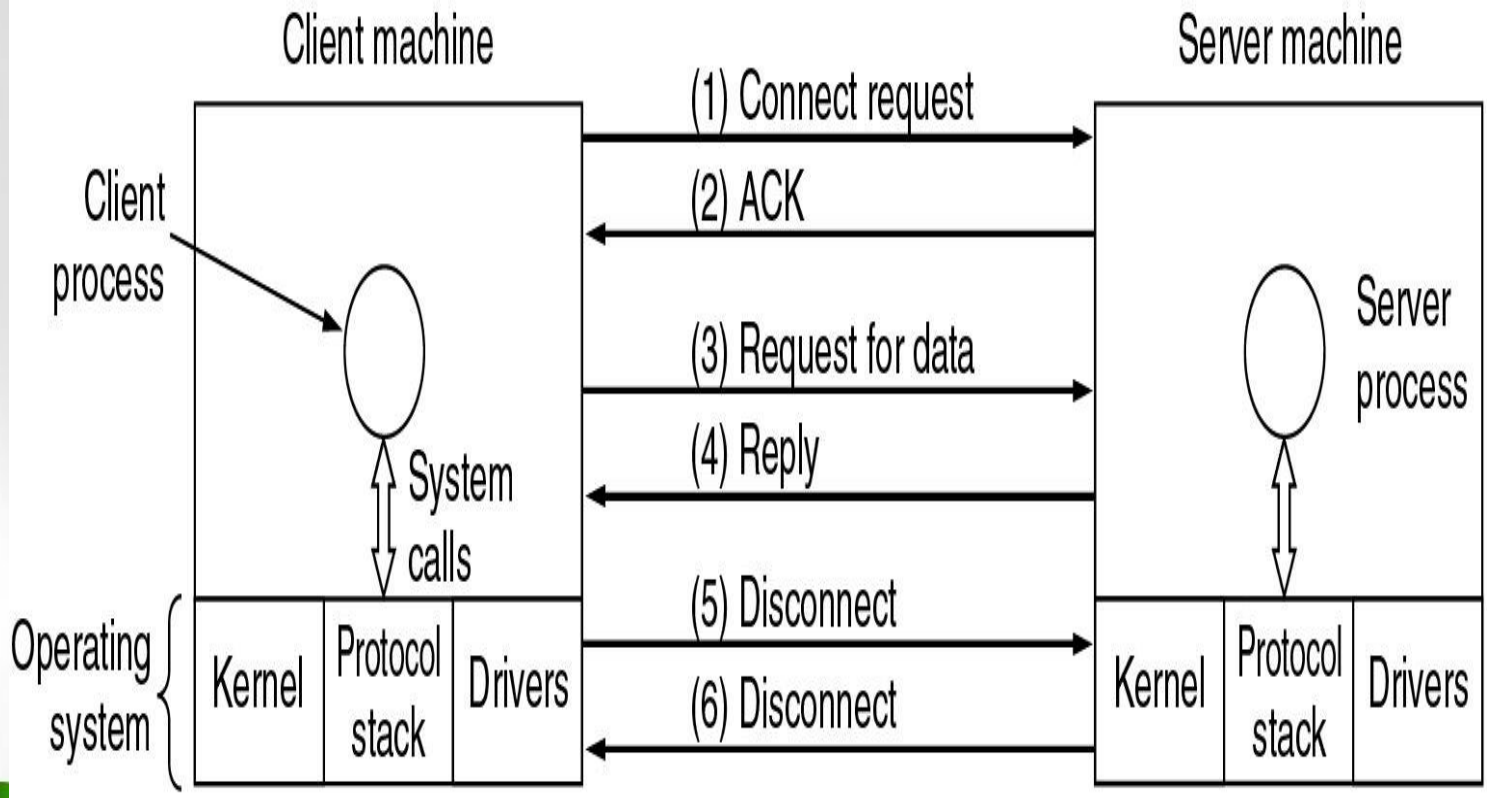
- Service is Characterized by QoS.
- Reliable :
  - waiting for a acknowledgment for sent data.
  - Never lose data
  - Overheads and delays
- Reliable Connection Oriented Services
  - Message Sequences (message boundary)
  - Byte Streams (boundary)
- Connection less services are not reliable.
- Datagram Services
- Unreliable Connection less Services are called Datagram Services
- Request – Reply Services

Service Primitives

- Service is a set of primitives (Operations) available to user process to access the service.
- Primitives are system calls, if protocol is in OS.
- Service Primitives depends upon service being provided and different for COS and CLS.
- Some of COS primitives are

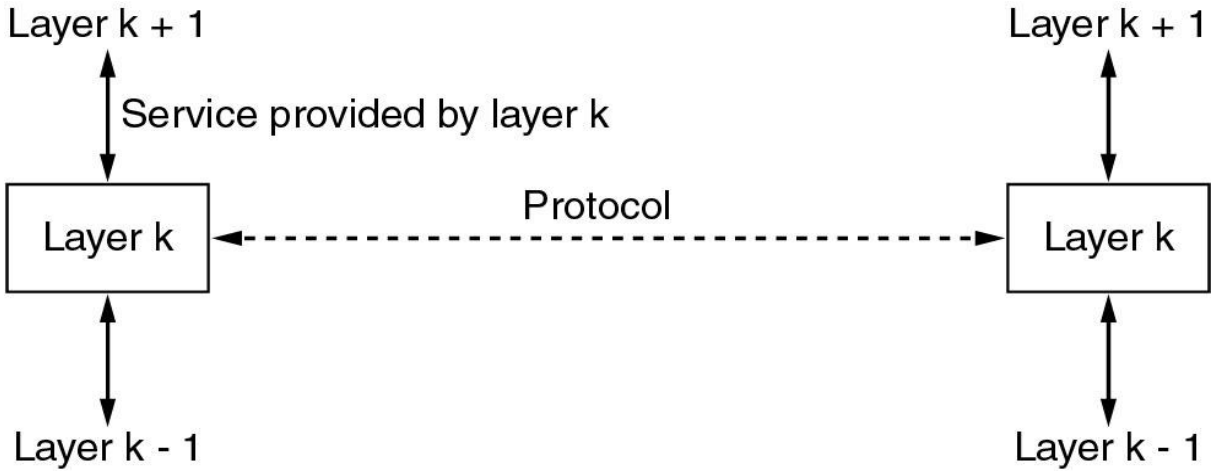
Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

Service Primitives



Services Vs Protocols

- Service defines the operation perform on be half of user
- Service relates to interface between layers
- Protocol is set of rules between peer entities to access data.
- Protocol relates to implementation of services, which is not visible to user



Reference Models

- Two main Reference models
  - 1. OSI Reference Model
    - protocols are not so popular and rarely used
    - Features of layers are valid and so important.
    - Model is popular due to layers functionality
  - 2. TCP/IP Reference Model
    - Model is not popular
    - Protocol are very popular
    - Internet Using these protocols

OSI Reference Model

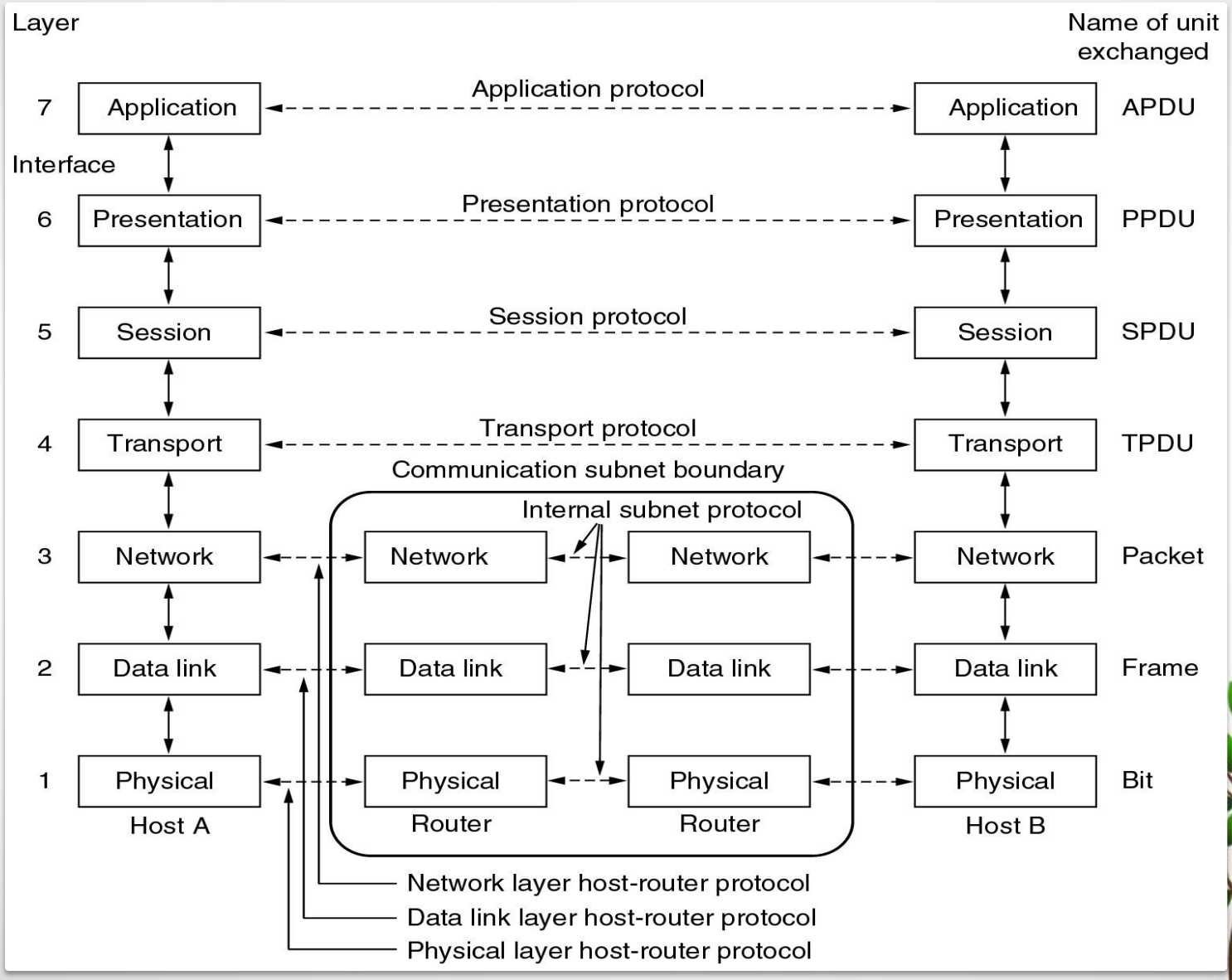
- The idea of Seven Layer was provided by the work of Charles Bachman in ARPANET.
- It is standard in 1983.
- Day and Zimmerman used these protocols.
- It was again revised in 1995, called ISO/OSI
- It is used to connect two open systems (communication)

- Why did has 7 layers?
  - A layer should be created where a different abstraction needed
  - Each layer should performed a well defined function
  - The functions of each layer should follows, international standards.
  - These should be minimized information across layers
  - The number of layers and functions should be balanced.

