CSE / T / 315A
Data Communications
Topic 1- Introduction

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Syllabus

- **Introduction:** Overview of Data Communications, Networks and Network models (OSI, TCP/IP), Protocols and standards, [1L]
- **Data and signals:** Analog and digital signals, Periodic and nonperiodic signals, Signal analysis, Composite signals, Time and Frequency domains, Bandwidth, Wave symmetry, Linear and non-linear mixing of signals. [2L]
- **Transmission Impairment:** Attenuation, Distortion, Noise - correlated and uncorrelated noises and their categories, Harmonic distortion and intermodulation distortion, Data rate limits for noisy and noiseless channels‡ [2L]
- **Performance:** Bandwidth, Throughput, Latency, Bandwidth-Delay Product, Jitter [1L]

Syllabus

- **Digital Transmission:** Problems with digital transmission, Different line coding schemes, Block coding schemes, Scrambling techniques; Analog to Digital Conversion – Sampling techniques, Sampling theorem, Pulse amplitude modulation, Pulse code modulation, Differential pulse code modulation, Delta modulation (along with advantages and disadvantages of each technique), Transmission modes (serial and parallel). [4L]
- **Analog Transmission:** Concepts of carrier signal, modulating signal and modulated signal; Amplitude modulation – double sideband suppressed carrier, double sideband transmitted carrier, single sideband; Frequency modulation – Narrowband FM and wideband FM; Digital to analog conversion – Amplitude shift keying, Frequency shift keying, Phase shift keying, Quadrature amplitude modulation, Performance. [4L]

Syllabus

- **Transmission Media:** Guided (wired) media – Twisted pair cable, Coaxial cable and Fibre optic cable, Construction, categories and connectors of each type, Performance, Advantages and disadvantages and applications of each type of media, Different propagation modes through fibre optic cable, Unguided (wireless) media – Different propagation modes, Radio waves, Terrestrial microwaves, Infrared, Applications and performances, Satellite communication. [4L]
- **Multiplexing and Spreading:** Concept of multiplexing, Frequency division multiplexing, Time division multiplexing – Synchronous and Statistical time division multiplexing, Handling variable length data, Pulse stuffing, Concept of spreading spectrum, Frequency hopping spread spectrum and Direct sequence spread spectrum. [6L]
- **Modems and Interfaces:** Dial-up modems, modem speed, standards; other modems; Interface standards. [4L]
- **Error Detection and Correction:** Types of errors, Basic concepts of error detection and correction, Redundancy, Hamming distance, Error detection – Simple parity check codes, Two-dimensional parity check, Cyclic redundancy check, Polynomials and cyclic code analysis, Checksum, Error correction – Hamming code. [6L]

Syllabus

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- **Protocols for Data Communication:** Flow control and Error control, Stop and Wait protocol and its efficiency, Sliding window protocols - Go-back-N and Selective repeat, Piggybacking, HDLC, Point-to-point protocol. [6L]

Suggested Readings

1. Data & Computer Communications, William Stallings, Pearson Education
2. Data Communications and Networking, Behrouz A Forouzan, McGraw Hill
3. Electronic Communications Systems, Tomasi, Pearson Education
4. Digital Communications, Haykin, Wiley

Slides are mainly prepared using online documents available of the above books and course materials of different institutes

Course Objectives (COs)

- Understand the fundamentals of network design, characteristics of analog and digital signals, relationship between data and signals, network topologies and devices and the concept of data communication within the network environment.

- Explain how impairments (noise, attenuation and distortion) affect signal traveling through a transmission medium (noiseless and noisy channel).

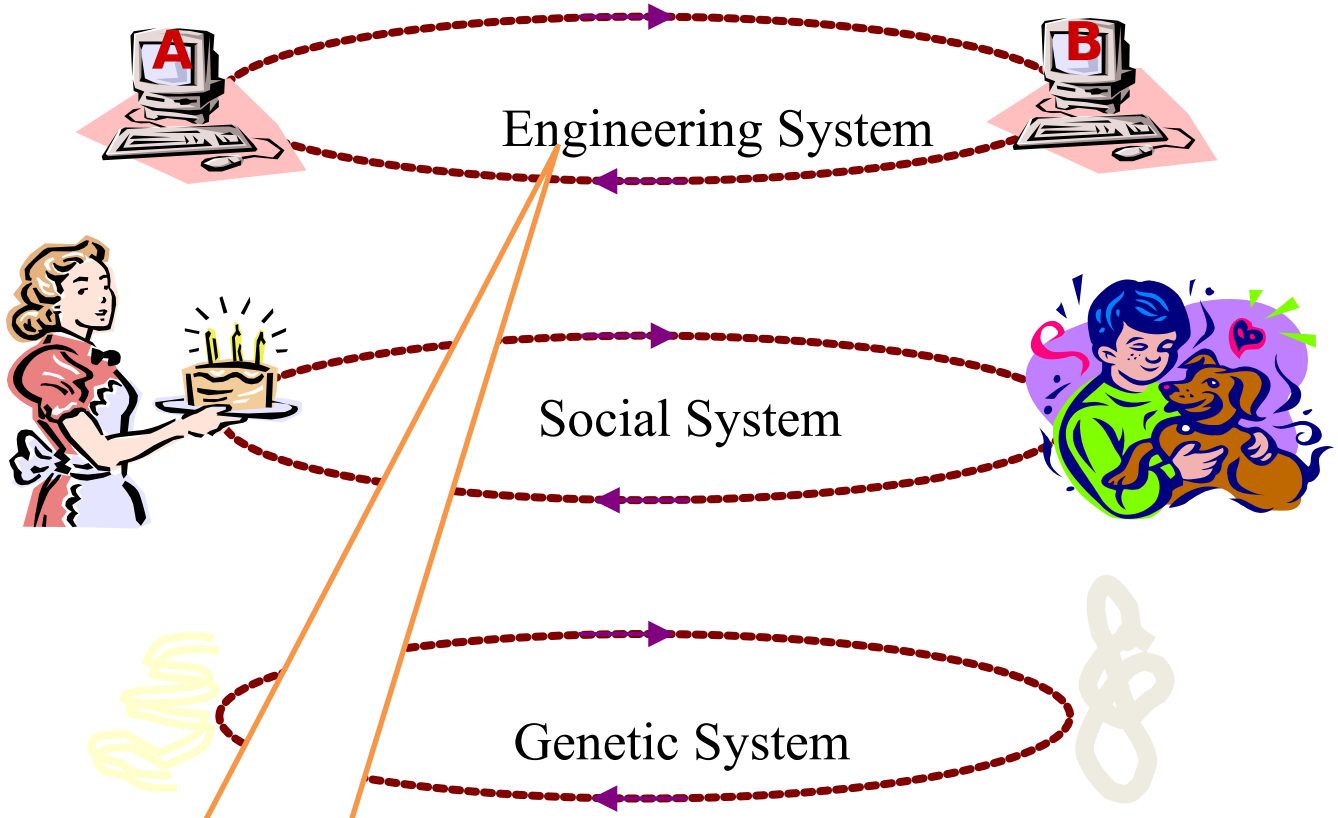
- Understand and describe the concepts of digital transmission of analog and digital data, encoding techniques, conversion techniques used to convert digital data and analog signals to digital signals for parallel and serial transmission.

- Understand and describe the concepts of analog transmission of digital and analog data, methods, and the procedures involved in converting digital data and analog low-pass to band-pass analog signals.

- Understand and illustratively explain errors in communication, error detection and correction mechanisms.

- Explain the concepts of logical link control with reference to framing, flow and error control.

Communication Systems

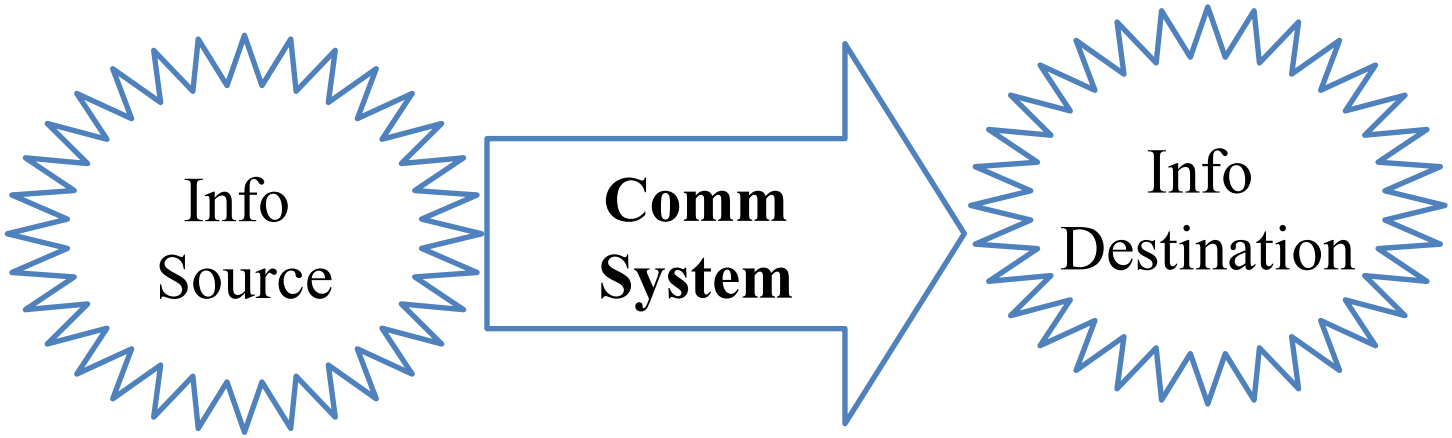


We are interested to study this system.

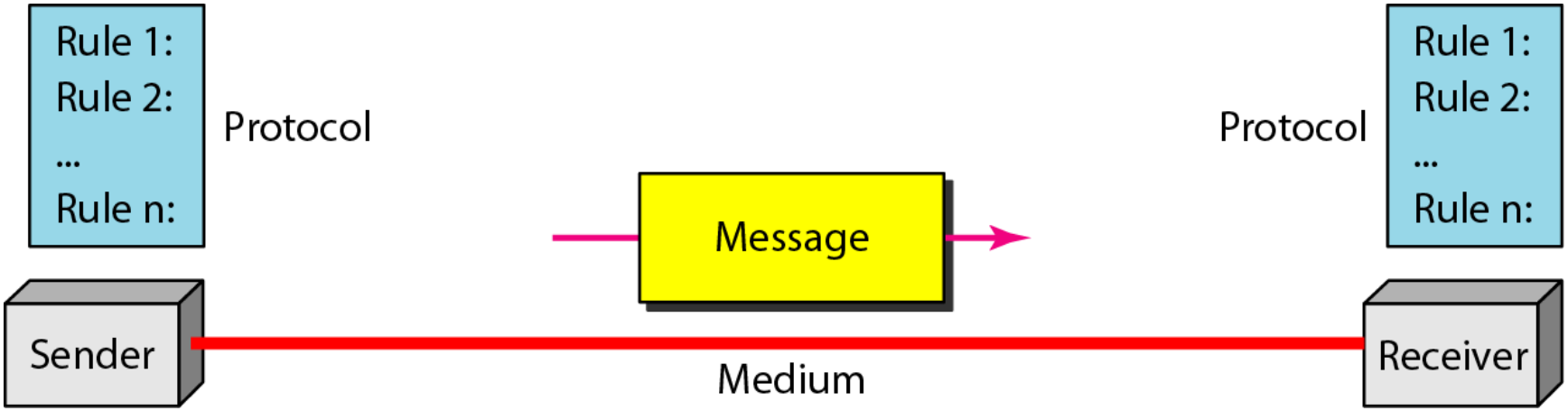
Data communications

- Telecommunication means communication at a distance.
- The word data refers to information presented in whatever form is agreed upon by the parties creating and using the data.
- Data communications are the exchange of data between two devices via some form of transmission medium such as a wire (cable) or wireless (any medium e.g., air, water).

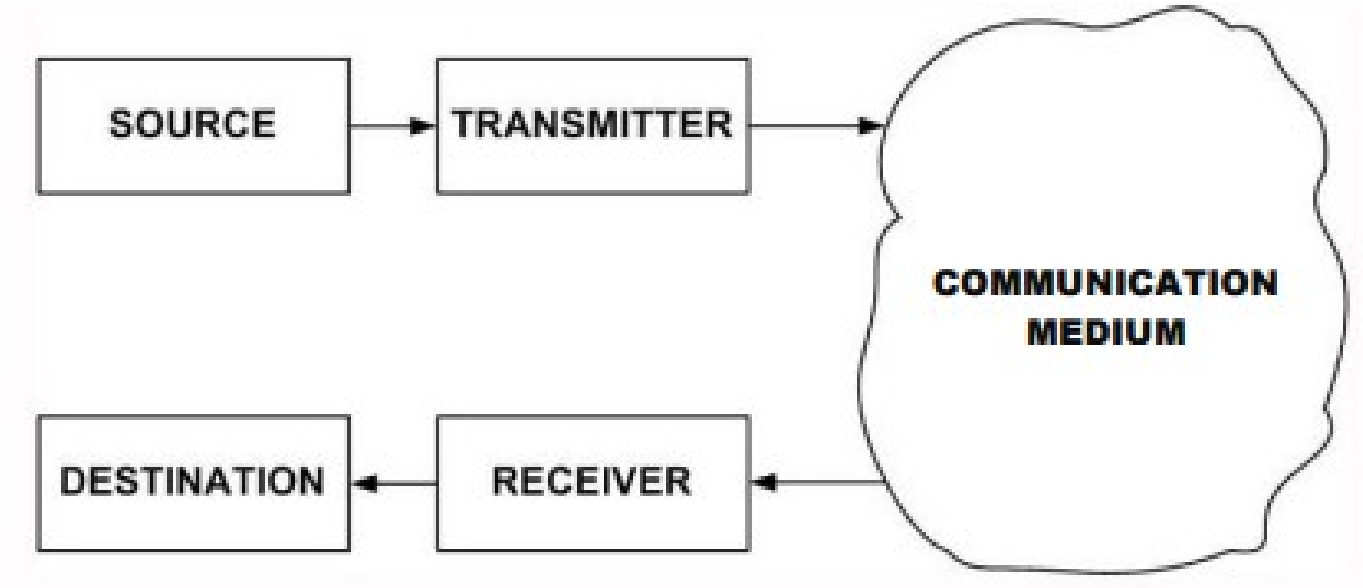
- Communications Systems: Systems designed to transmit and receive *information*



Data communication system



Simplified model of data communication system



Five basic components

- **Source:** Source is where the data is originated. Typically it is a computer, but it can be any other electronic equipment such as telephone handset, video camera, etc, which can generate data for transmission to some destination. The data to be sent is represented by **d(t)**.