OSI Reference Models

- 1. Physical Layer
- 2. Data Link Layer
- 3. Network Layer
- 4. Transport Layer
- 5. Session Layer
- 6. Present Layer
- 7. Application Layer

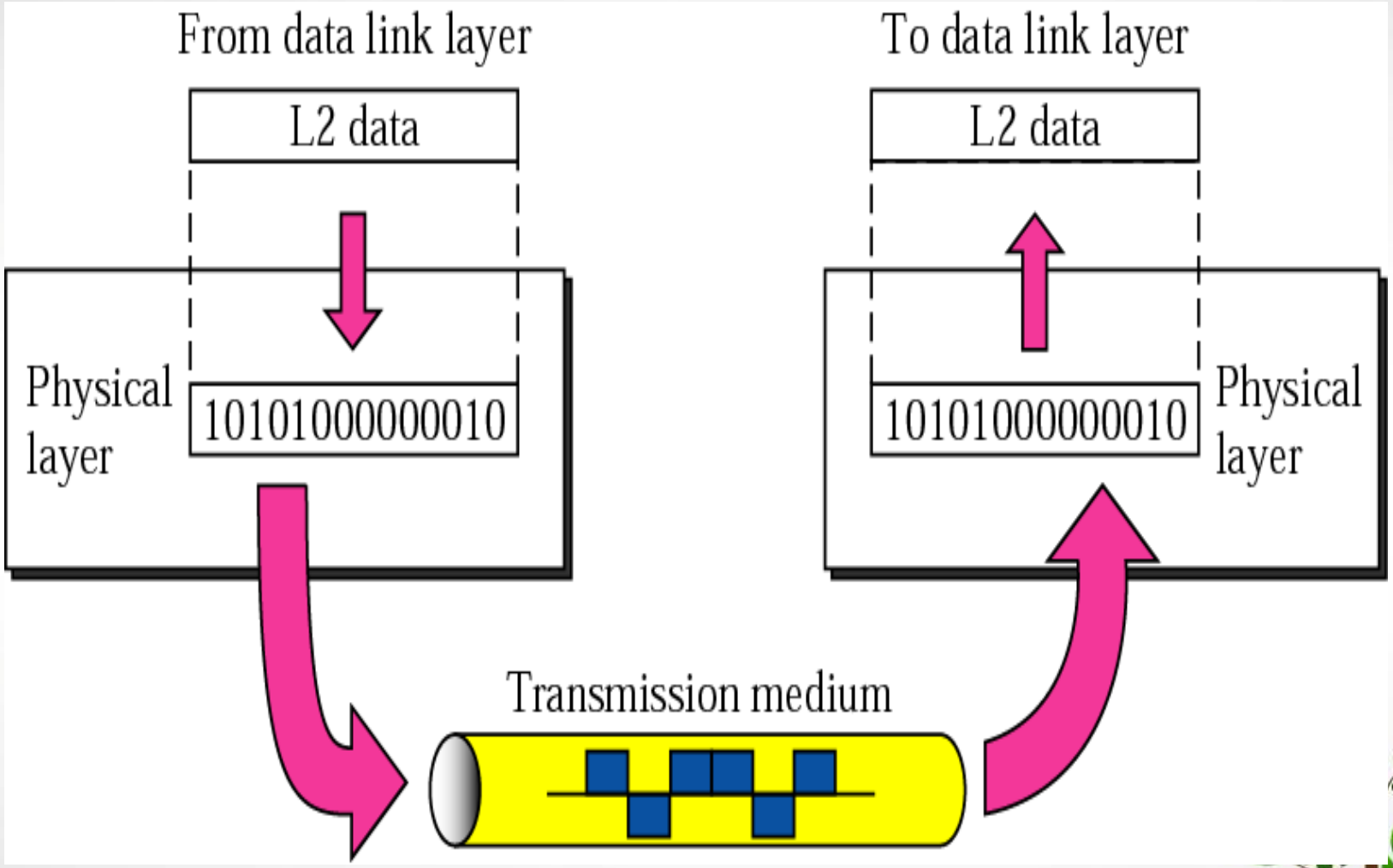
OSI Reference Model



Physical layer

- It is concerned with transmitting of raw bits over communication Channel.
- How the raw bits are transmitting.
- Questions?
  - 1. How many volts are needed to represent 1 bit
  - 2. How many volts are needed to represent 0 bit
  - 3. How many nanoseconds a bit last
  - 4. Transmission directions ; simultaneously on both
  - 5. How the initial connection is established
  - 6. How the connection is torn down
- The design issues related mechanical, electrical and timing interfaces.

Physical layer

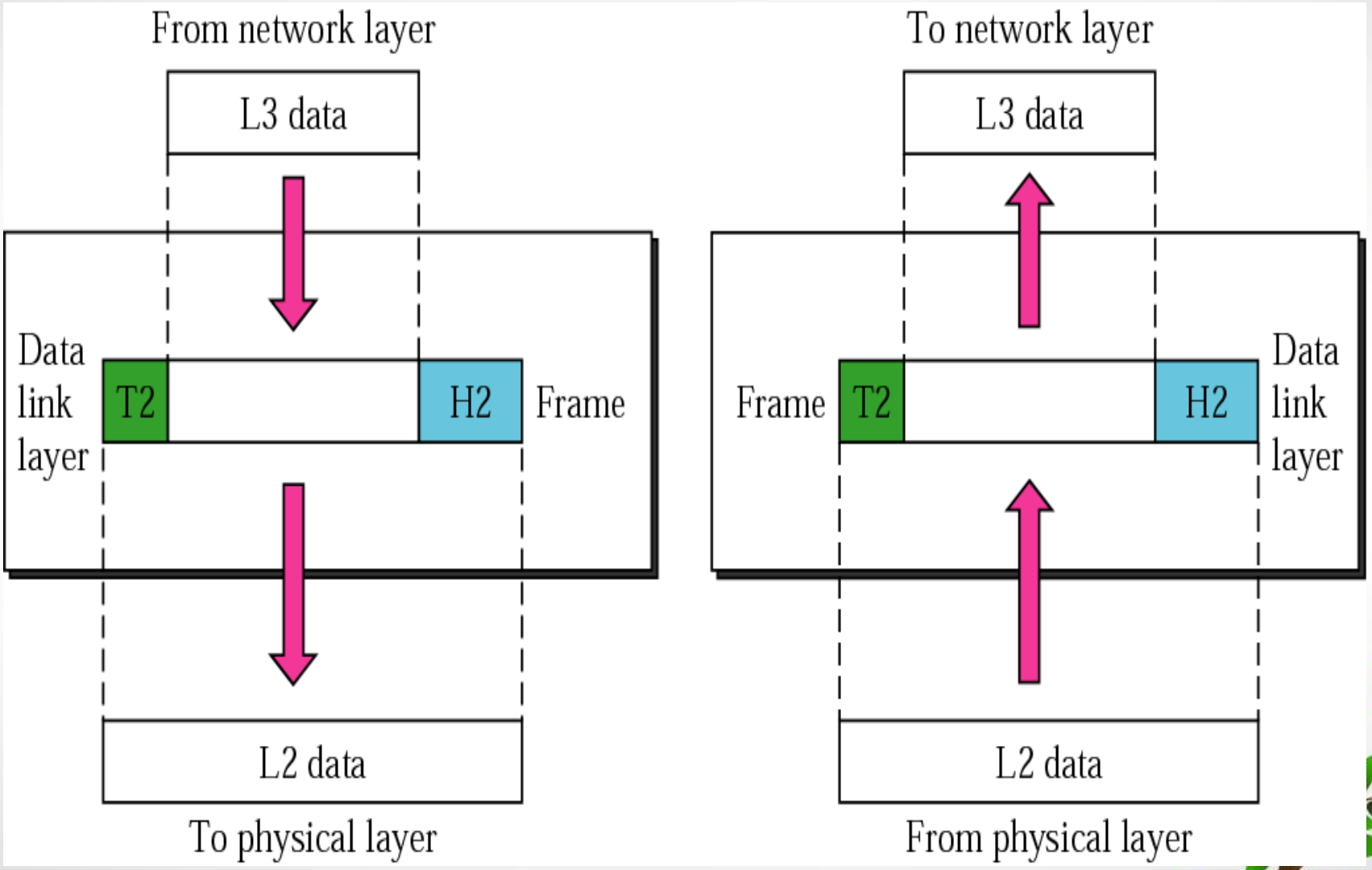


Data Link layer

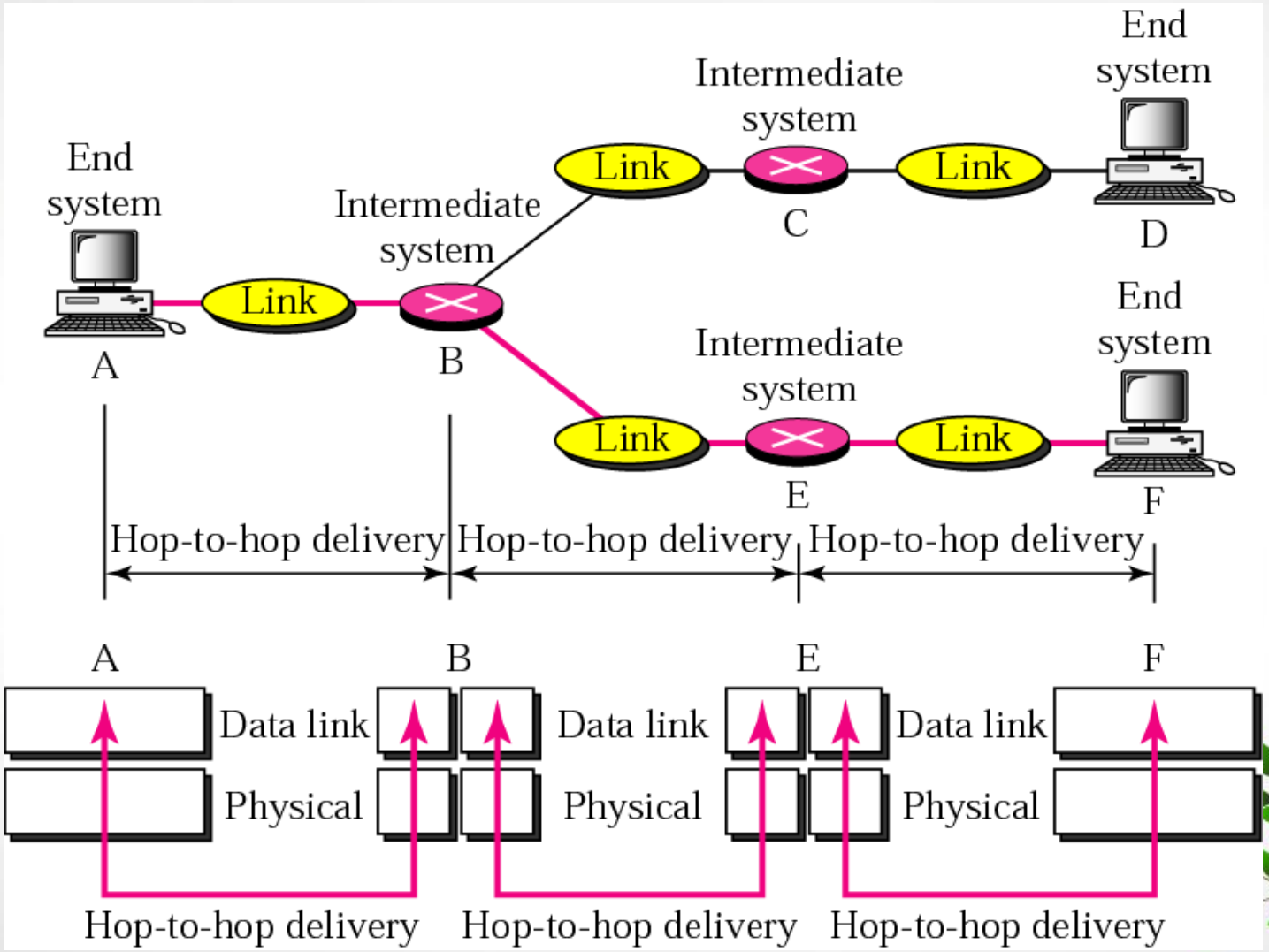
- Its task is to transform raw transmission into a line, which does not contains any errors.
  - HOW ?
  - the sender sends a data in break up format. Which is called data frames. (hundred / thousand bytes)
  - Data frames are transmitted sequentially.
  - If the layer offers a reliable service, then acknowledgment frame.
  - Issue : fast transmitter and slow receiver. ???? (flow control mechanism).
  - Issue : error control
  - If network is a broadcast network , DLL issue is

    Control of channel (Medium Access Layer (MAC) sub layer) (Channel Allocation Problem)