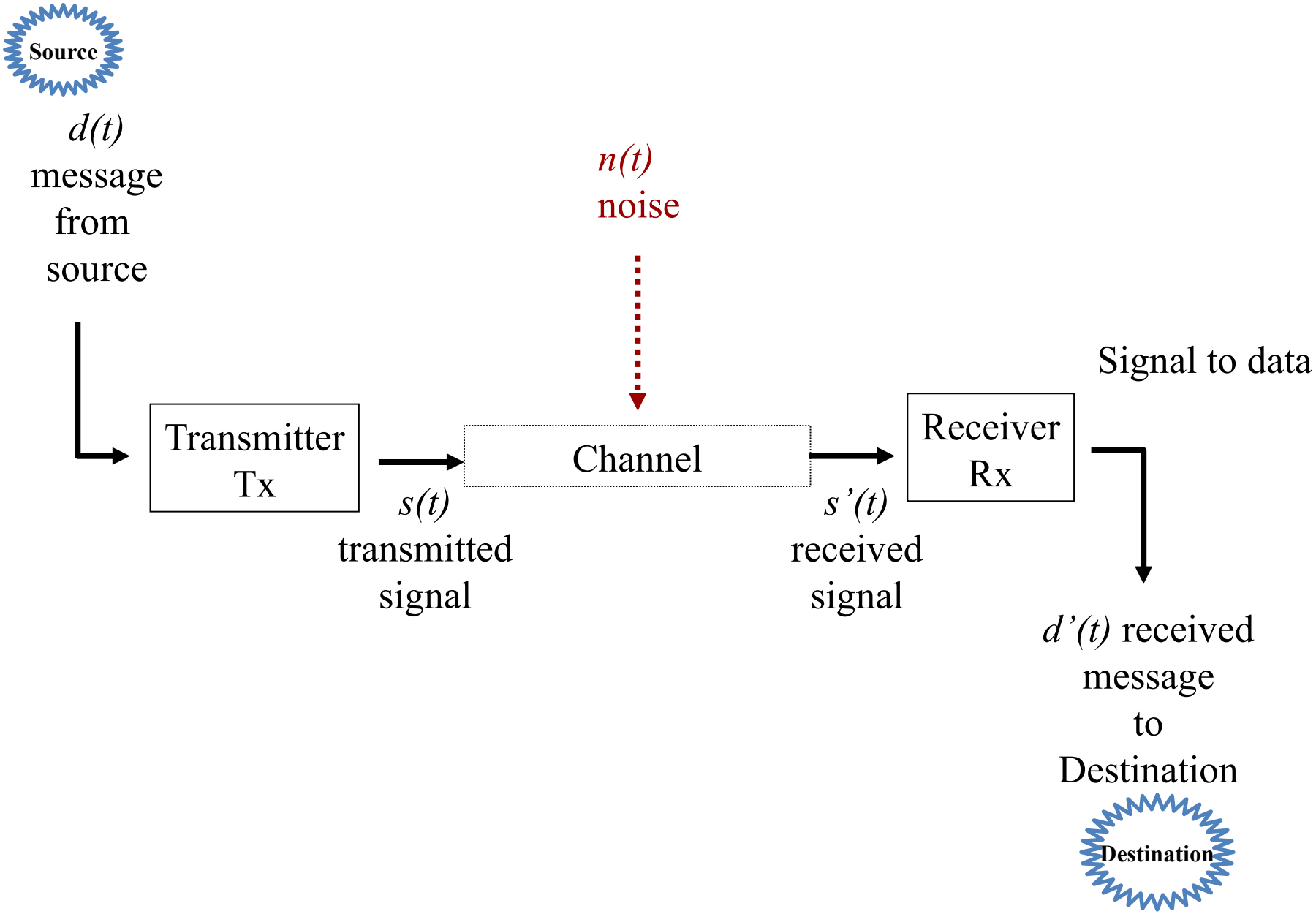
- **Transmitter:** As data cannot be sent in its native form, it is necessary to convert it into signal. This is performed with the help of a transmitter such as modem. The signal that is sent by the transmitter is represented by **s(t)**.

- **Communication Medium:** The signal can be sent to the receiver through a communication medium, which could be a simple twisted-pair of wire, a coaxial cable, optical fiber or wireless communication system. It may be noted that the signal that comes out of the communication medium is **s'(t)**, which is different from **s(t)** that was sent by the transmitter. This is due to various impairments that the signal suffers as it passes through the communication medium.

- **Receiver:** The receiver receives the signal **s’(t)** and converts it back to data **d’(t)** before forwarding to the destination. The data that the destination receives may not be identical to that of **d(t)**, because of the corruption of data.

- **Destination:** Destination is where the data is absorbed. Again, it can be a computer system, a telephone handset, a television set and so on.

Block Diagram



What is Data?

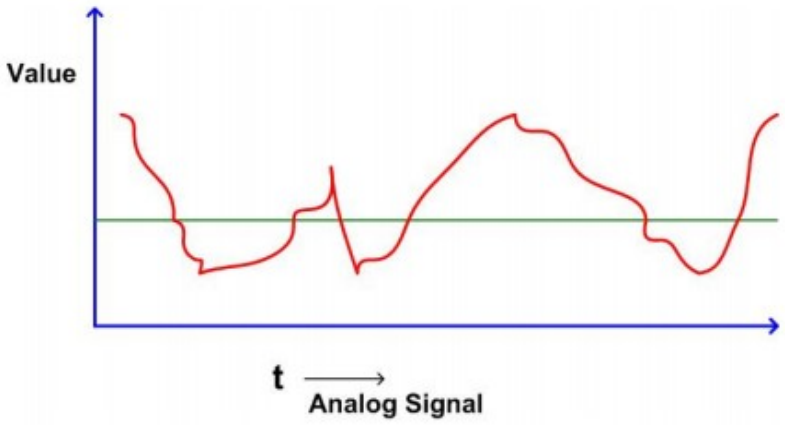
- Data refers to information that conveys some meaning based on some mutually agreed up rules or conventions between a sender and a receiver.
- And today it comes in a variety of forms such as *text*, *graphics*, *audio*, *video* and *animation*.
- Data can be of two types: *analog* and *digital*.

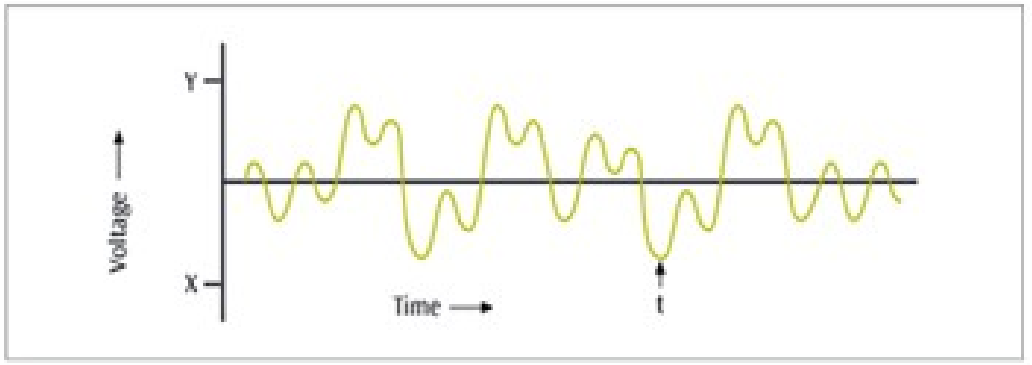
Signal

- Stated in mathematical terms, a signal is merely a function of the data.
  - For example, a microphone converts voice data into voice signal, which can be sent over a pair of wire.
- Analog signals are continuous-valued; digital signals are discrete-valued.
  - The independent variable of the signal could be time (speech, for example), space (images), or the integers (denoting the sequencing of letters and numbers in the football score).

Analog Data/Signal

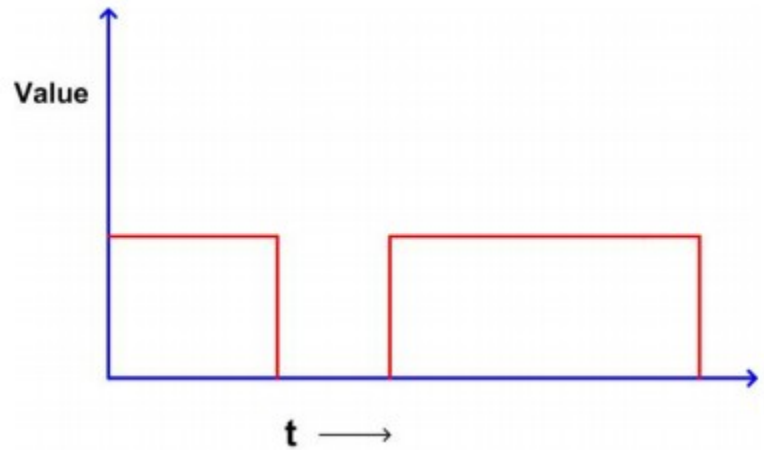
- Analog data take on continuous values on some interval. Typical examples of analog data are *voice* and *video*. The data that are collected from the real world with the help of transducers are continuous-valued or analog in nature.

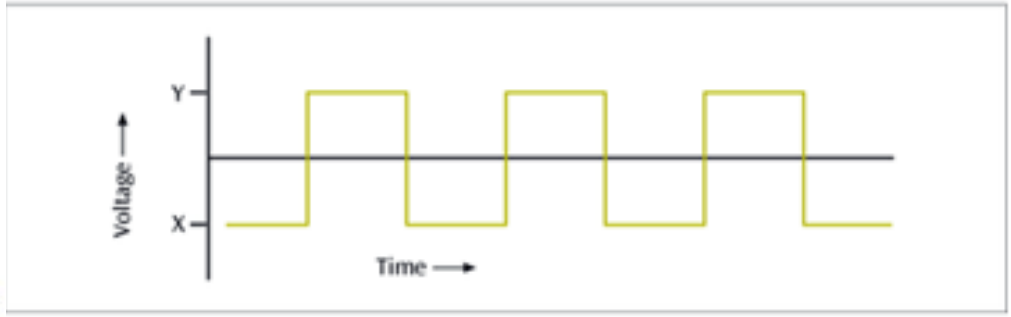




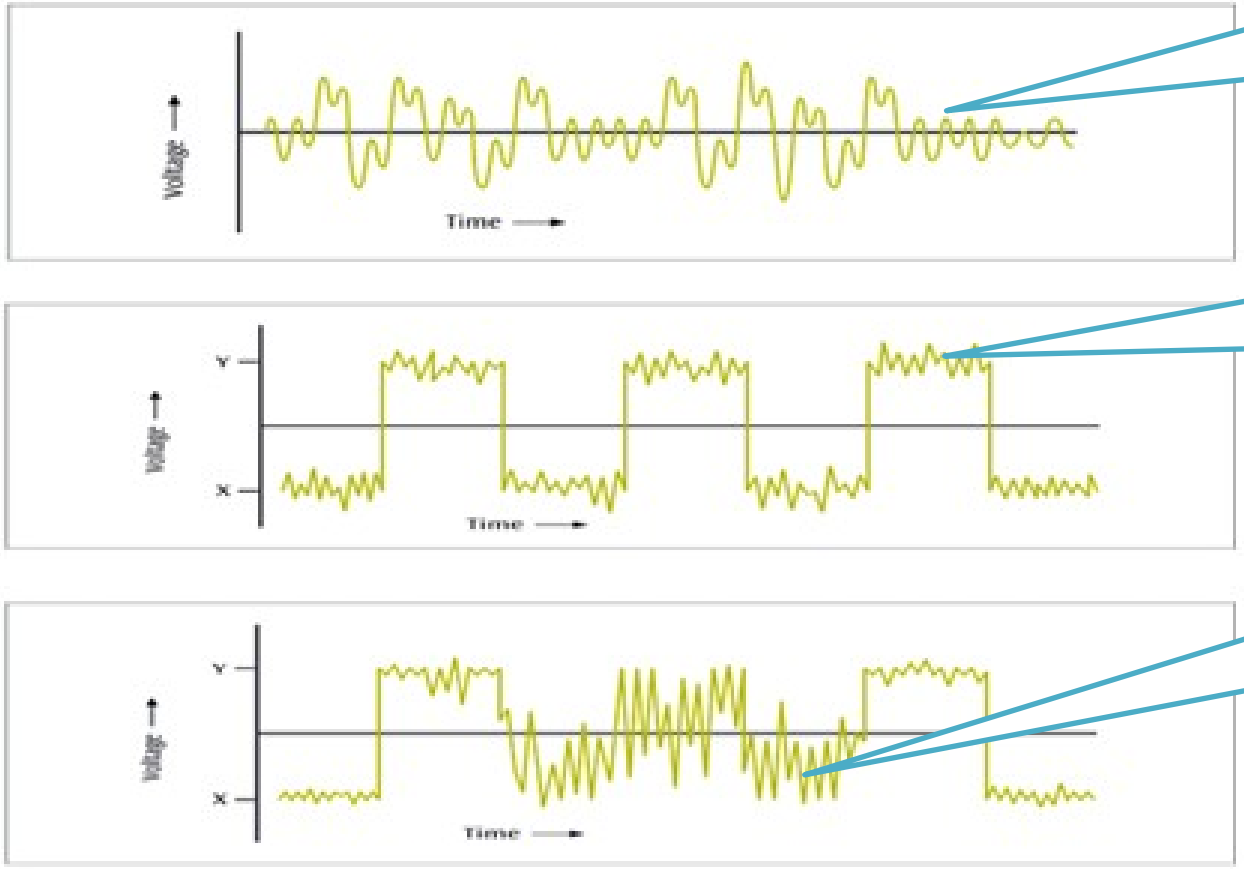
Digital Data/Signal

- Digital data take on discrete values. Text or character strings can be considered as examples of digital data. Characters are represented by suitable codes, e.g. ASCII code.





Noise (also a signal)



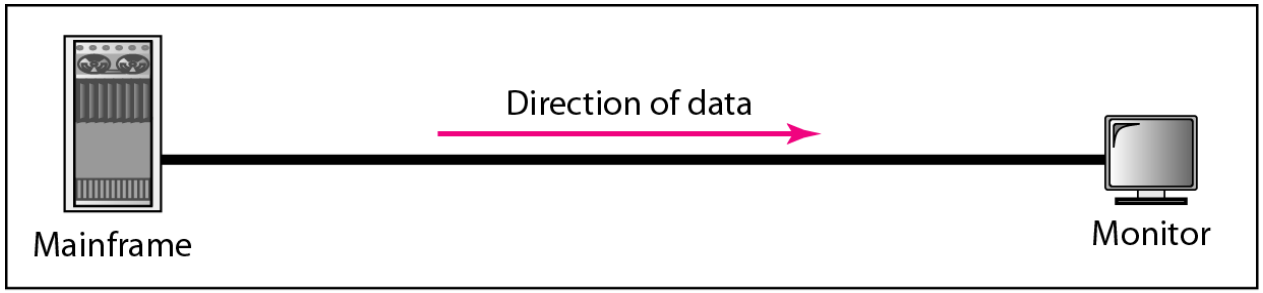
Analog signal with noise

Digital signal with some noise

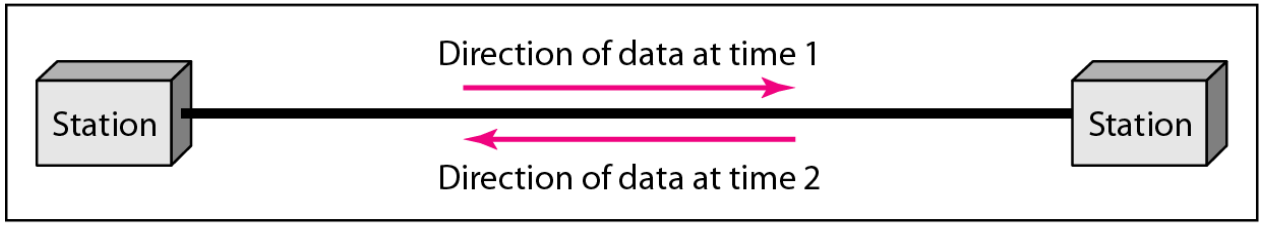
Too much of noise ..cannot recognize the actual signal

- **Signaling:** It is an act of sending signal over communication medium
- **Transmission:** Communication of data by propagation and processing is known as transmission.

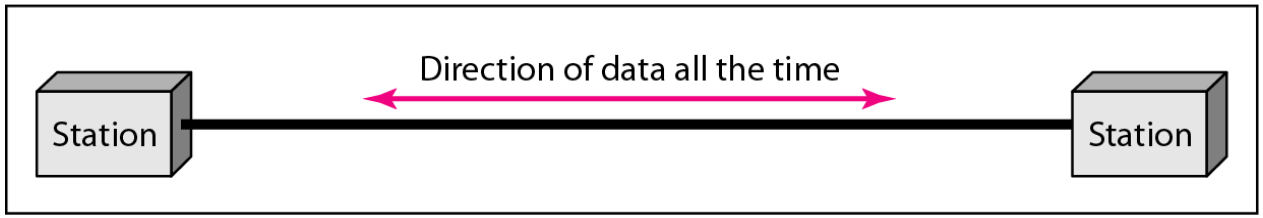
Data flow (simplex, half-duplex, and full-duplex)



a. Simplex



b. Half-duplex



c. Full-duplex

Transmission Media

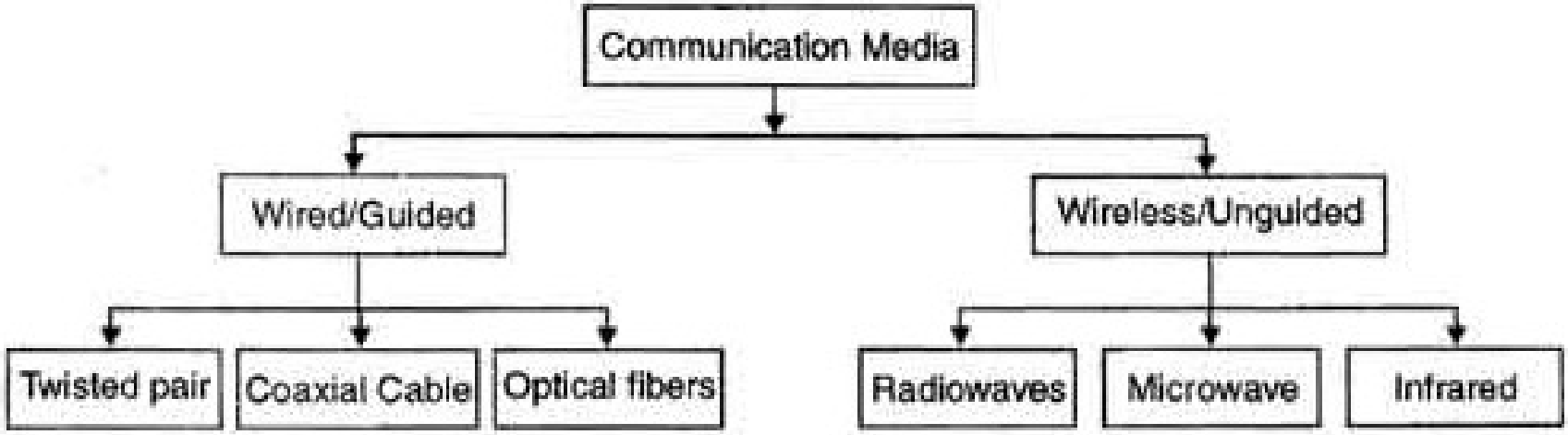
- Transmission media is a pathway that carries the information from sender to receiver.
  - Different types of cables or waves are used to transmit data.
  - Data is transmitted normally through electrical or electromagnetic signals.
    - An electrical signal is in the form of current.
    - An electromagnetic signal is series of electromagnetic energy pulses at various frequencies.
  - These signals can be transmitted through copper wires, optical fibers, atmosphere, water and vacuum.
- Different Medias have different properties like bandwidth, delay, cost and ease of installation and maintenance.
- Transmission media is also called **Communication channel**.

Different deciding factors

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

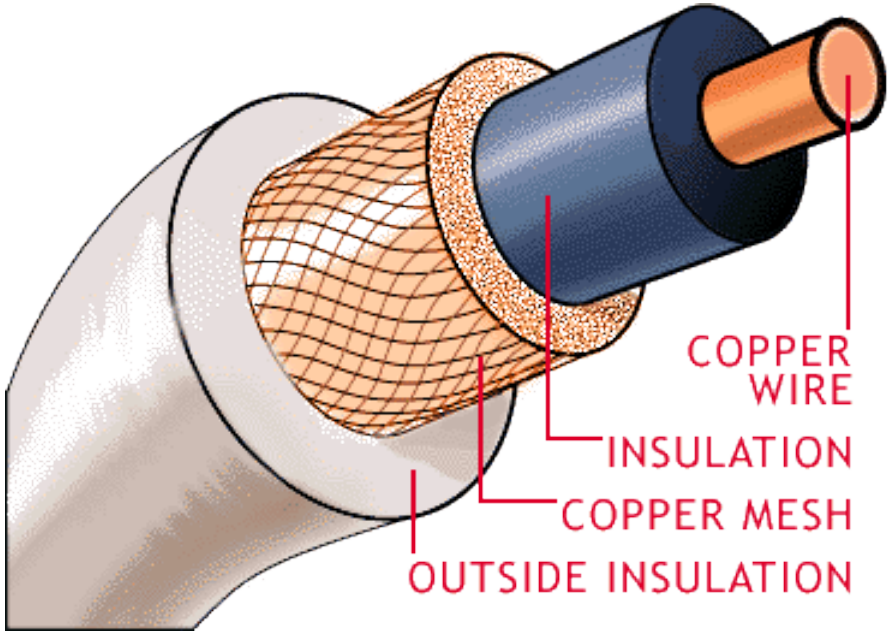
Broad Categories

- Transmission media is broadly classified into two groups.
  - Wired or Guided Media or Bound Transmission Media
  - Wireless or Unguided Media or Unbound Transmission Media



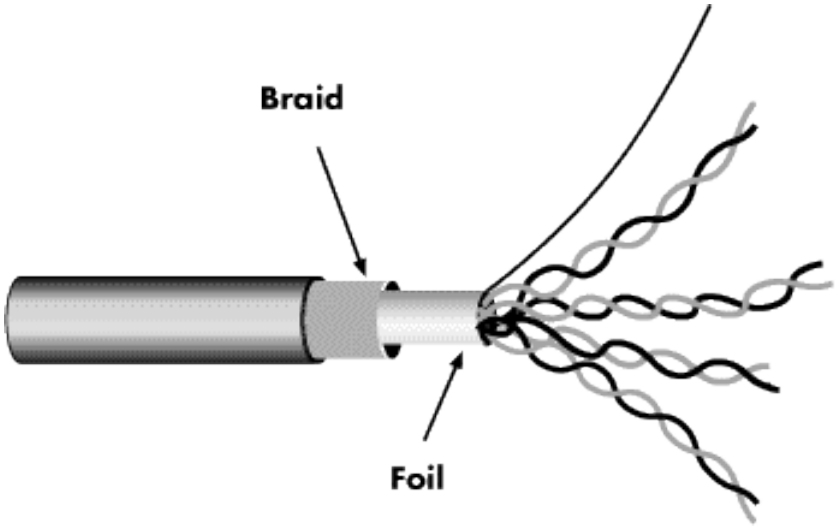
Coaxial Cable

- First type of networking media used
- Available in different types (RG-6 – Cable TV, RG58/U – Thin Ethernet, RG8 – Thick Ethernet
- Largely replaced by twisted pair for networks

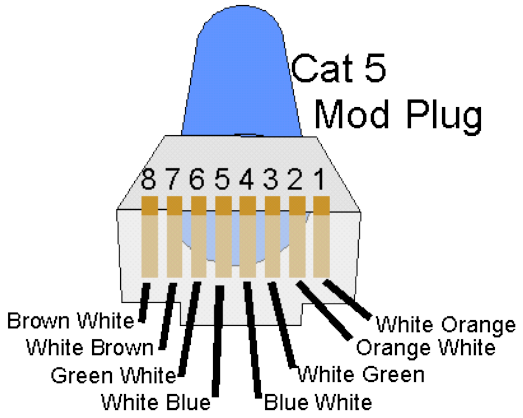


Unshielded Twisted Pair

- Advantages
  - Inexpensive
  - Easy to terminate
  - Widely used, tested
  - Supports many network types

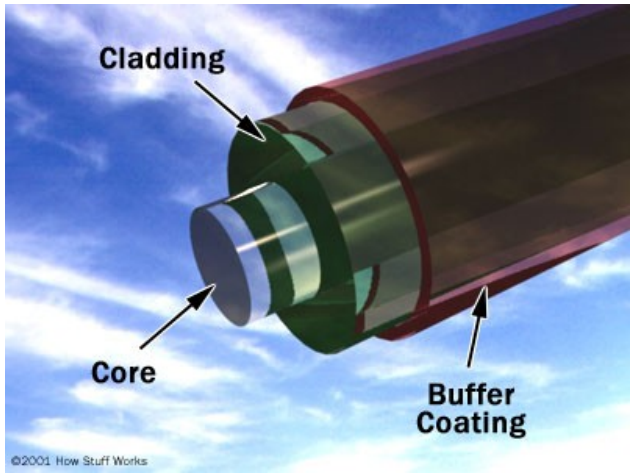


- Disadvantages
  - Susceptible to interference
  - Prone to damage during installation
  - Distance limitations not understood or followed



Glass Media

- Core of silica, extruded glass or plastic
- Single-mode is 0.06 of a micron in diameter
- Multimode = 0.5 microns
- Cladding can be Kevlar, fibreglass or even steel
- Outer coating made from fire-proof plastic

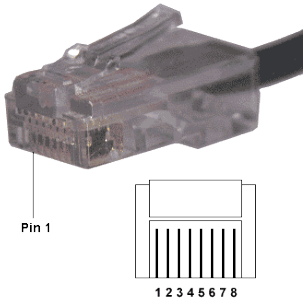


- Advantages
  - Can be installed over long distances
  - Provides large amounts of bandwidth
  - Can not be easily tapped (secure)

- Disadvantages
  - Most expensive media to purchase and install
  - Rigorous guidelines for installation

Connectors

Fibre Optic



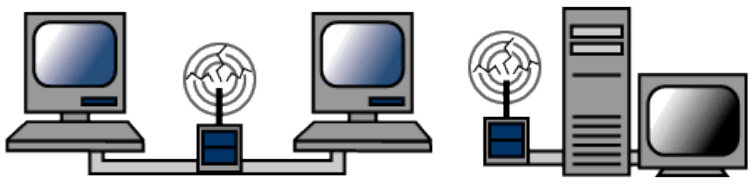
RJ45

Token Ring

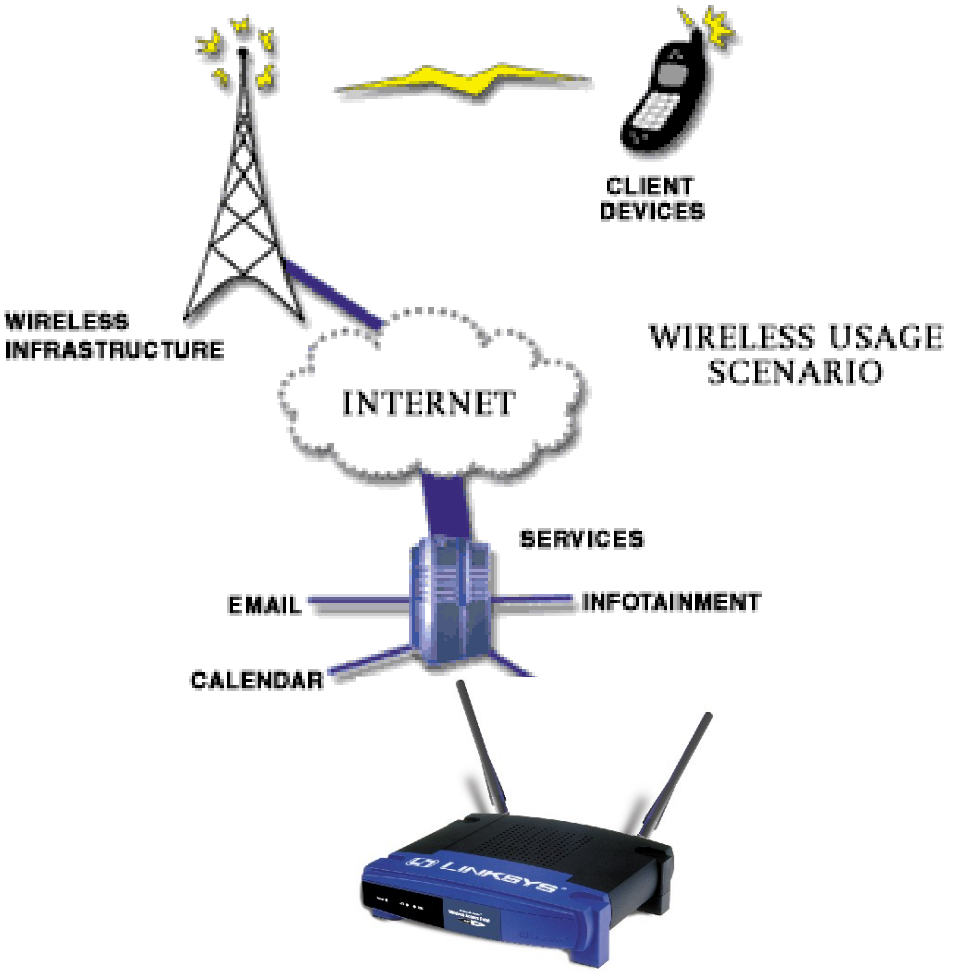
Thicknet

T-Piece

Wireless




Instant Wireless
Network PC Card
LINKSYS

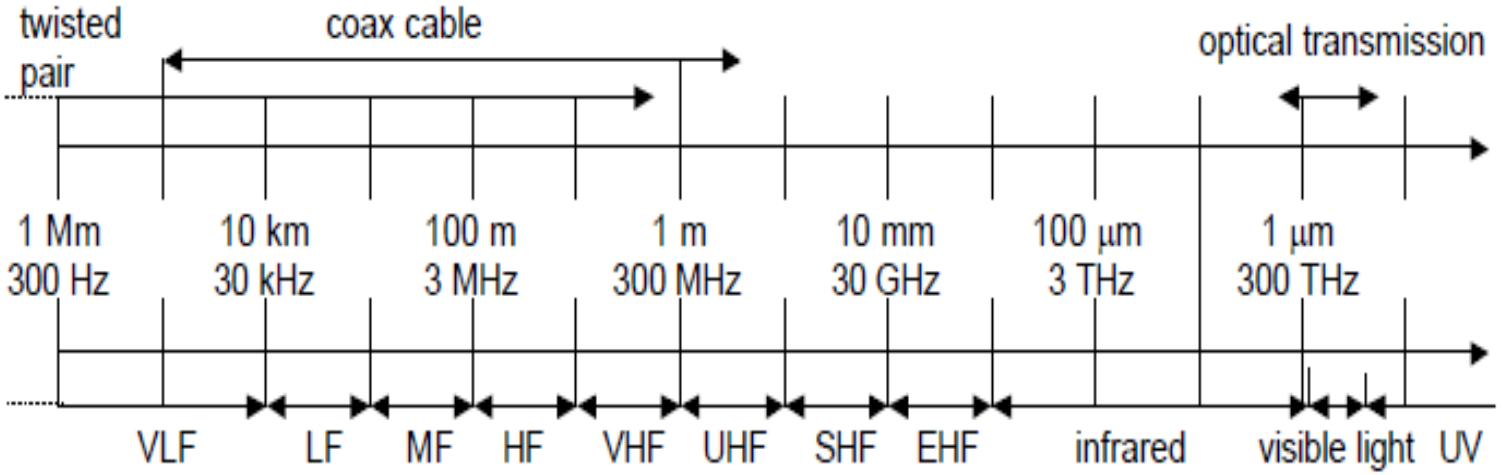

CLIENT DEVICES
WIRELESS INFRASTRUCTURE
WIRELESS USAGE SCENARIO
INTERNET
SERVICES
EMAIL
INFOTAINMENT
CALENDAR
LINKSYS

What is Wireless Communication ?