Data link layer



Network layer

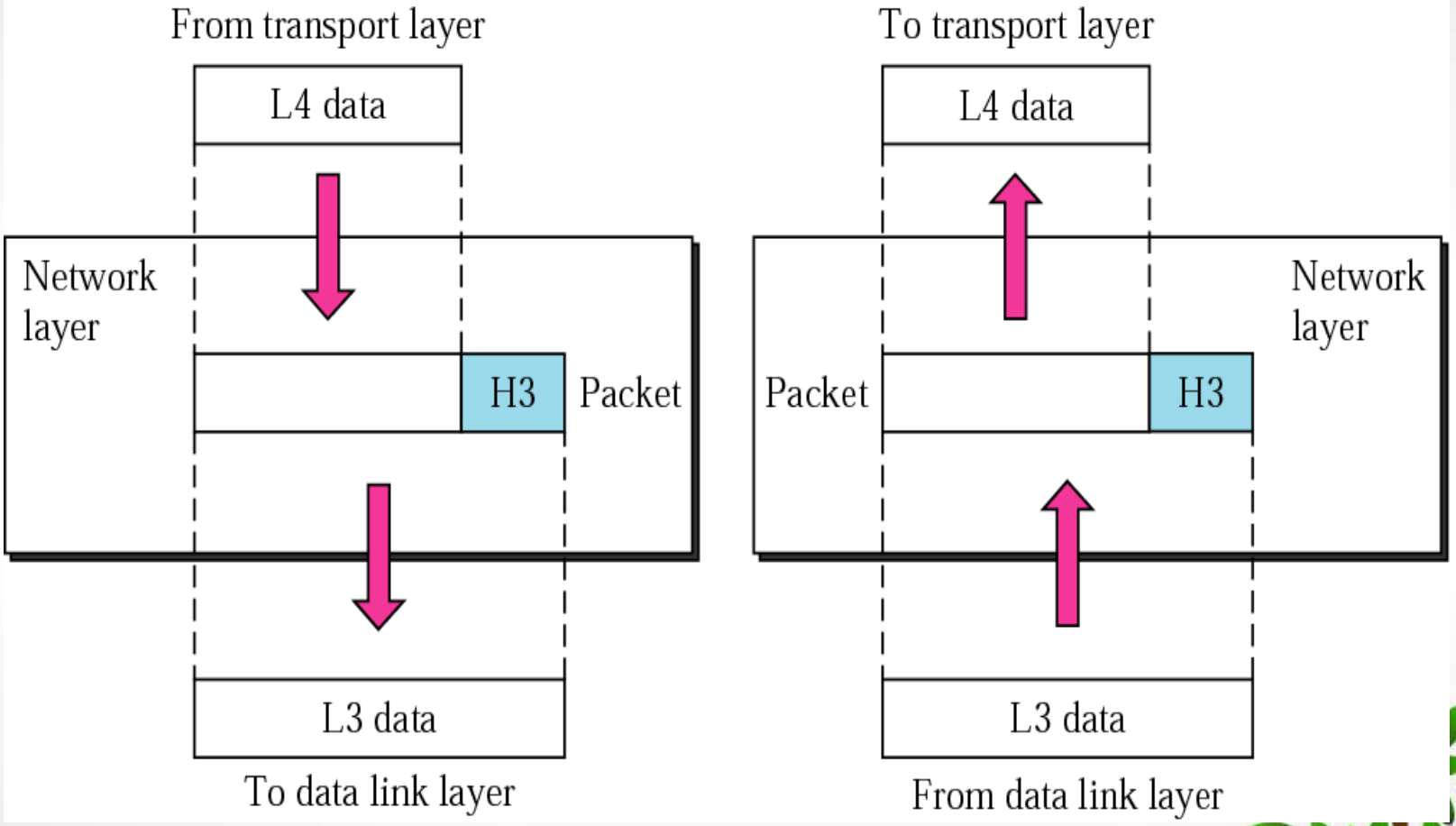


Network layer

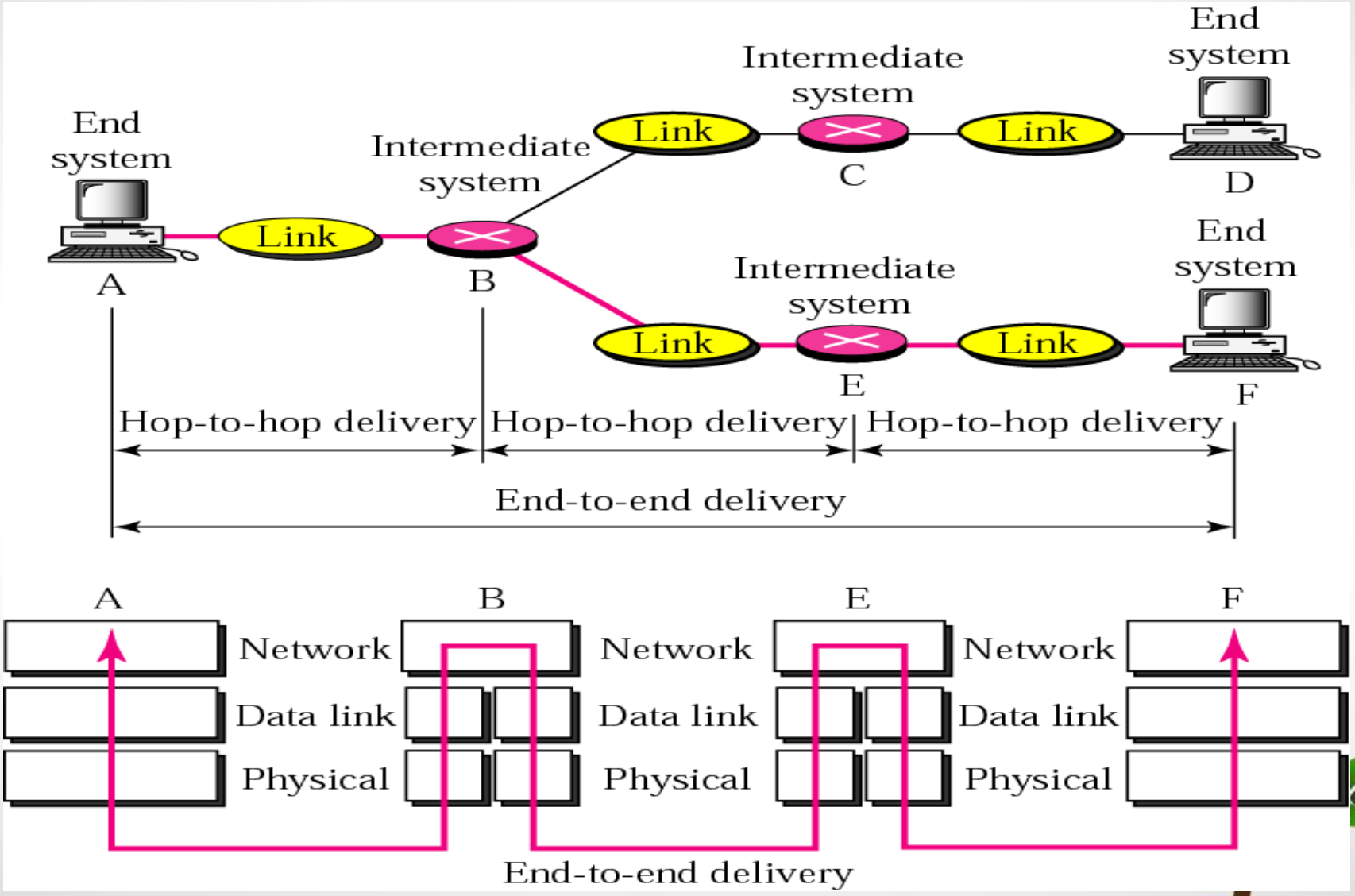
- It mainly concerned with communication subnet.
- Issues :
  - Routing
  - Congestion Control.
  - Quality of Service (QoS)
  - In Heterogeneous network
    - Addressing
    - Protocol
    - Size of Packets

Routing is easy in broadcast networks

Network layer



Network layer

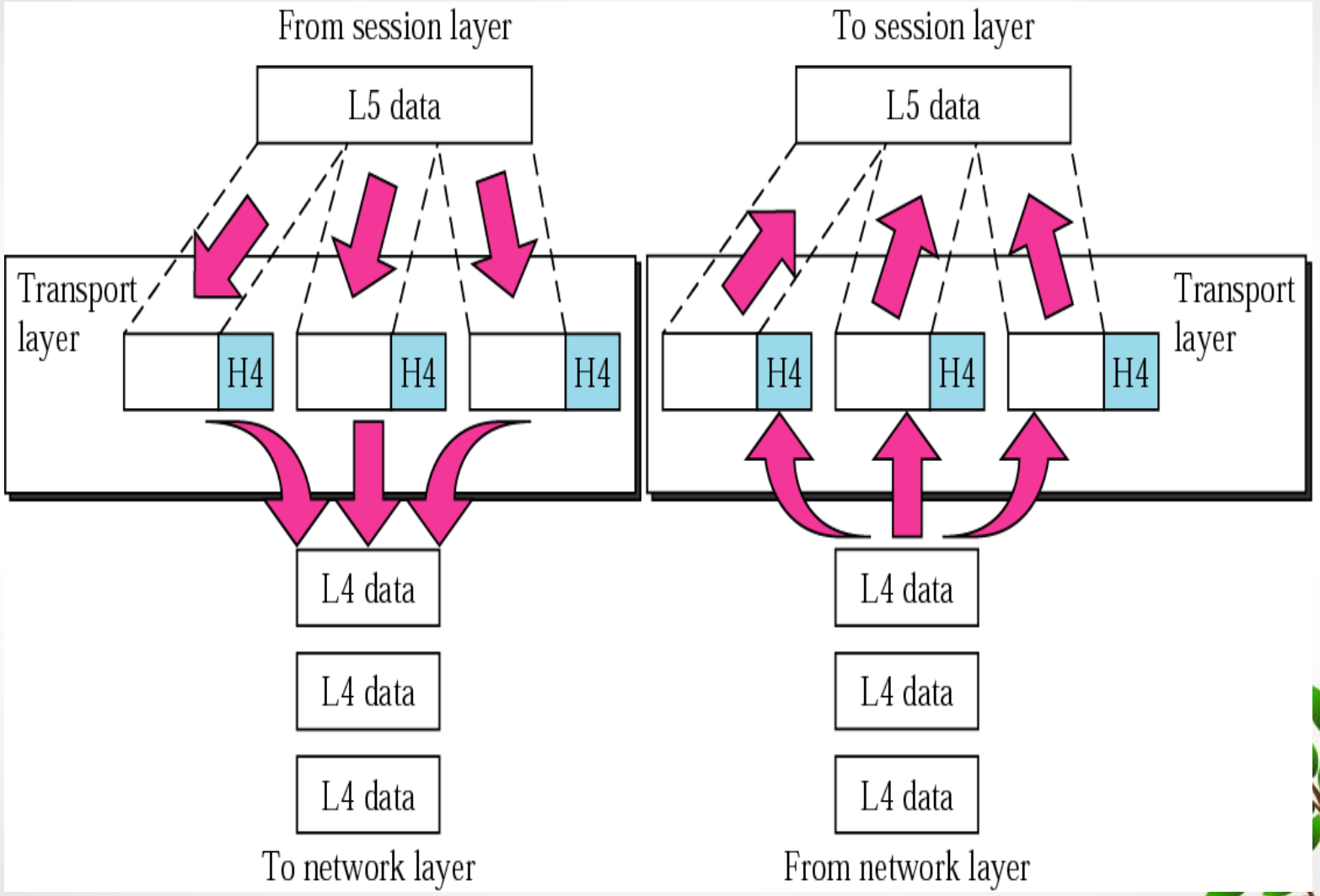


Transport layer

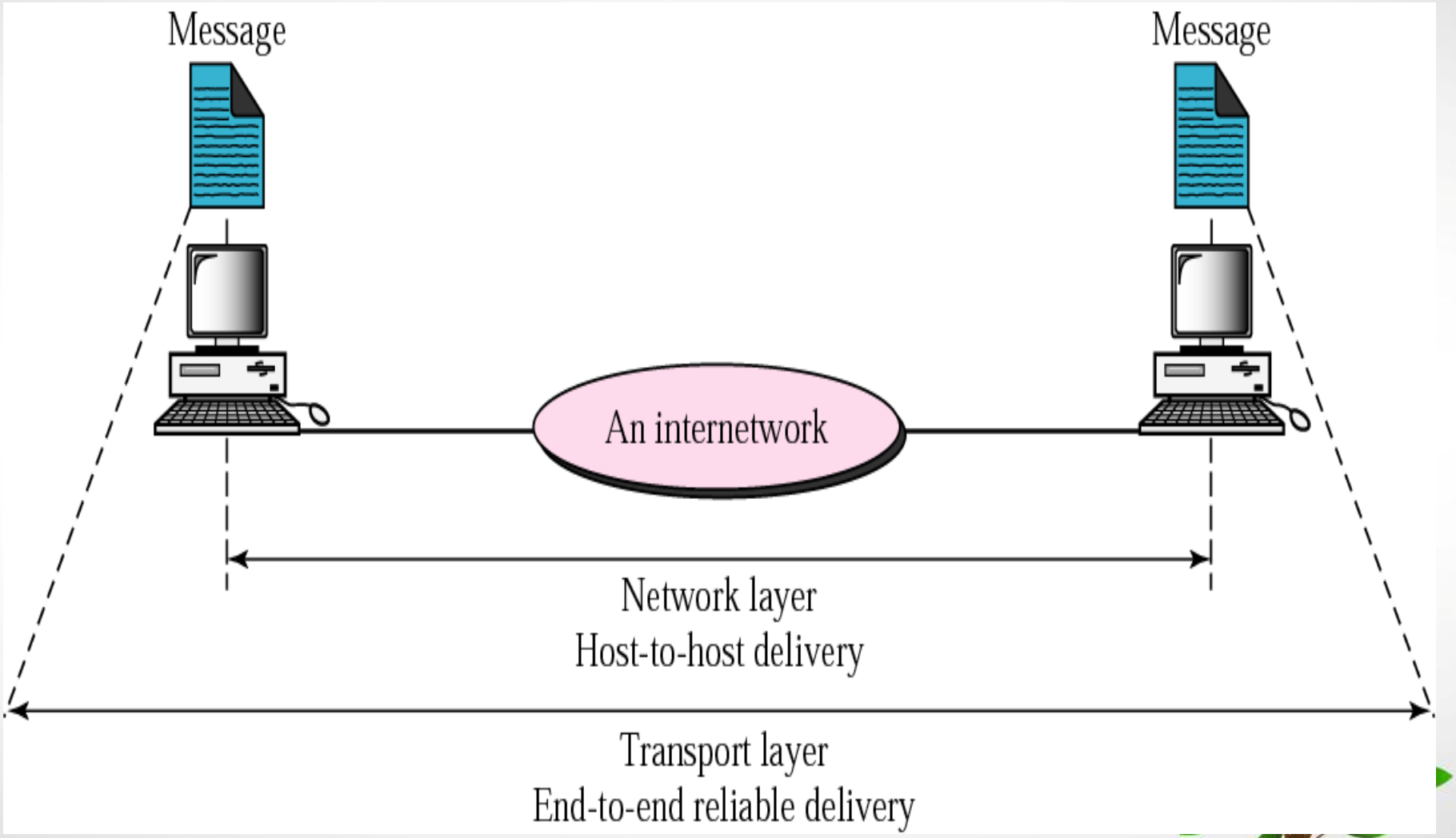
- It accepts the data from session layer , split up into small units it need, passes to the network layer.
- ensures → the data that should be correctly delivered.
- Two different type of services provided
  - 1. Connection Oriented Service
  - 2. Connection Less service
- Transport Layer is True End to End layer. same processes running on different machines for communication

- The able to communicate the destination in network, where as all other lower layer are able to communicate to next neighbor nodes only.

Transport layer



Transport layer



Session layer

- It allows users on different machines to establish session among them.
- Service : Dialog Control (Who's turn next)
- Token Management (avoid collisions)
- Synchronization (check points → after a crash)

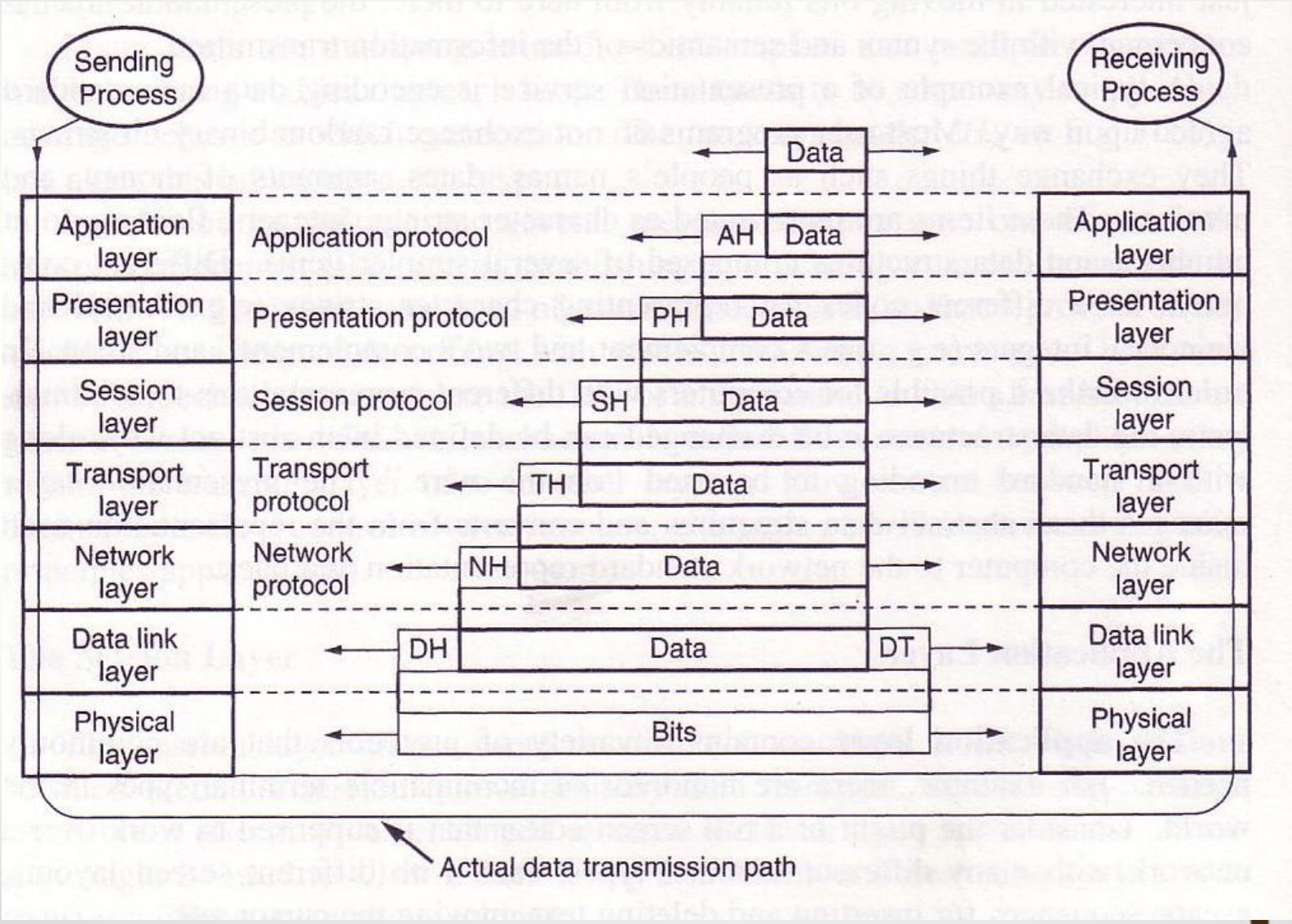
Presentation layer

- It concerns syntax and semantics of the data being transformed.
- It uses abstract data structure to make the communication between different data representation.

Application layer

- It provides set protocol to end user to communicate network.
- FTP,SMTP,POP3 etc…..

Data Transmission in OSI



TCP/IP Reference Model

- It is a older Reference model
- Its design goal is provide the connection among the networks seamlessly.
- It is defined by Cerf and Khan in 1974, updated in 1985 and 1988.
- It is composed of 4 layers
  - 1. Host-to-Network Layer
  - 2. Internet Layer
  - 3. Transport Layer
  - 4. Application Layer
- There is no Session and Presentation Layer.

Internet Layer

- TCP/IP should provide services to user even any one of the node failed in network.
- TCP/IP should provide seamless services.
- So it leads to use packet switching at Internet layer and support to provided connection less services.
- So the internet layer injects the packets in network and allow them travel independently to destination.
- If the destination receives out of order packets, higher layers will take about that.
- Internet layer uses Special Protocol, IP (internet protocol) and special meaningful format of IP.
- Packet routing with avoiding congestion → issue

Transport Layer

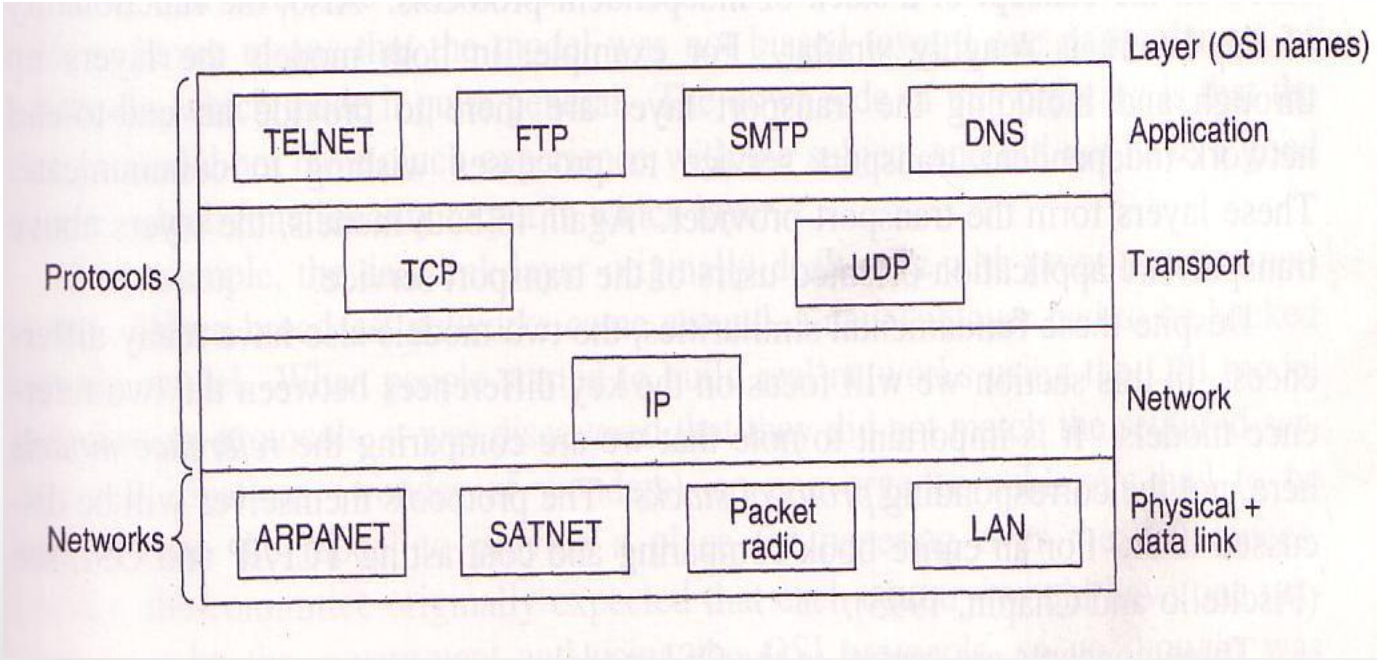
- Its task is to design a paradigm that allows two peer entities on source and destination for conversions.
- It use two different protocol :
- TCP (Transmission Control Protocol)
  - It is a reliable connection oriented protocol
  - Byte stream with out errors.
  - Support assembling.
  - Handles flow of control (Overhead is high)
- UDP (User Data Gram Protocol)
  - Unreliable connection less protocol
  - Speech , video applications ..
  - No control of flow, no sequence numbering…
  - Less overhead

Application Layer

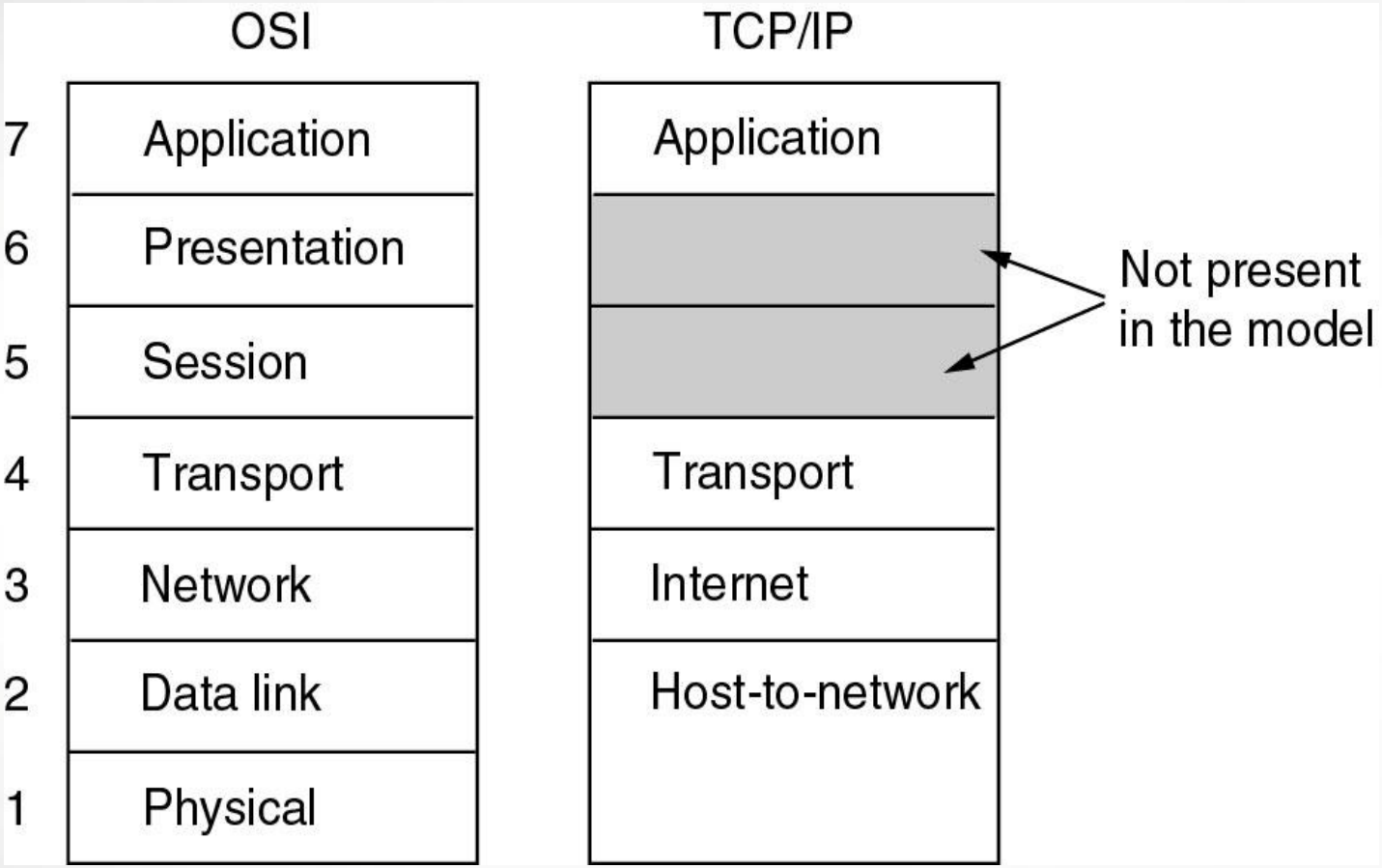
- No Session and presentation layers.
- The application layer will includes the functions of session and presentation layer.
- It contains all high level protocols
- It have the protocols like FTP, TFTP, SMTP, DNS, HTTP..