- Transmitting voice and data using electromagnetic waves in open space (atmosphere)
- Electromagnetic waves
  - Travel at speed of light ($c = 3x10^8$ m/s)
  - Has a frequency (f) and wavelength (λ)

    $c = f \times \lambda$
  - Higher frequency means higher energy photons
  - The higher the energy photon the more penetrating is the radiation

Electromagnetic wave



VLF = Very Low Frequency

LF = Low Frequency

MF = Medium Frequency

HF = High Frequency

VHF = Very High Frequency

UHF = Ultra High Frequency

SHF = Super High Frequency

EHF = Extra High Frequency

UV = Ultraviolet Light

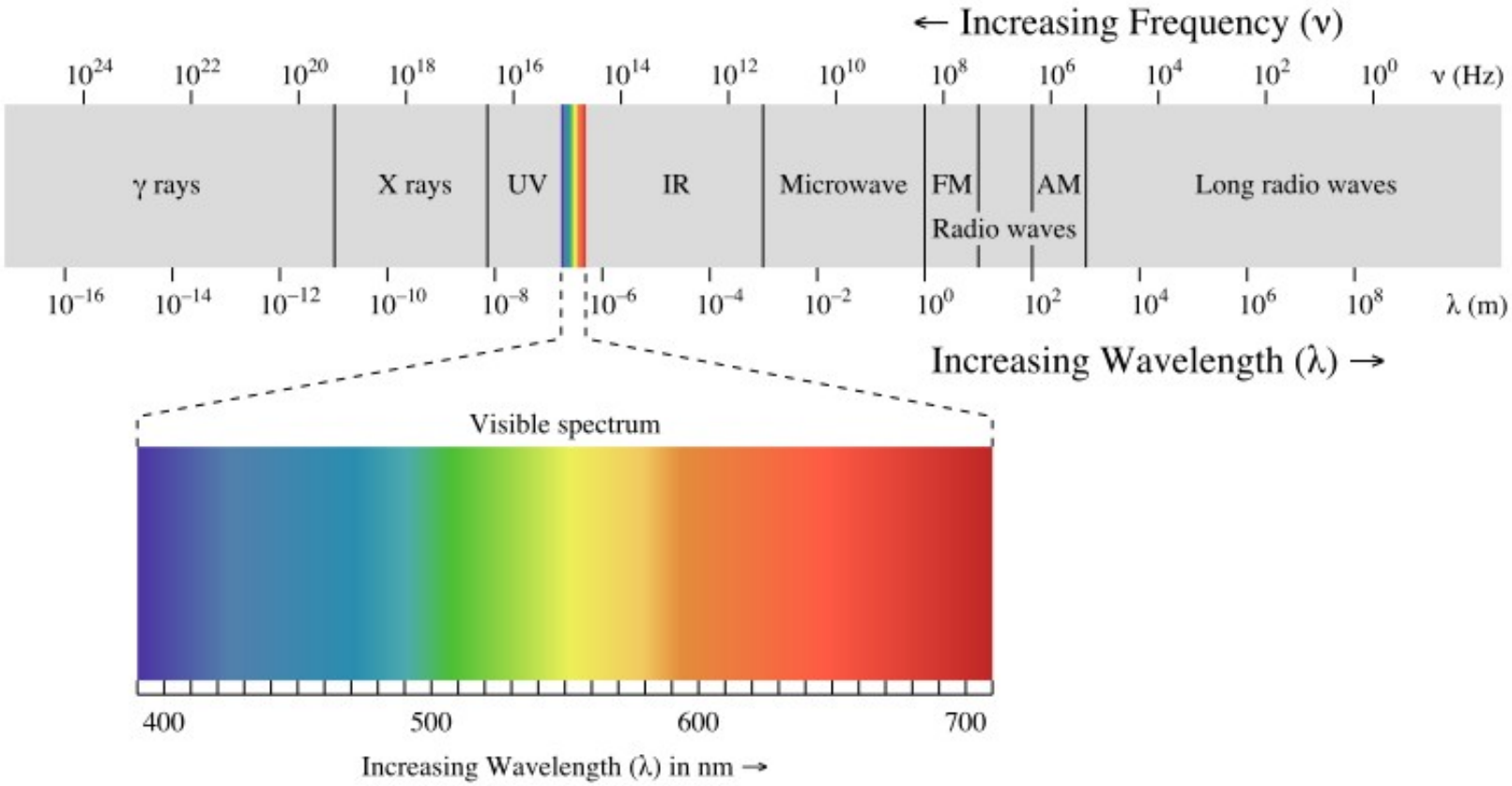
Electromagnetic wave

- The amount of information carried by an electromagnetic wave depends on
  - Width of the wavelength band
  - Encoding technique
    - No of bits encoded per Hz
- X-rays and Gamma rays are better for communication theoretically
  - Difficult to modulate, generate and are harmful

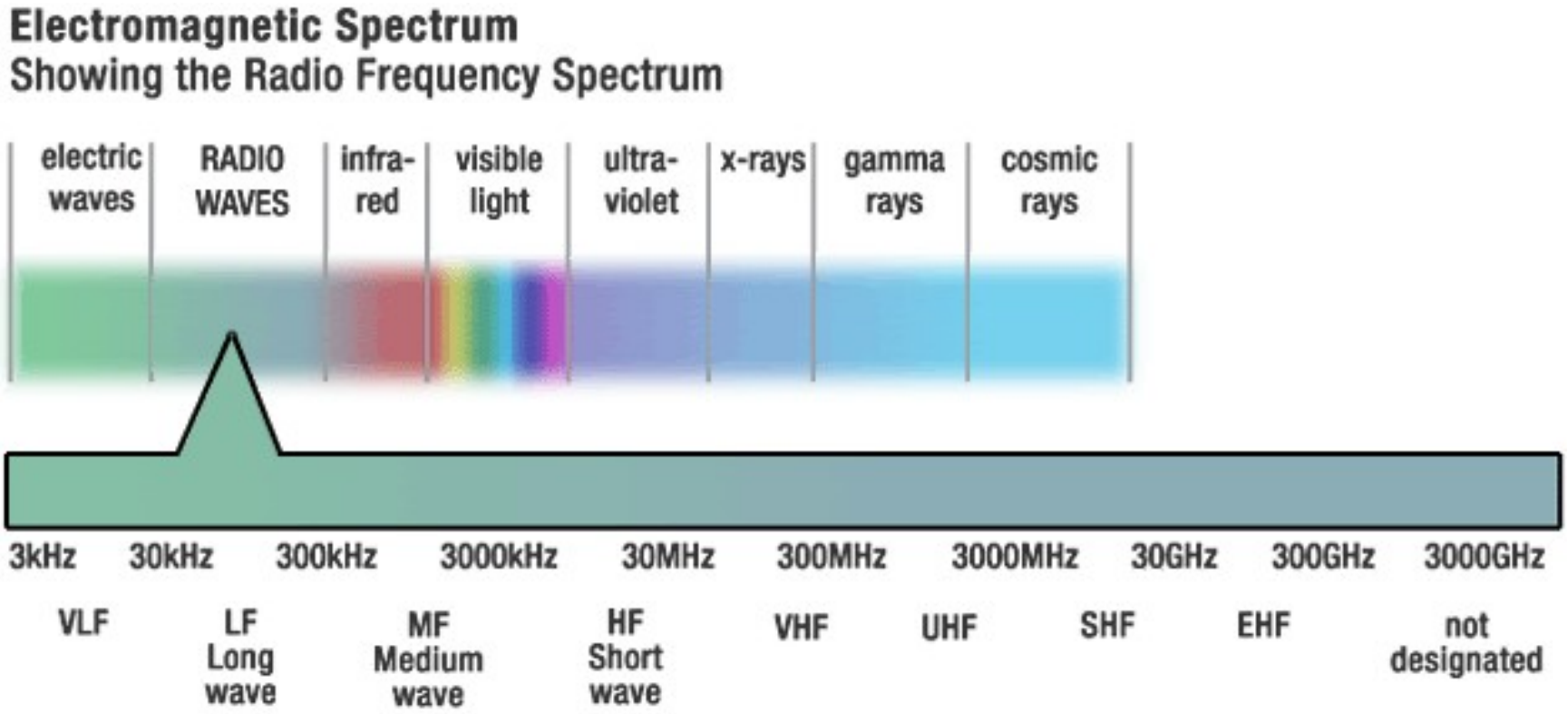
What is RF?

- Radio frequency is an electromagnetic signal with a frequency between 3kHz and 300 GHz
- RF signals carry analog or digital information
  - Analog: Information content varies continuously over time
    - Example: radio and TV station
  - Digital: Information content consists of discrete units (0s and 1s)
    - Example: Cell phones and wireless networks

Electromagnetic radiation spectrum



Wireless



VLF: Very Low Frequency, LF: Low Frequency, MF: Medium Frequency,
HF: High Frequency, VHF: Very High Frequency, UHF: Ultra High Frequency,
SHF: Super High Frequency, EHF: Extremely High Frequency

Wired vs Wireless

Wired

- Each cable is a different channel
- Signal attenuation is low
- No interference
- Immensely high speeds (depending on cable and hardware)

Wireless

- One media shared by all
- High Signal attenuation
- High interference
  - Noise
  - Co-channel interference
  - Adjacent channel interference
- Speed not as fast as wired

communication systems

NETWORKS

Networks

- Network is a set of devices (often referred to as nodes) connected by communication links.
- A node can be a computer, printer, or any other device capable of sending and/or receiving data generated by other nodes on the network. A link can be a cable, air, optical fiber, or any *medium* which can transport a signal carrying information.

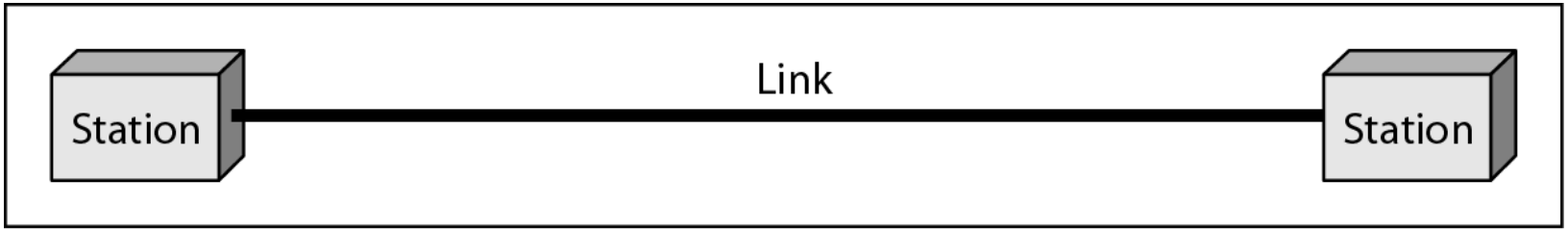
Network Criteria

- Performance
  - Depends on Network Elements
  - Measured in terms of Delay and Throughput
- Reliability
  - Failure rate of network components
  - Measured in terms of availability/robustness
- Security
  - Data protection against corruption/loss of data due to:
    - Errors
    - Malicious users

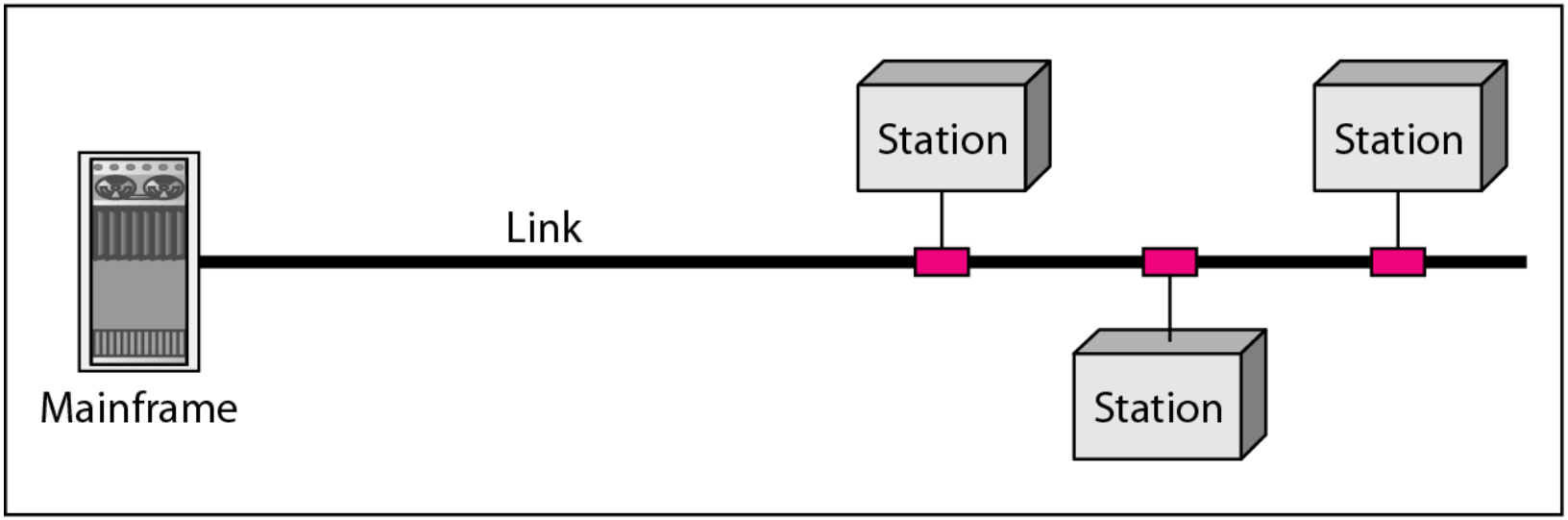
Physical Structures

- Type of Connection
  - Point to Point - single transmitter and receiver
  - Multipoint - multiple recipients of single transmission
- Physical Topology
  - Connection of devices
  - Type of transmission - unicast, mulitcast, broadcast