Host-to-Network Layer

- **Host is connect to Network using some protocols.**
- **These protocols are vary based on the host to host and network to network.**
- **It does not specially defines the protocol used to transfer the packets at this level.**



Comparison of OSI with TCP/IP



Comparison of OSI with TCP/IP

- **Similarities**
  - **Stack of Independent protocol**
  - **Functionalities of layers are some what similar**
  - **Layers above transport layers are application oriented**
- **Differences**
- **Services, interfaces and protocols**
  - **No clear distinguish among them in TCP/IP**
  - **Protocols**
  - **In OSI, Model first, then protocols**
  - **No of layers**
  - **Protocols are better hidden, can replace easily.**
  - **CLS and COS in OSI network layer.**

Protocols

- Protocol is a set of rules and regulations that governs the data communications.
- It define,
  - What is communicated,
  - When it is communicated
  - How it is communicated
- Key elements of protocols are
  - Syntax (Structure of The data)
  - Semantics(meaning of each section of bits, interpretation)
  - Timing (When data should be sent, how fast)

Protocols and Standards

- Standards provides guidelines to manufactures, vendors, etc… to ensure connectivity between marketplace and international communications
- These are essential in creating and maintain products.
- These are also providing national and international interoperability.
- Data Communication Standard
  - 1. De facto (Standards are not approved by organization body)
  - 2. De jure (Standards are approved by organization body)

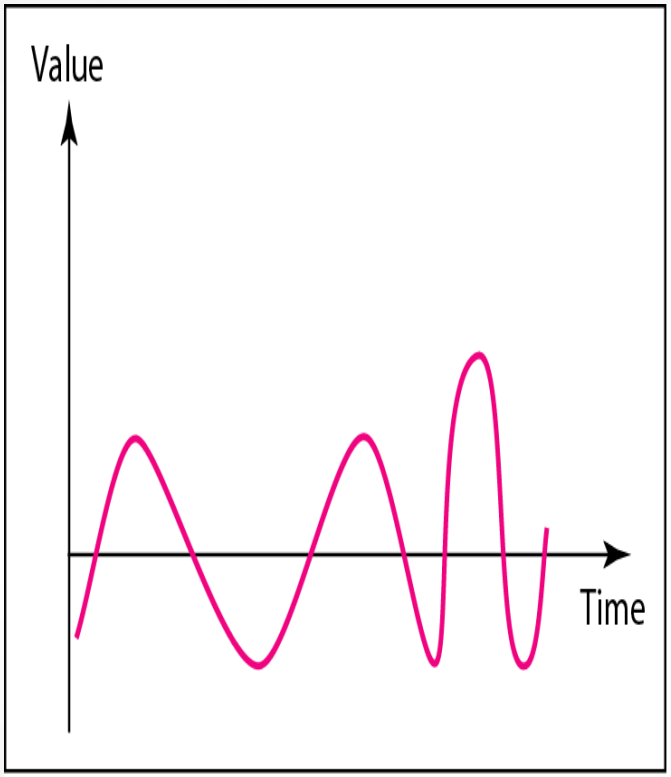
Protocols and Standards

- Standards are developed by
- Standards Creation Committee
  - ISO (International Organization for Standardization)
  - ITU – T (International Telecommunication Union – Telecommunication Sector)
  - CCITT(Consultative Committee for International Telegraphy and Telephony)
  - ANSI (American National Standards Institute)
  - IEEE(Institute of Electrical and Electronics Engineers)
  - EIA(Electronic Industries Association)
- Forums
- Regulatory Agencies
  - US → FCC (Federal Communication Commission)
  - INDIA
- Internet Standards (IETF, RFC's)

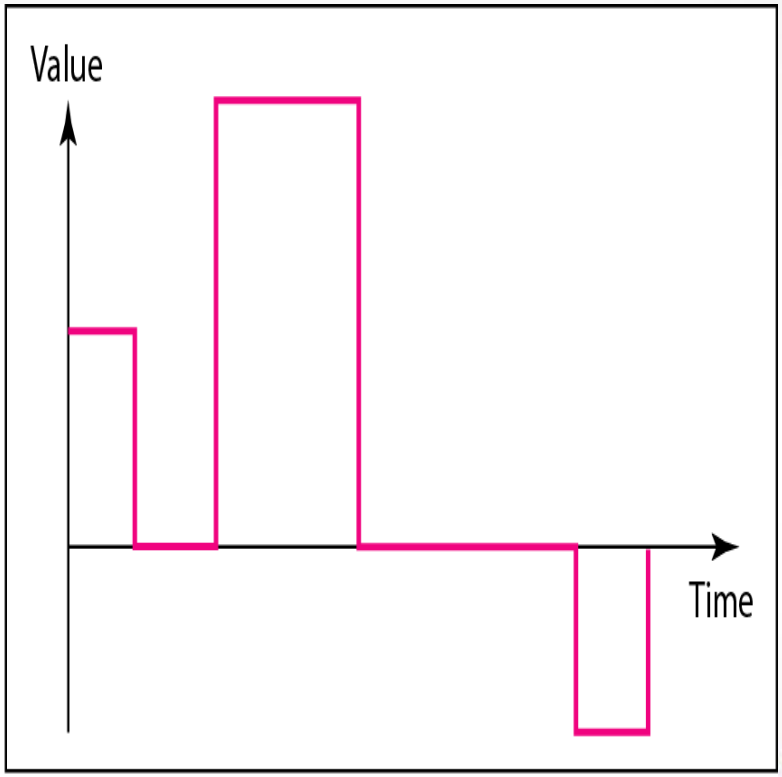
Physical Layer

- It defines Mechanical, Electrical and Timing Interface to the network.
- Analog Data : Information is Continues.
  - Example: human Voice
- Digital Data: Information has Discrete states
  - Example: microphone sound capture
- Analog Signal : Infinity levels of intensity over period of time.
- Digital Signal : Have limited number of defined values.
- Signals may Analog or Digital
- Digital signal possess digital data
- Analog signals possess analog data

Physical Layer



a. Analog signal

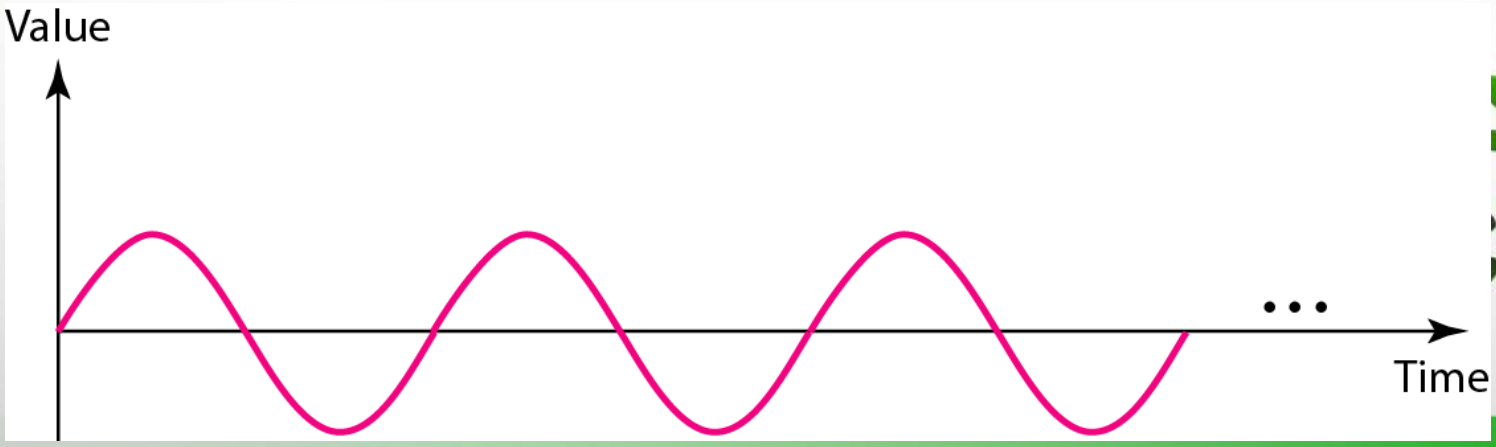


b. Digital signal

- **Periodic and Non Periodic signal**

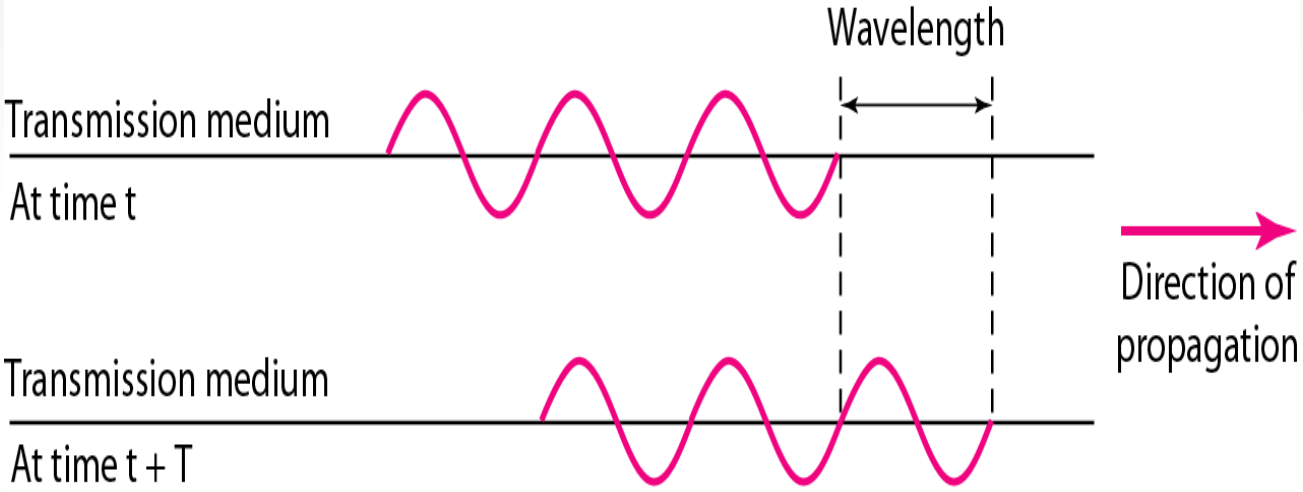
Physical Layer

- Periodic Analog signal and Non-Periodic Digital signals are used in Data communication.
- Periodic Analog Signals
- Simple periodic analog signal(single sine wave, not decomposed further)
- Composite Periodic analog signal (Composed of multiple sine waves)
- Sine Wave is form of period analog signal.
- Amplitude, Frequency and Phase



Physical Layer

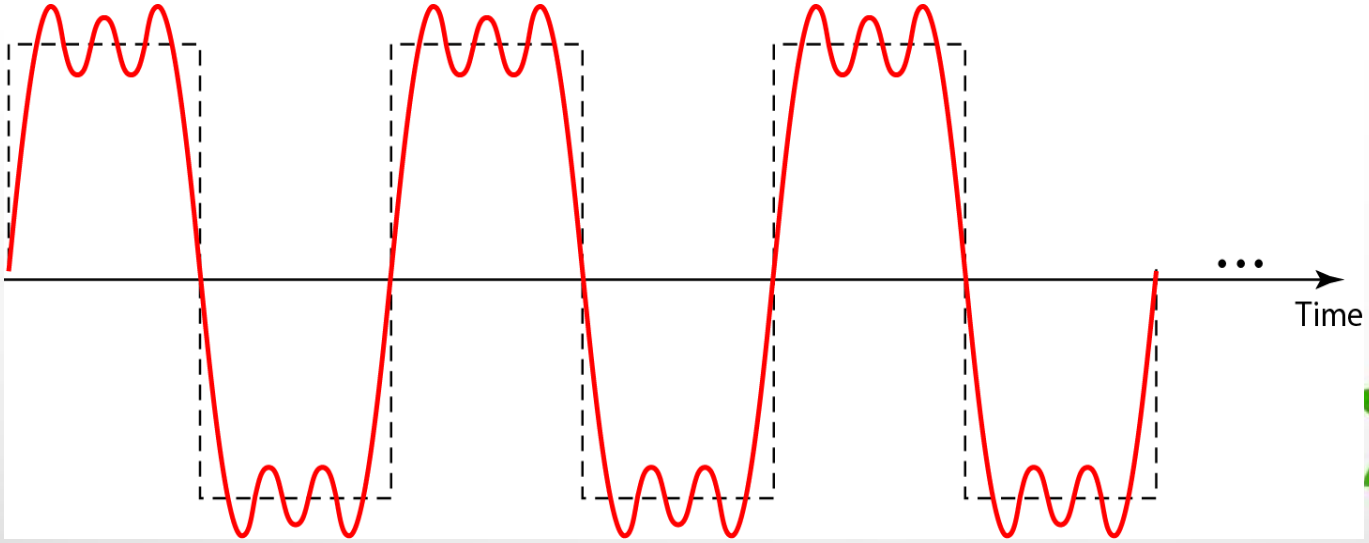
- **Wave Length : Wave Length is the distance a simple signal transmitted in one period of time.**



- **Wave Length = Propagation Speed X Period**

Physical Layer

- A single-frequency sine wave is not useful in data communications
- We need to send a composite signal, a signal made of many simple sine waves.
- According to Fourier analysis, any composite signal is a combination of simple sine waves with different frequencies, amplitudes, and phases.



Physical Layer

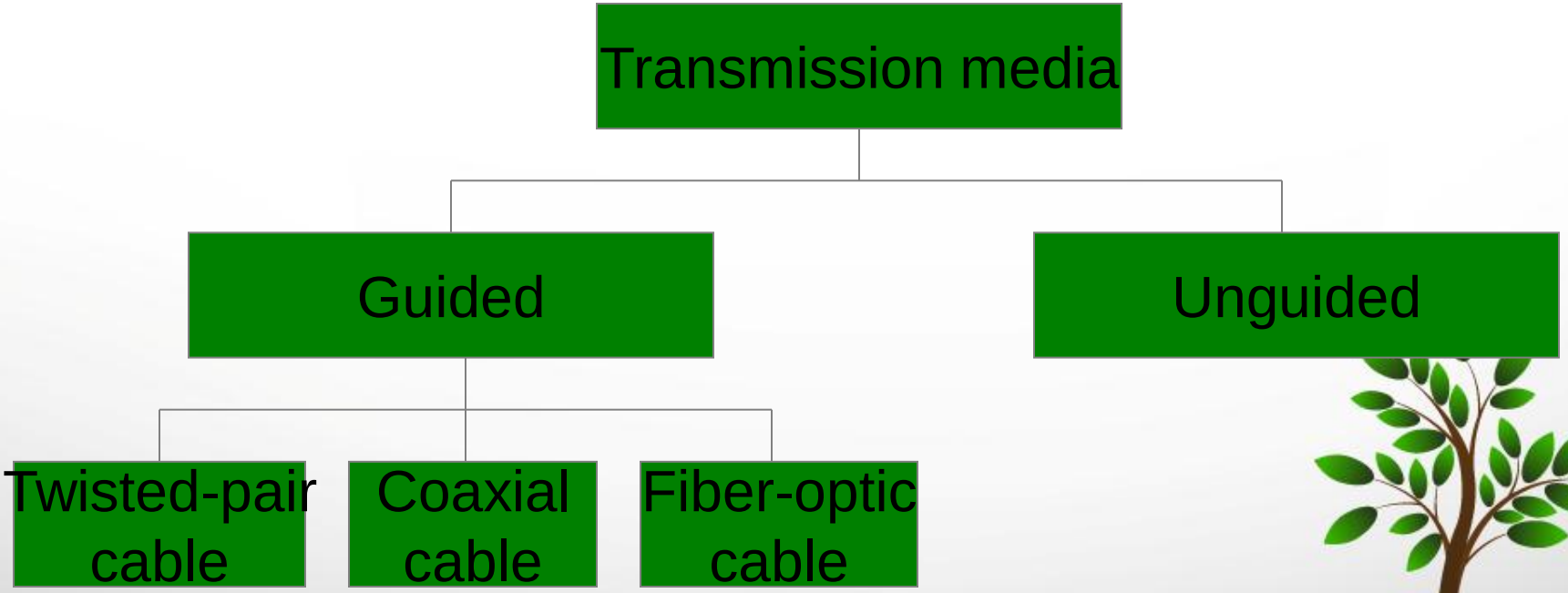
- **Bandwidth : The bandwidth can be specified by the difference between highest and lowest frequencies of that signal.**
- **Simply the range of frequencies.**

Physical Layer

- **Digital signal : voltage or current can be used to represents the signal values.**
- **Bit Length: The distance occupied by bit in transmission medium**
- **Bit length = propagation speed X bit duration**
- **The behavior of signal can be specified mathematically by fourier series.**

Transmission Media

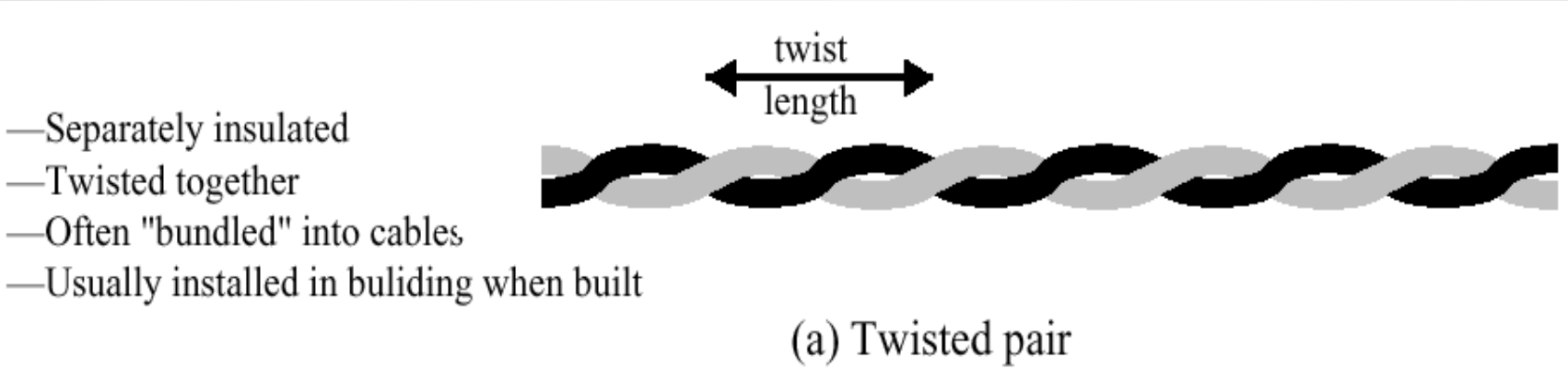
- **Physical layer is to transport raw bit streams.**
- **Bandwidth, delay, cost etc are depends upon on physical media.**
- **Two types of physical media**
  - **Guided Media**
  - **Un-Guided Media**



Twisted pair

- **Magnetic Media (removable Media)**
- **Twisted Pair**
- **Two insulated copper wires, about 1mm thickness.**
- **These wires are twisted like helical form.**
- **Twisting?**
- **Two parallel wires act as a antenna.**
- **Radiates less frequency & reduce electrical interference.**
- **These wires runs several KM with out using amplification. Repeaters are used if more distance.**
- **These wires are used to transmits either analog or digital signals.**

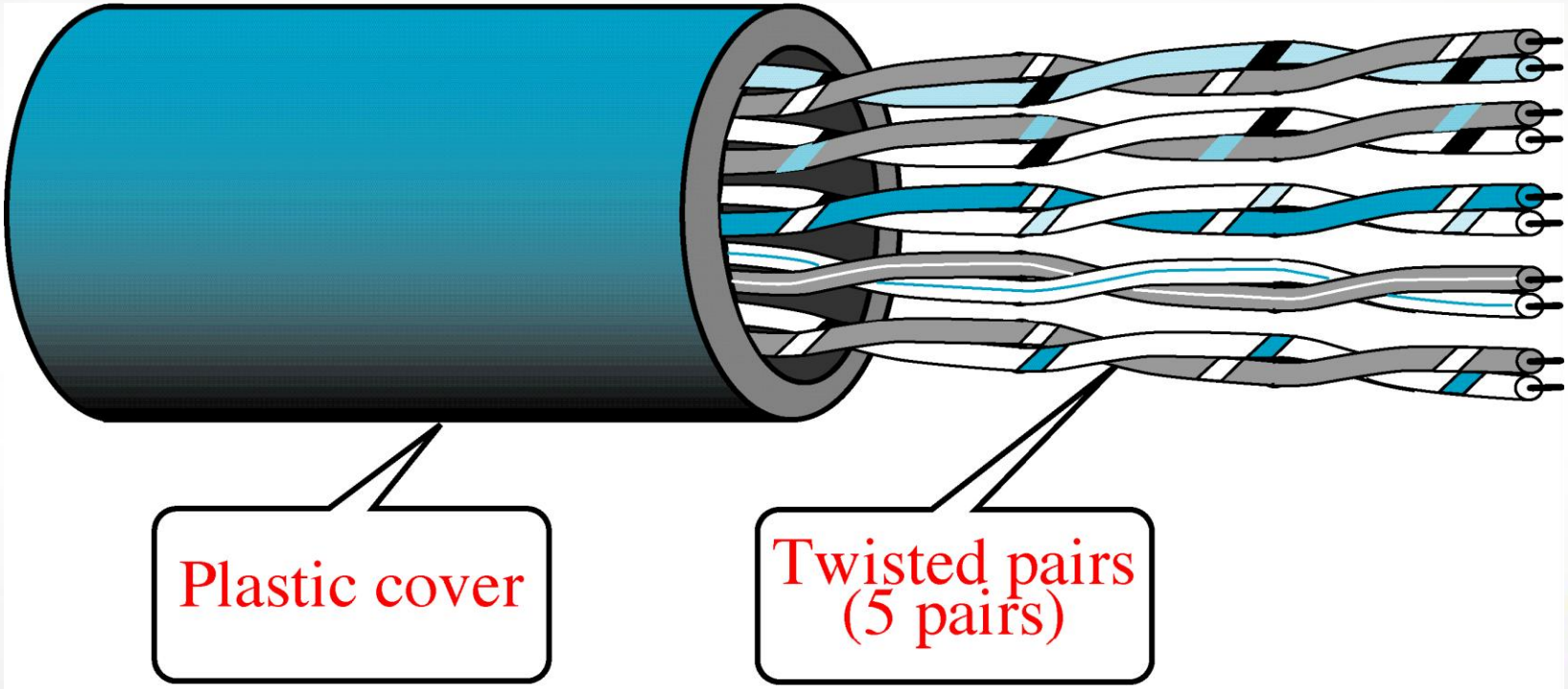
Twisted Pair



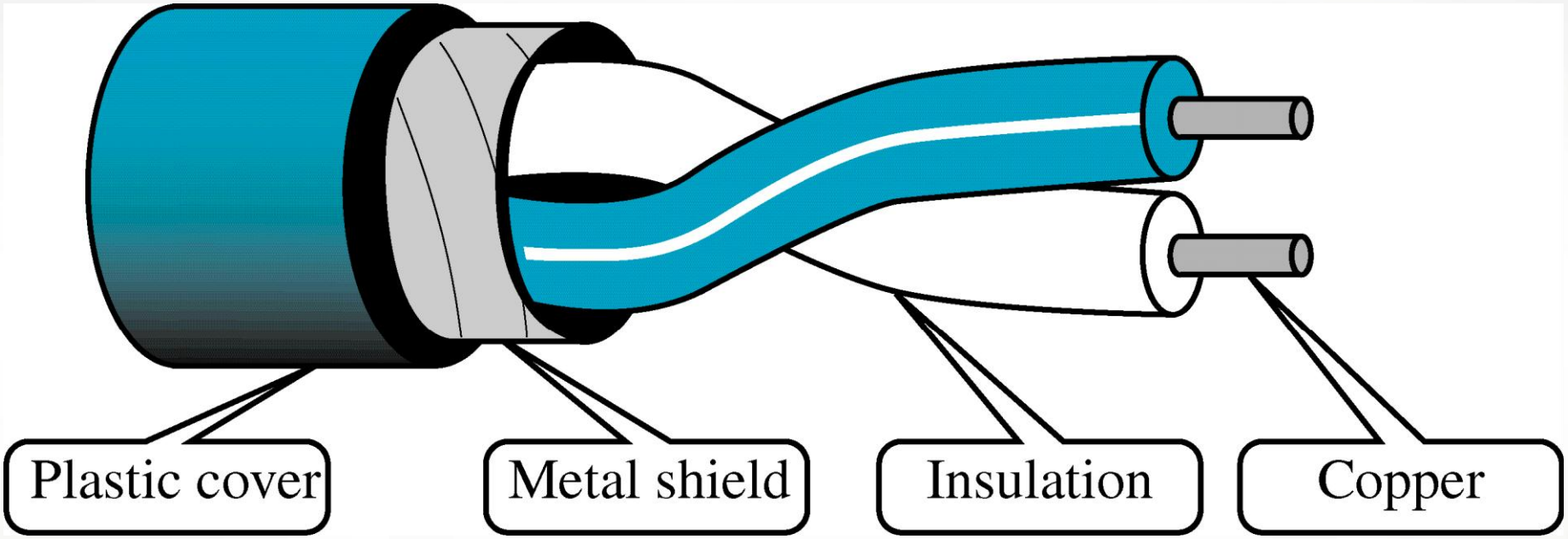
(a) Twisted pair

- **Two Types of Twisted pairs**
- **STP (shielded twisted pair)**
  - **the pair is wrapped with metallic foil or braid to insulate the pair from electromagnetic interference**
- **UTP (unshielded twisted pair)**
  - **each wire is insulated with plastic wrap, but the pair is encased in an outer covering**