Types of Connections

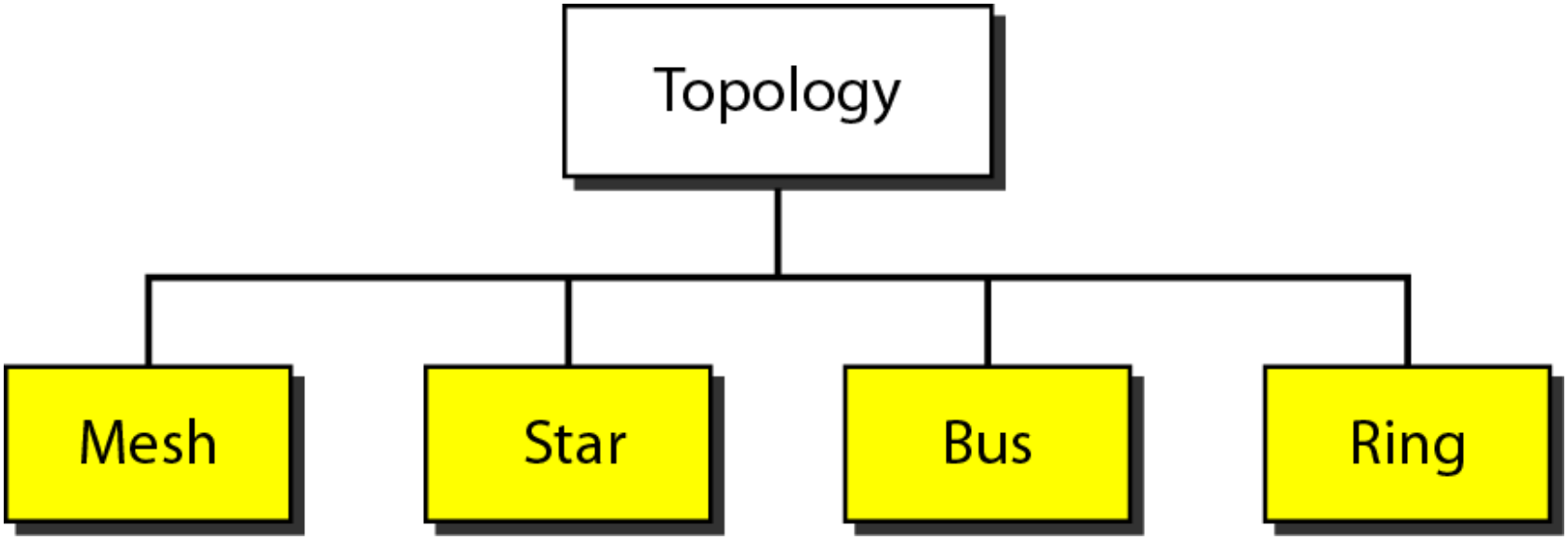


a. Point-to-point

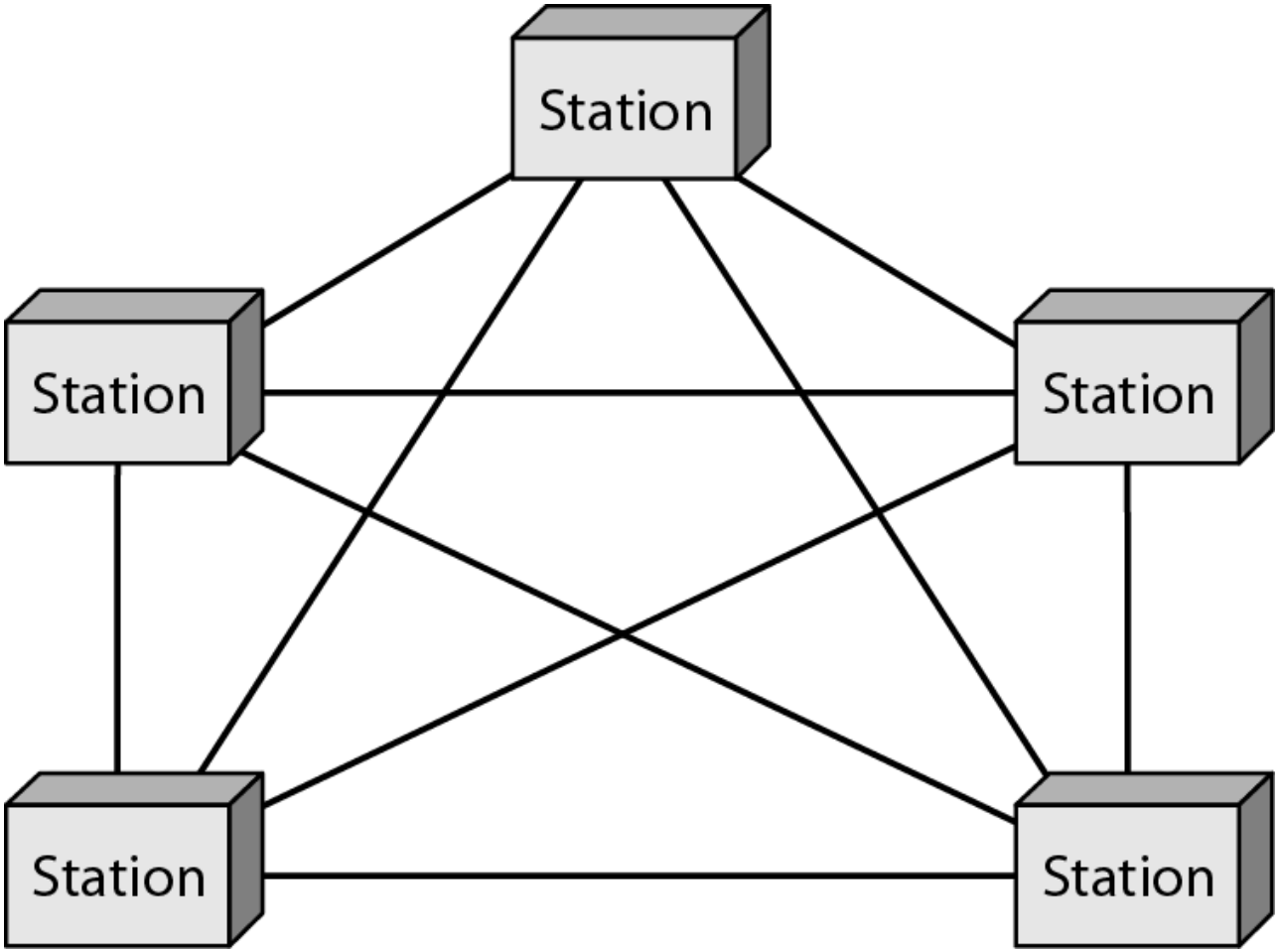


b. Multipoint

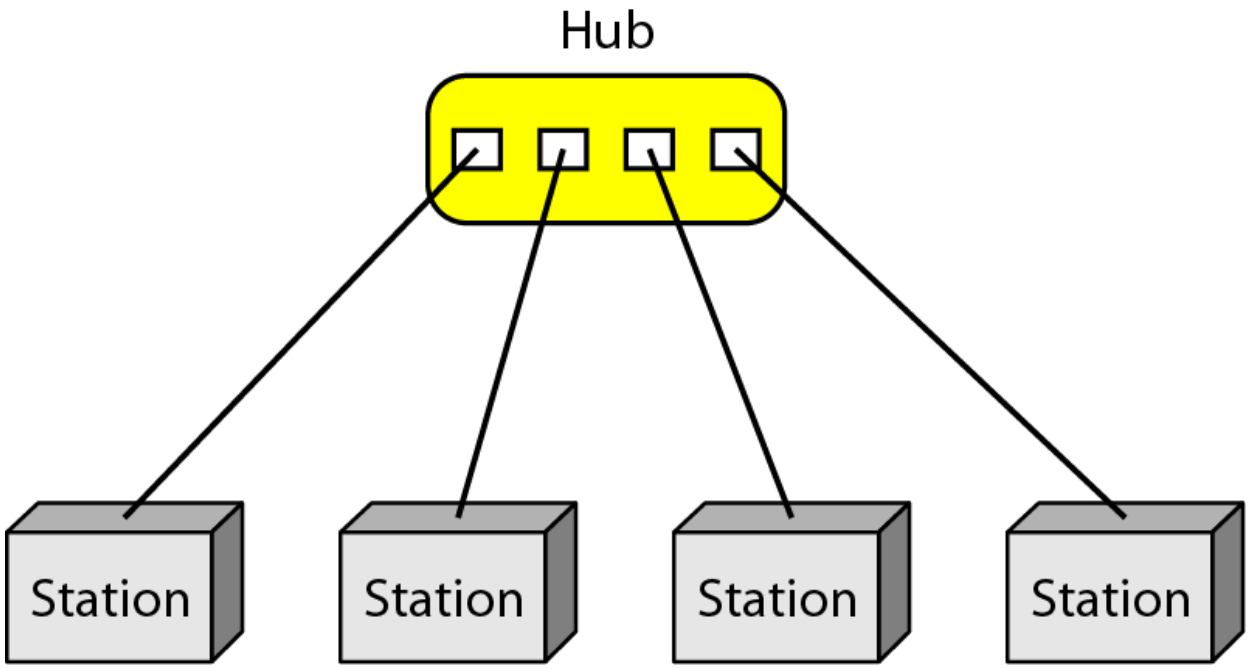
Categories of Topology



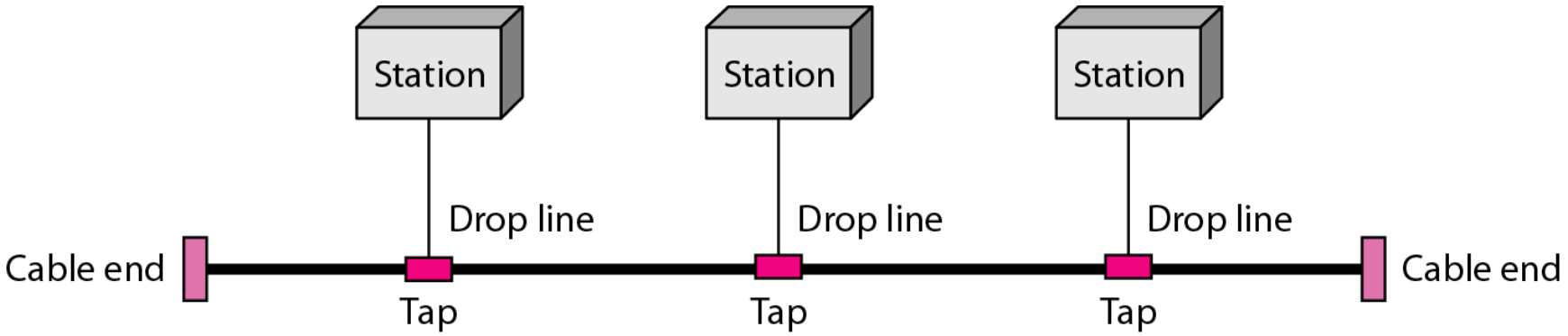
A fully connected mesh topology (five devices)



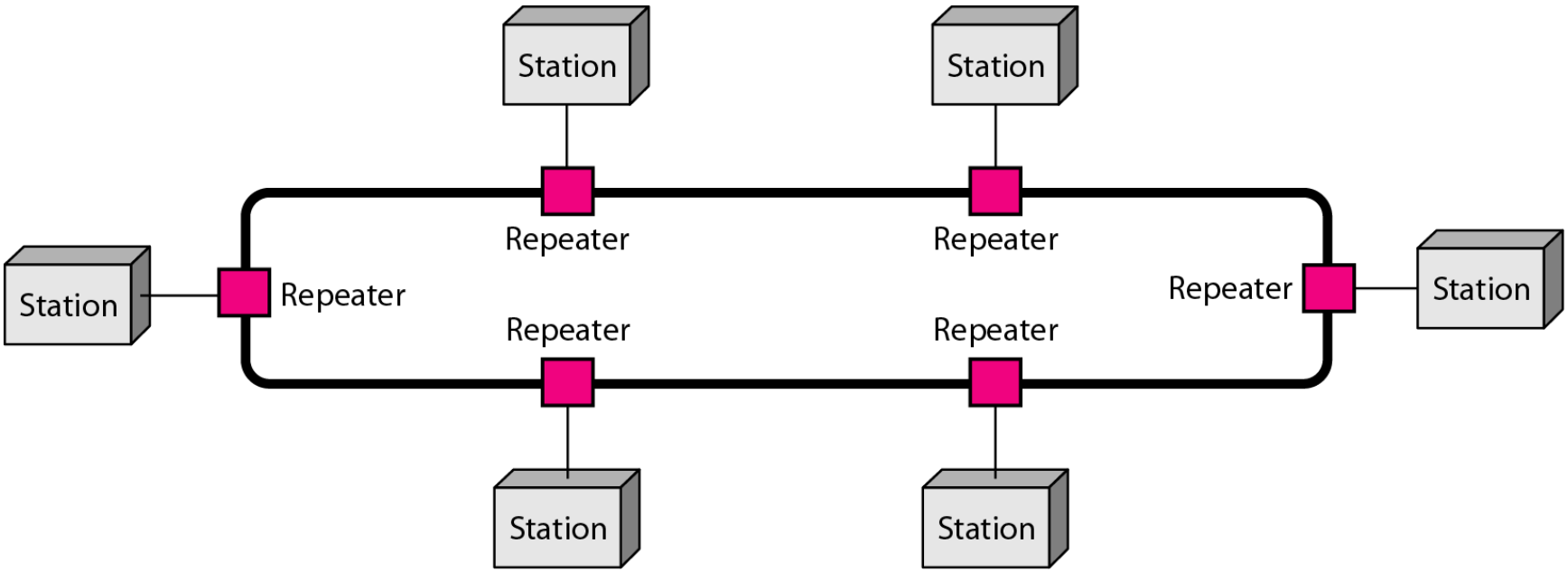
A star topology connecting four stations