Unshielded Twisted Pair



Shielded Twisted Pair

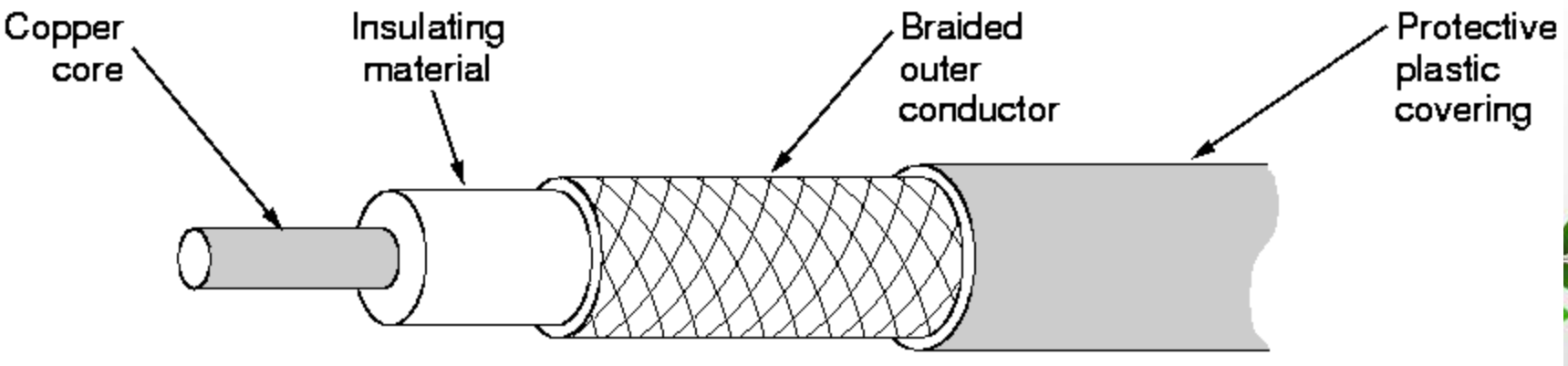


Ratings of Twisted Pair

- Category 3
  - UTP cables and associated connecting hardware whose transmission characteristics are specified up to 16 MHZ.
  - data rates of up to 16mbps are achievable
- Category 4
  - UTP cables and associated connecting hardware whose transmission characteristics are specified up to 20 MHz.
- Category 5
  - UTP cables and associated connecting hardware whose transmission characteristics are specified up to 100 MHz.
  - data rates of up to 100mbps are achievable
  - more tightly twisted than Category 3 cables
  - more expensive, but better performance
- Category 5 enhanced, Cat 6, cat 7
  - Fast and giga-ethernet

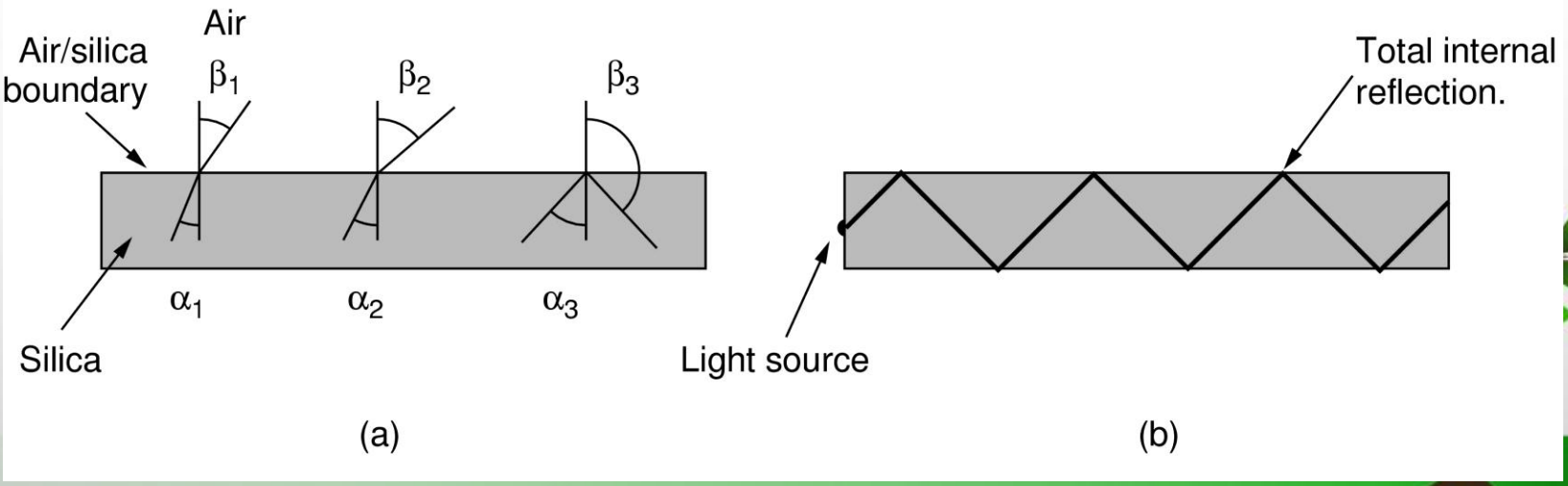
Coaxial Cable

- It is better shielded than twisted pair, so it can span longer distance with higher speed.
- Solid center conductor running coaxially inside a solid (usually braided) outer circular conductor.
- Center conductor is shielded from external interference signals.
- Speed 1 GHz
- 50-ohm cable → digital transmission
- 75-ohm cable → analog transmission



Fiber Optics

- Optical Transmission technology has three components.
  - Light source (the presence of light indicates 1, absence as 0 bit)
  - Transmission Media(ultra thin fiber of glass)
  - Detector (it generates an electrical signal when light fall on it)
- Attach light source on end and detector at other end of fiber.
- The transmission system uses light waves, which is based on physics principle.
- Principle : when a light moves from one medium to another the ray may be refracted at boundary.
- In fiber optics, the sources are air and silica.
-



Fiber Optics

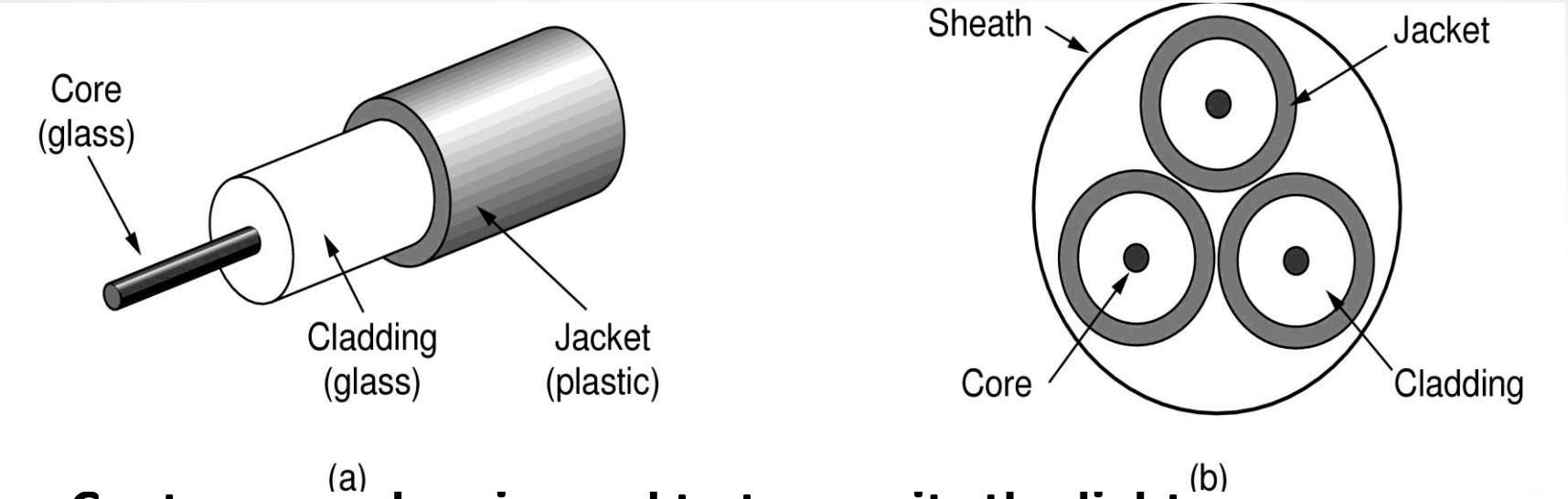
- The amount of refraction depends upon material (refraction index).
- The refraction index of silica is more than air, so the light bounced back to silica. And passes long distances.
- The ray may be in single mode or multimode fiber.
- Multimode Fiber
  - Multiple wavelengths of light
  - Thicker core (50 microns)
  - Cheaper
- Single Mode Fiber
  - Small diameter core
  - Propagates light in a straight line
  - Longer distances
  - More expensive fiber, end equipment

Transmission of light through Fiber

- The Optical fiber is made up of glass, which is made from sand.
- The glass diameter is 1 mm thickness and transparent.
- The attenuation of light through glass depends upon wavelength.
- Light pulses sent down a fiber is called chromatic dispersion.
- Overlapping is reduced only by reducing signaling rate.
- Hyperbolic cosine → reduce overlap

Fiber Cables

- **Similar like coax, except without braid.**



- **Center core glass is used to transmits the light rays.**
- **Glass cladding has less refractive index.**
- **Thin plastic jacket to protect the cladding.**
- **Fiber can be connected 3 different ways.**
  - **Connector and fiber sockets**
  - **Sliced and clamp.**
  - **Sliced and melted.**

Fiber Cables

- **Light sources**
  - **LEDs**
  - **Semiconductor laser**
- **Receiving end**
  - **Photo Diode**

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

Fiber vs. Copper

- Fiber has much higher bandwidth
- Very low signal attenuation relative to copper
  - Repeaters needed after long distance –
    - 50 km for fiber vs. 5 km for copper*
- Light weight
  - One km of 1000 pair copper twisted pair = more than 17,000 lbs.
  - One km of 1 fiber pair = about 220 lbs.
  - 1 fiber pair can carry more data than 1000 copper twisted pair cables