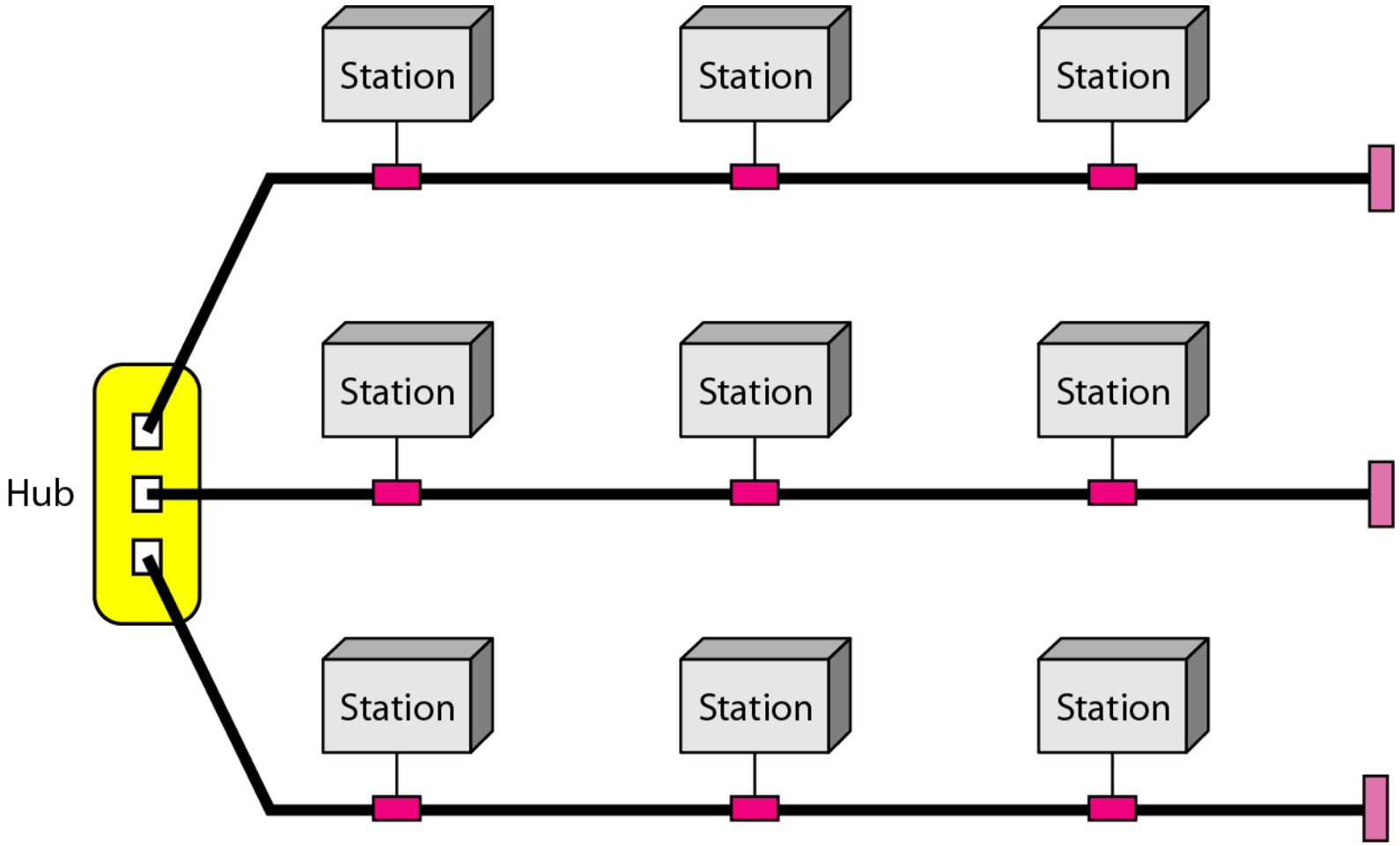
A bus topology connecting three stations



A ring topology connecting six stations



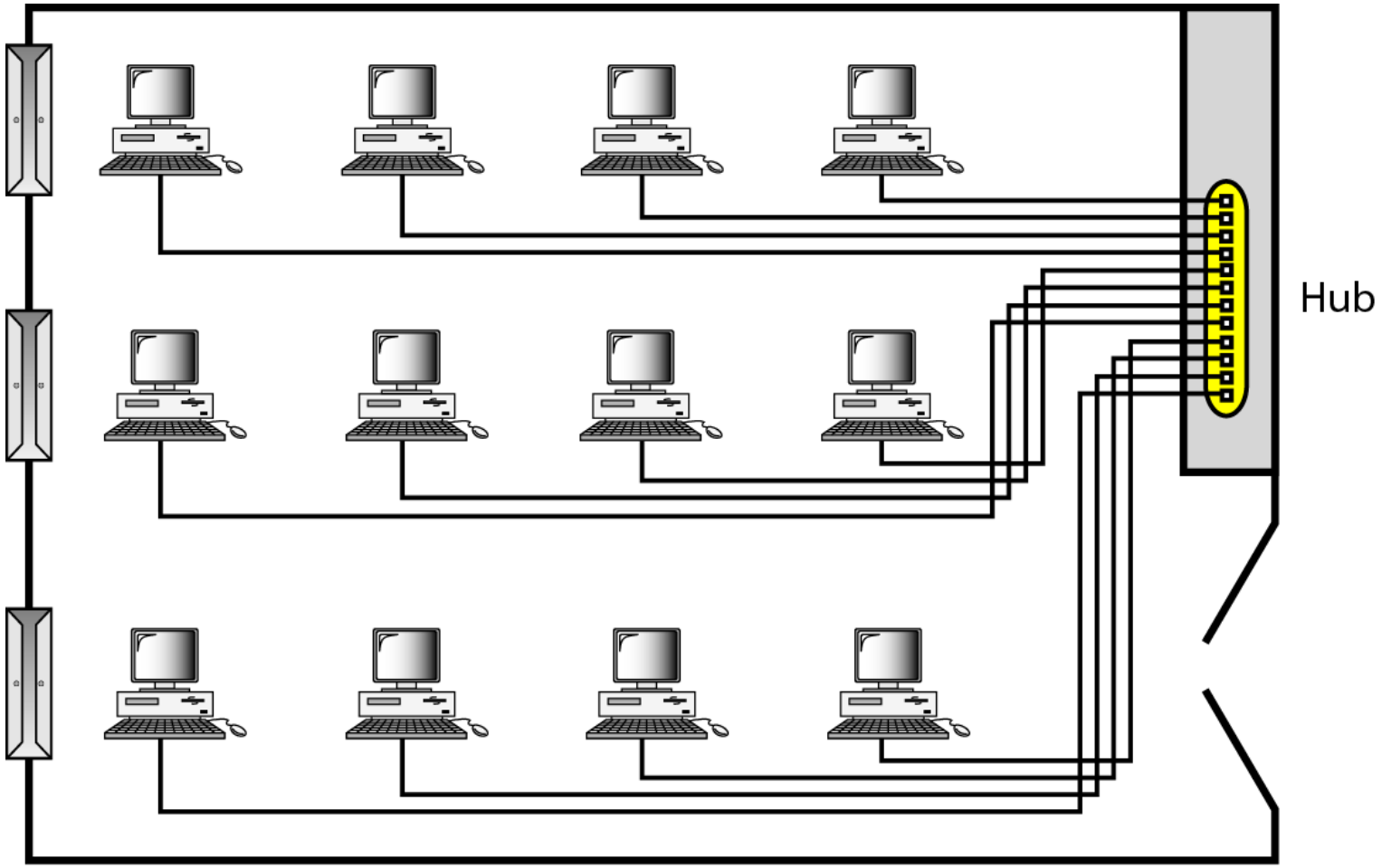
A hybrid topology: a star backbone with three bus networks



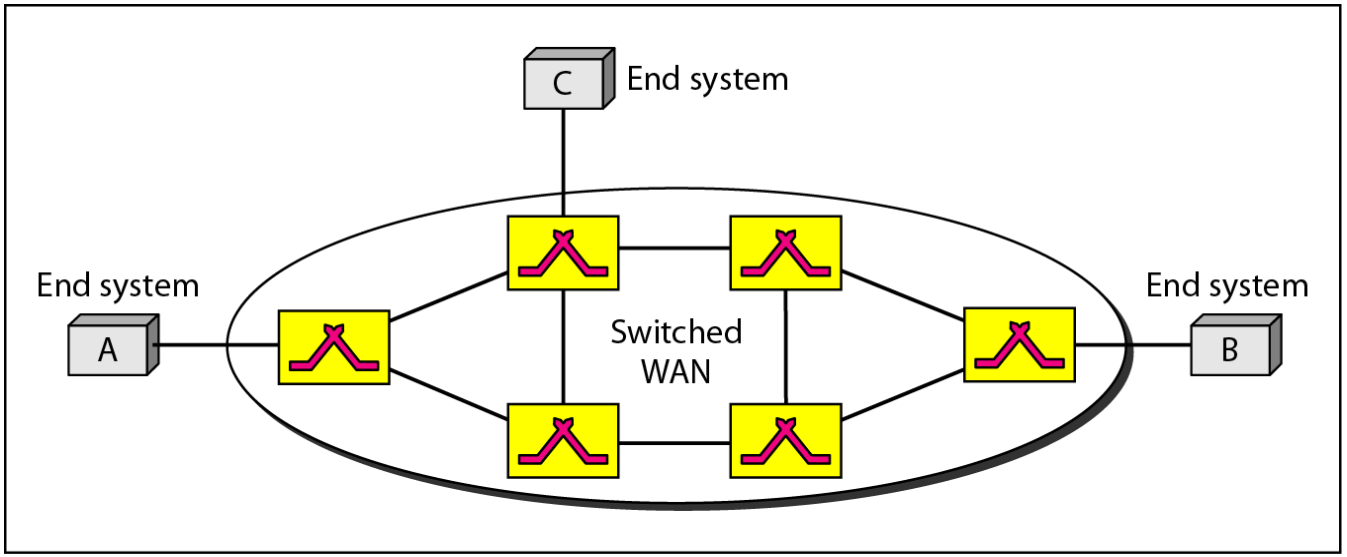
Categories of Networks

- Local Area Networks (LANs)
  - Short distances
  - Designed to provide local interconnectivity
- Wide Area Networks (WANs)
  - Long distances
  - Provide connectivity over large areas
- Metropolitan Area Networks (MANs)
  - Provide connectivity over areas such as a city, a campus

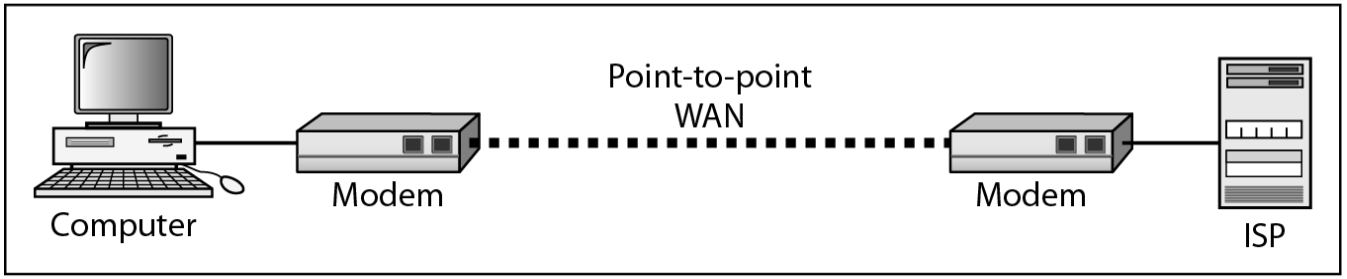
LAN



WANs: a switched WAN and a point-to-point WAN



a. Switched WAN



b. Point-to-point WAN

WAN technologies

- There are two types of long distance communication technologies that are used for WANs.
  - Dedicated connection
    - A dedicated line is a full-time point-to-point connection provided by a communication carrier that lasts for the length of the lease period.
  - Switched connection
    - There are several types of switched connections: circuit switched, packet switched, and cell switched

Circuit Switching

- In circuit switching, circuits are established prior to the transmission of data and torn down at the end of the transmission.
- During transmission of data, all of the packets take the same path.
- The Public Switch Telephone Network (PSTN) is an example of a circuit switch system.
  - A call is placed and a circuit established when the other end of the circuit is answered.
  - Modems that operate between computer systems are a specific example.

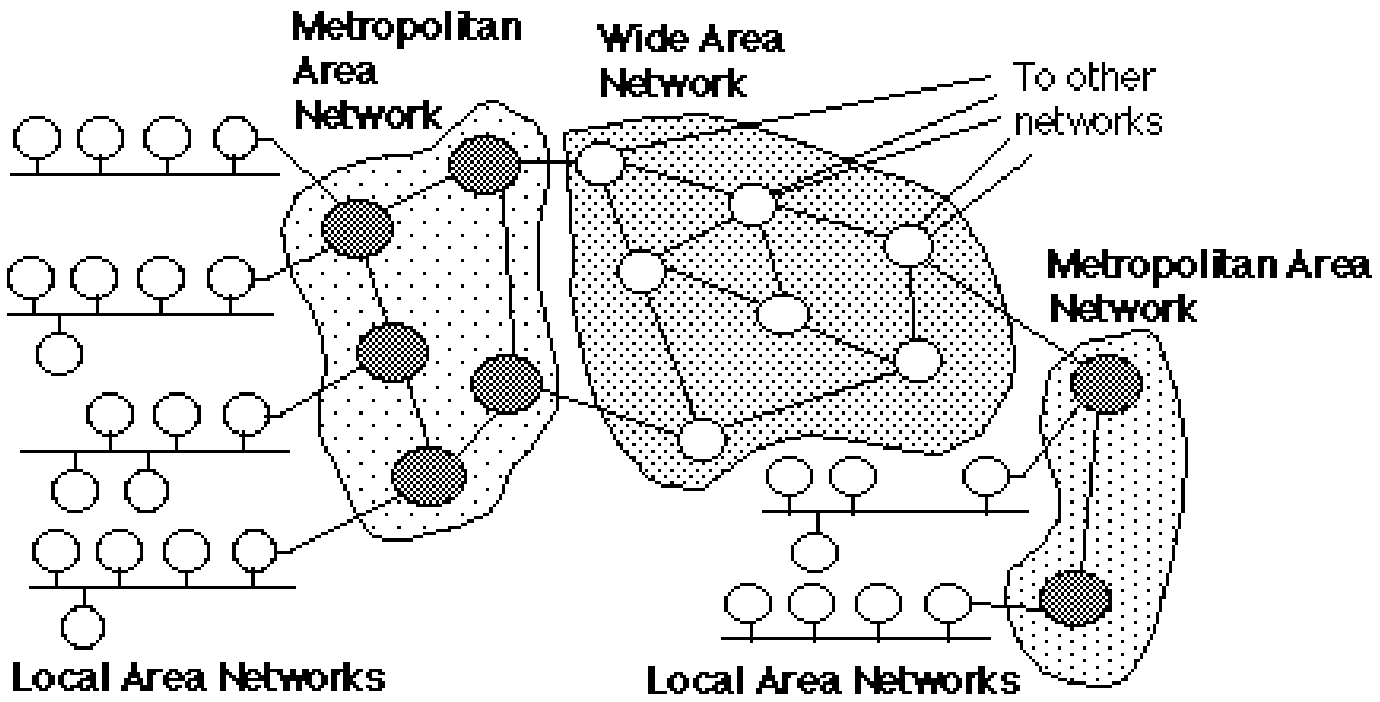
Packet Switching

- In packet switching, circuits may be selected on a packet-by-packet basis.
- The Internet widely uses packet switch networks, for individual packets in the same transmission may take different routes through the network to the same destination.
- Upper layers of the OSI model place the packets into the correct order.

Cell Switching

- **Cell switching** is associated with Asynchronous Transmission Mode (ATM) which is considered to be a high speed switching technology that attempted to overcome the speed problems faced by the shared media like Ethernet.
- Cell switching uses a connection-oriented packet-switched network.
  - It is called cell switching because this methodology uses a fixed length of packets of 53 bytes out of which 5 bytes are reserved for header.
  - Unlike cell technology, packet switching technology uses variable length packets.
  - Even though cell switching closely resembles packet switching because cell switching also breaks the information into smaller packets of fixed length.