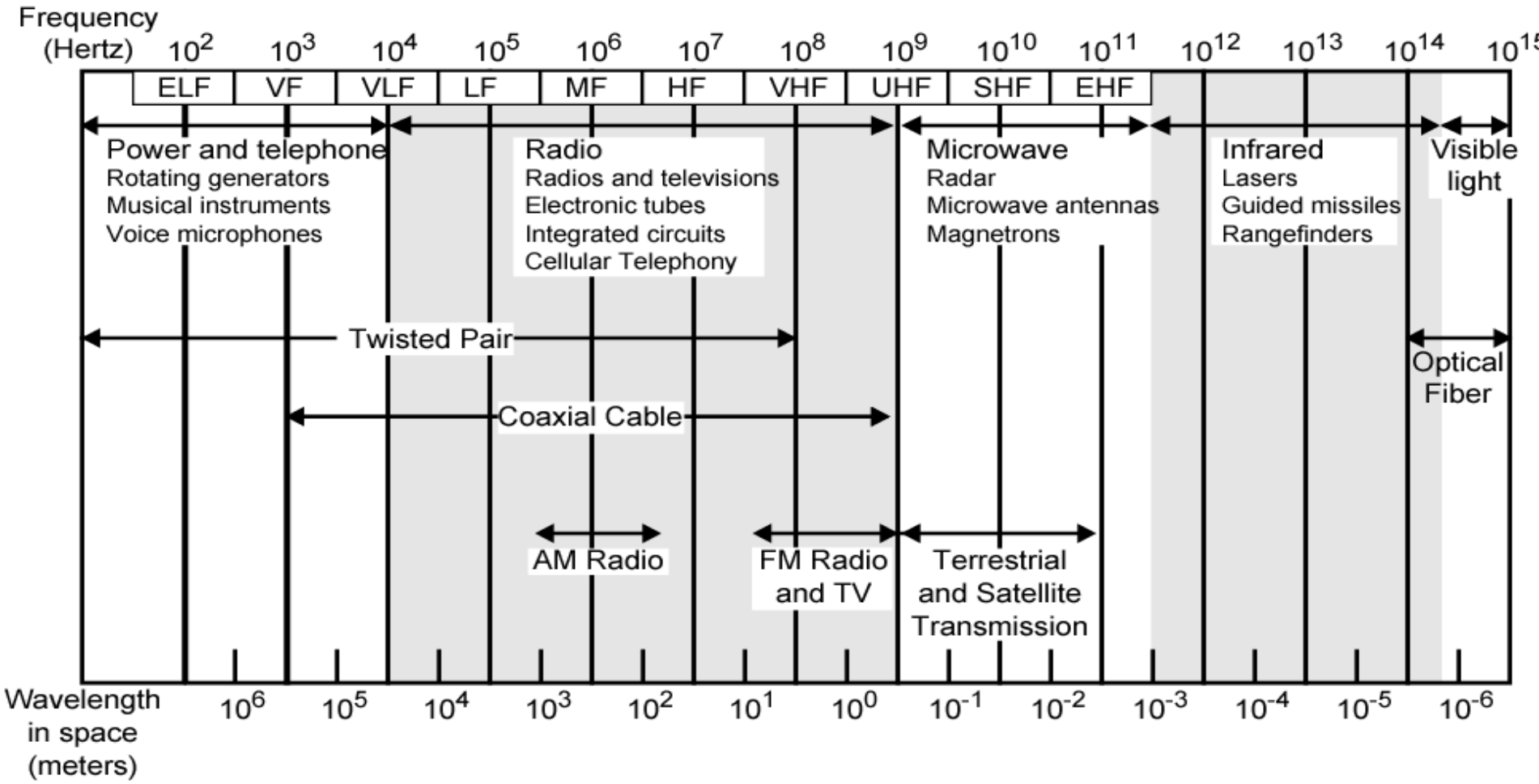
Fiber vs. Copper

- Security
  - Copper leaks
  - Fiber does not leak
- Fiber deployment requires more advanced skill
- Fiber sensitive to damage

Wireless Transmission

- Unguided media
- When Electrons are moving in space, they create electromagnetic waves those can propagate through space.
- When an antenna is attached to electrical circuit, the electromagnetic waves can be broadcast efficiently and received by a receiver some distance away.
- The amount of information that an electromagnetic wave can carry is depends upon it bandwidth.
- Most transmission uses narrow frequency band. Some applications uses wide frequency band with two variations
  - 1. Frequency Hopping Spread Spectrum
  - 2. Direct Sequence Spread Spectrum

Electromagnetic Spectrum



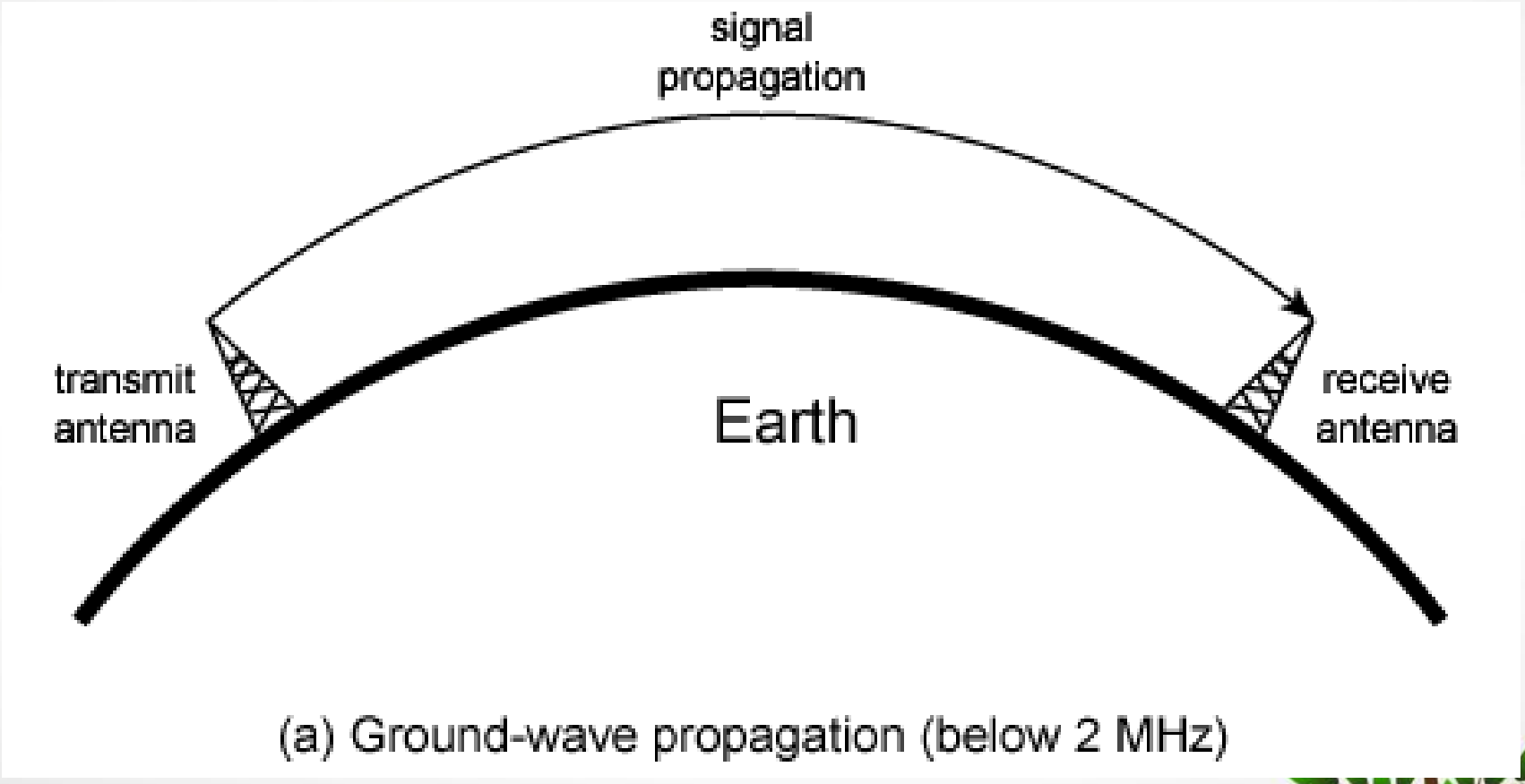
ELF = Extremely low frequency
VF = Voice frequency
VLF = Very low frequency
LF = Low frequency
MF = Medium frequency
HF = High frequency
VHF = Very high frequency
UHF = Ultrahigh frequency
SHF = Superhigh frequency
EHF = Extremely high frequency

Radio Transmission

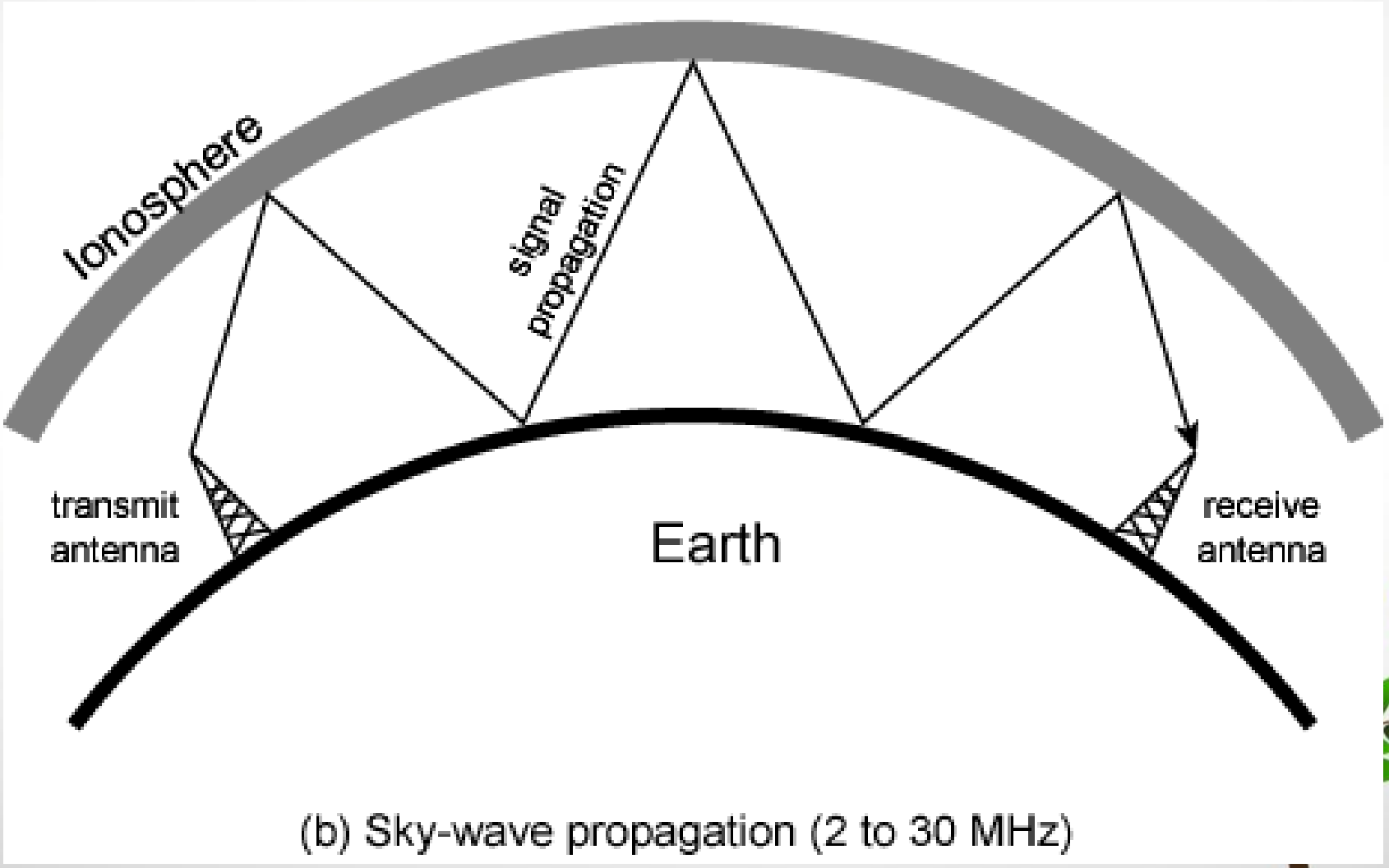
- Radio waves are generated easily, travels long distances, & penetrates buildings easily.
- Radio waves are omnidirectional. → no care @ receiver
- Radio waves pass through obstacles easily at lower frequency. But power falls off sharply.
- Radio waves passes as straight lines and bounce off obstacles at higher frequency. Absorbed by rain.
- Interference from motors and electrical equipment at all frequency. → license
-

Wireless Propagation

- Signal travels along three routes
  - Ground wave
    - Follows contour of earth
    - Up to 2MHz
    - AM radio
  - Sky wave
    - Amateur radio, BBC world service, Voice of America
    - Signal reflected from ionosphere layer of upper atmosphere
    - (Actually refracted)
  - Line of sight
    - Above 30Mhz
    - May be further than optical line of sight due to refraction



(a) Ground-wave propagation (below 2 MHz)



(b) Sky-wave propagation (2 to 30 MHz)

Microwave Transmission

- The waves travel in straight lines, if they are above 100MHz.
- Transmitter and receiver should be aligned accurately.
- Used for point – to – point communications
- It uses parabolic antenna. → directs the waves in narrow beam
- It uses repeaters → distance between repeaters is the sqrt of tower height → longer distances
- Microwaves do not passes through buildings.
- Multipath padding. (weather and frequency dependent)
- Inexpensive
- Advantage over fiber
-

Infrared and Millimeter waves

- Short range communications
- Used in remote controls.
- Relatively directional, cheap and easy to build.
- Do not pass through solid objects.
- → more security
- No government licenses.
-

Light wave Transmission

- **CLASS**

Switching

- **CLASS**