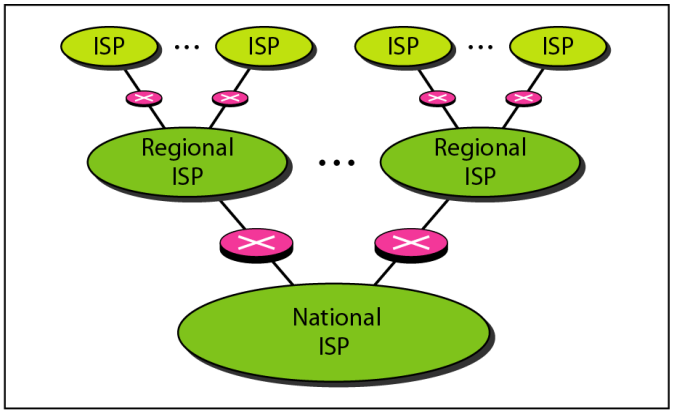
LAN ⊂ MAN ⊂ WAN


Metropolitan
Area
Network
Wide Area
Network
To other
networks
Metropolitan Area
Network
Local Area Networks
Local Area Networks

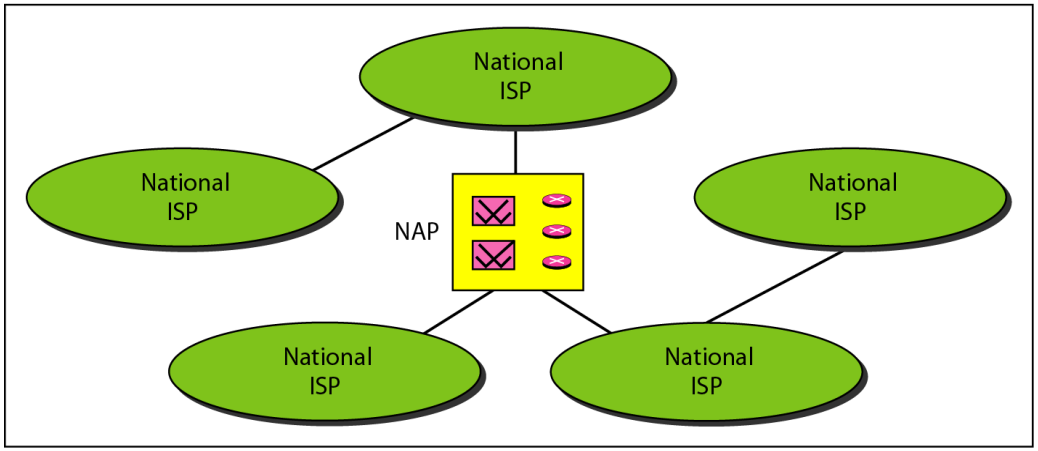
Big and getting bigger….

INTERNET

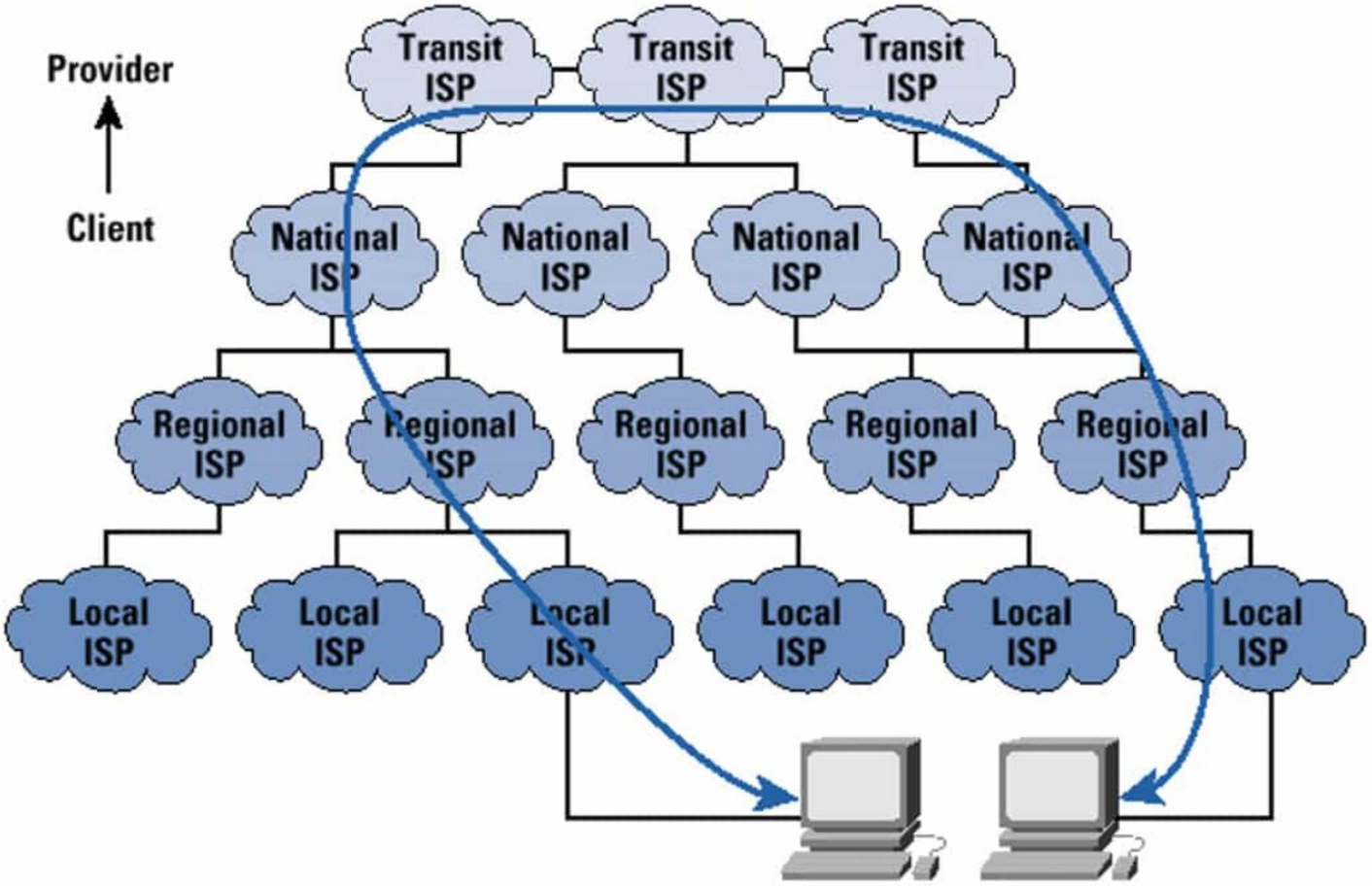
Hierarchical organization of the Internet



a. Structure of a national ISP



b. Interconnection of national ISPs


Provider
Client
Transit ISP
Transit ISP
Transit ISP
National ISP
National ISP
National ISP
National ISP
Regional ISP
Regional ISP
Regional ISP
Regional ISP
Regional ISP
Local ISP
Local ISP
Local ISP
Local ISP
Local ISP
Local ISP

Protocols

- A protocol is synonymous with rule. It consists of a set of rules that govern data communications. It determines -
  - what is communicated
  - how it is communicated and
  - when it is communicated.
- The key elements of a protocol are *syntax*, *semantics* and *timing*

Elements of a Protocol

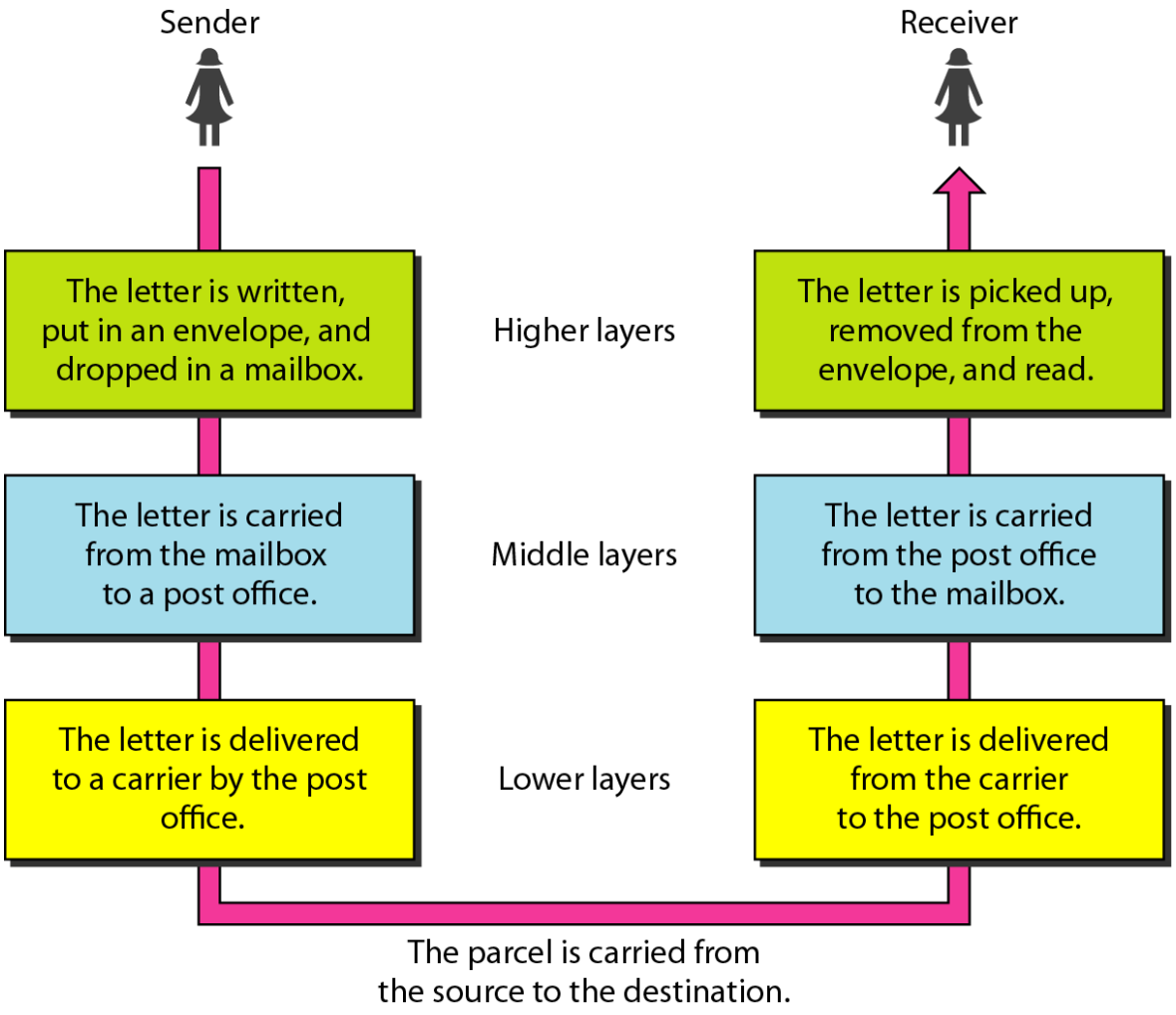
- Syntax
  - Structure or format of the data
  - Indicates how to read the bits - field delineation
- Semantics
  - Interprets the meaning of the bits
  - Knows which fields define what action
- Timing
  - When data should be sent and
  - What speed at which data should be sent or speed at which it is being received.

NETWORK MODELS

Example

- We use the concept of layers in our daily life. As an example, let us consider two friends who communicate through postal mail. The process of sending a letter to a friend would be complex if there were no services available from the post office.

Tasks involved in sending a letter



OSI Model

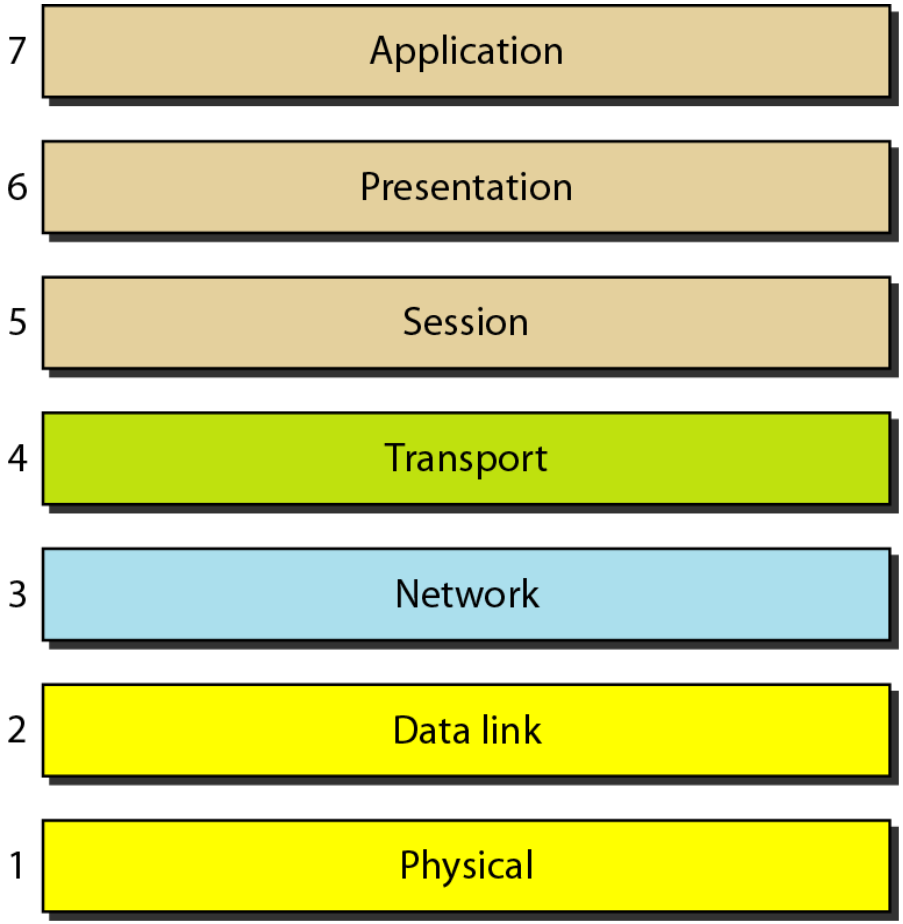
- Established in 1947, the International Standards Organization (ISO) is a multinational body dedicated to worldwide agreement on international standards. An ISO standard that covers all aspects of network communications is the Open Systems Interconnection (OSI) model. It was first introduced in the late 1970s.

ISO or OSI

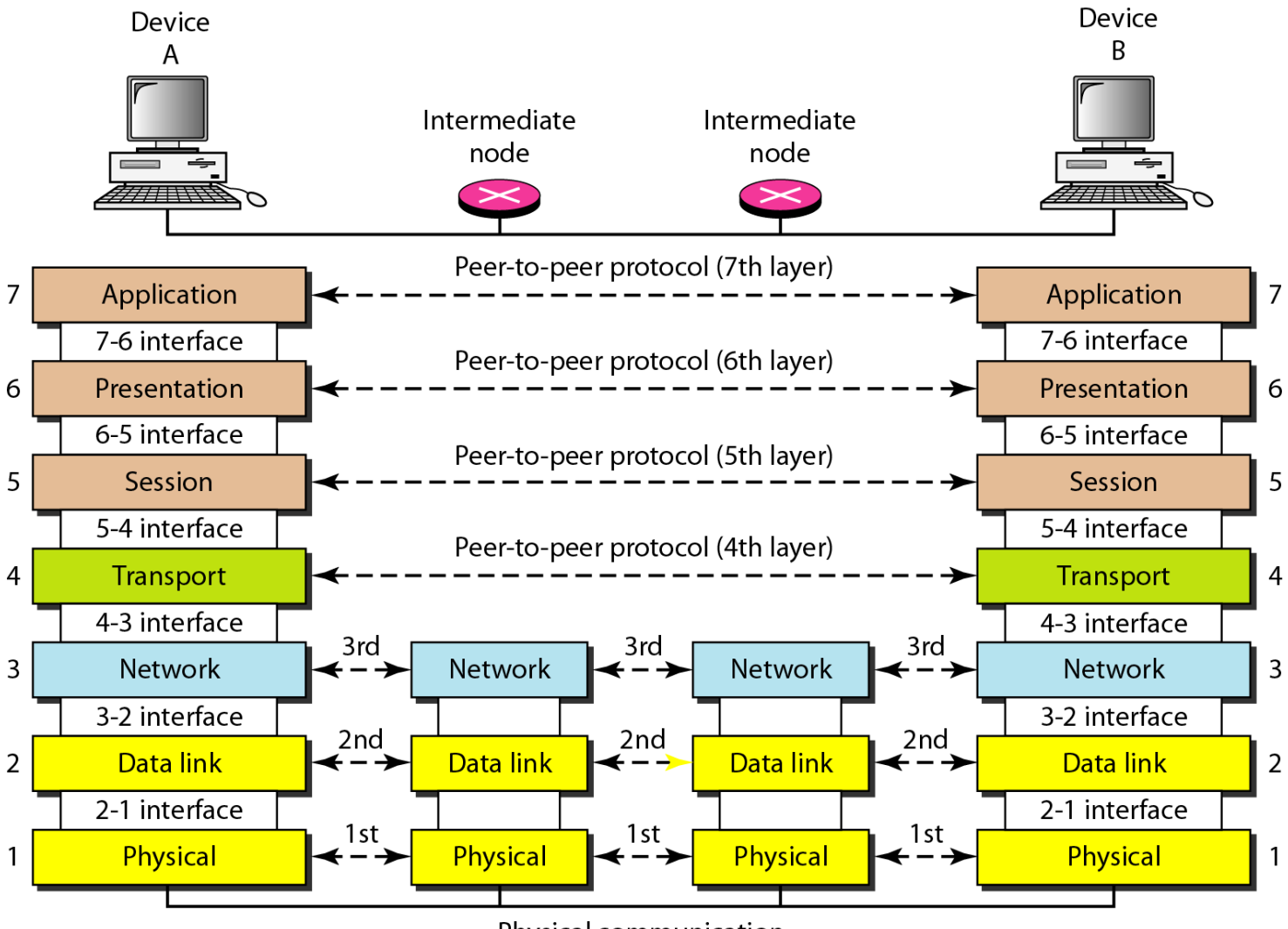
- ISO (International Organization for Standardization)
  - is the organization.

- OSI (Open Systems Interconnection)
  - is the model.

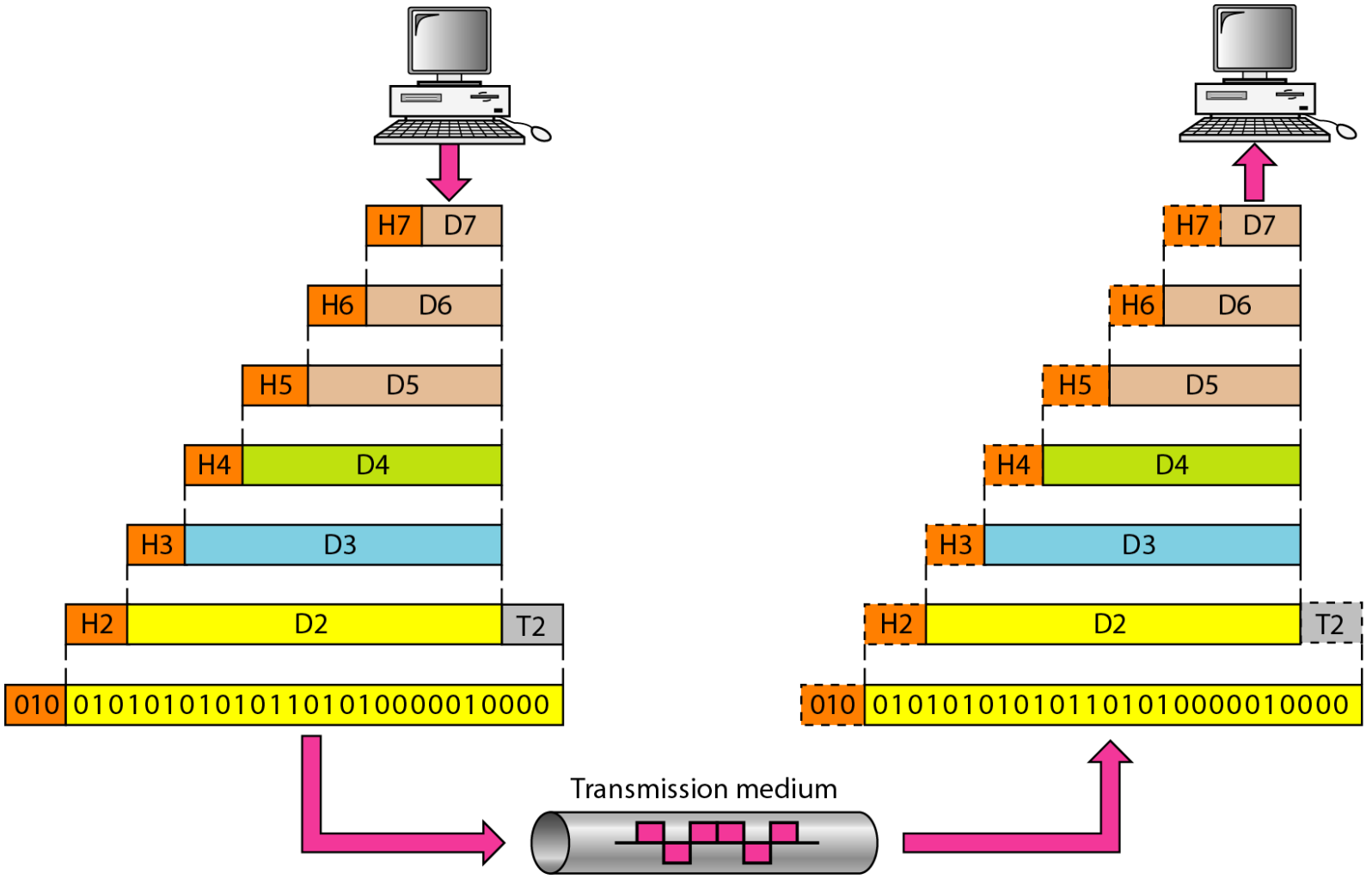
OSI Model


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

The interaction between layers in the OSI model

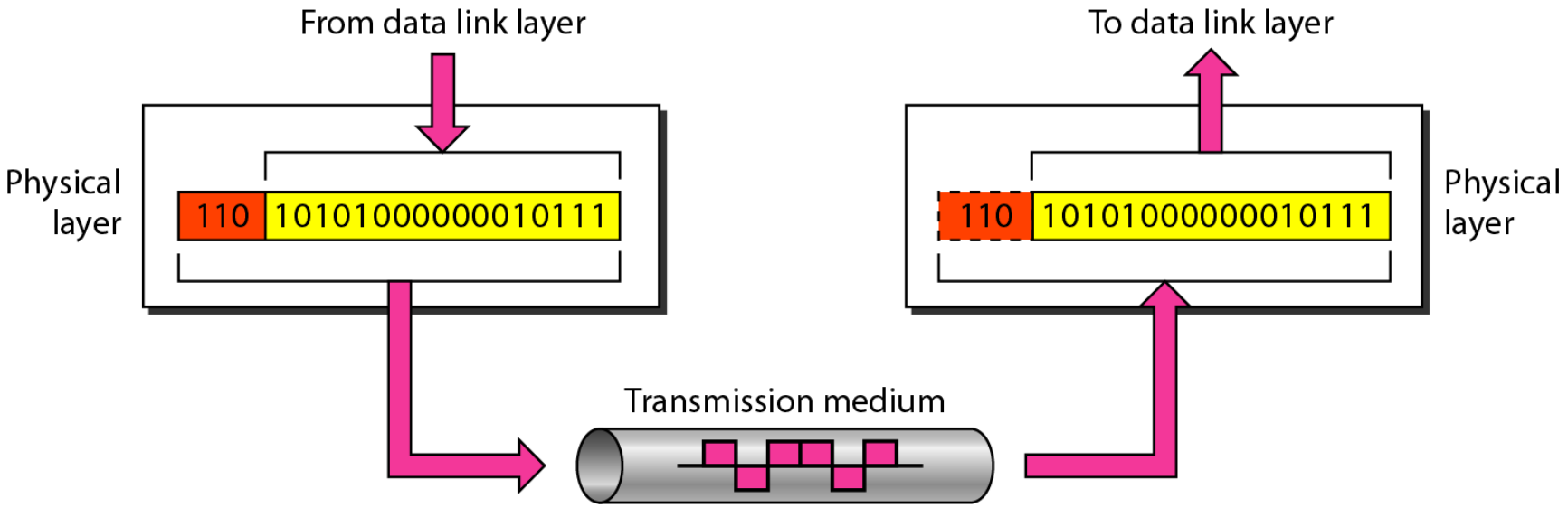


An exchange using the OSI model



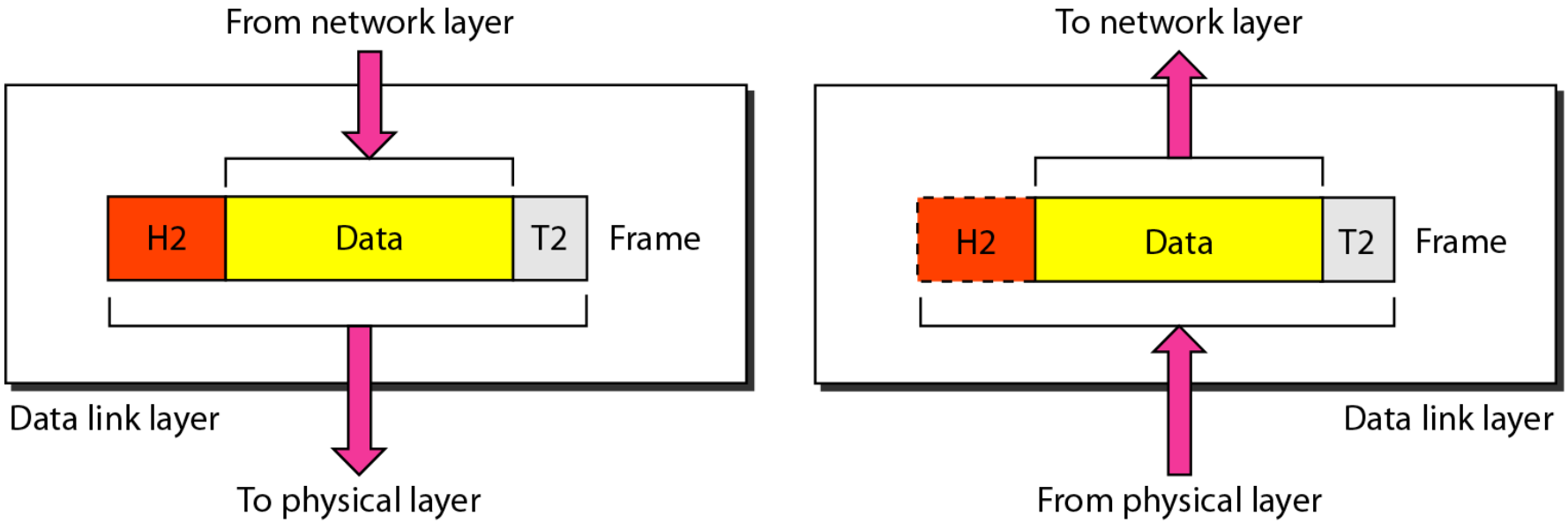
Physical Layer

The physical layer is responsible for movements of individual bits from one hop (node) to the next.

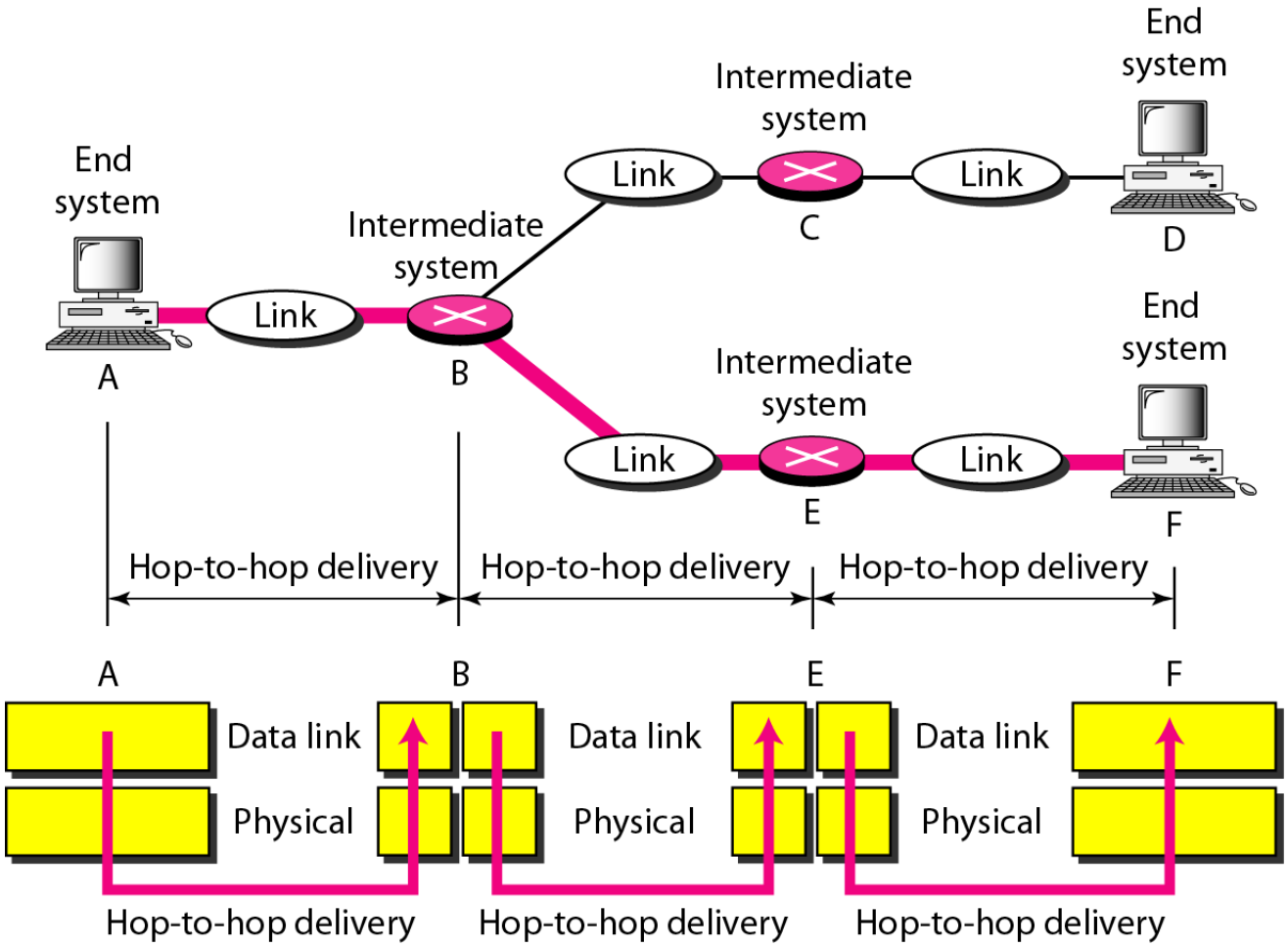


Data Link Layer

The data link layer is responsible for moving frames from one hop (node) to the next.

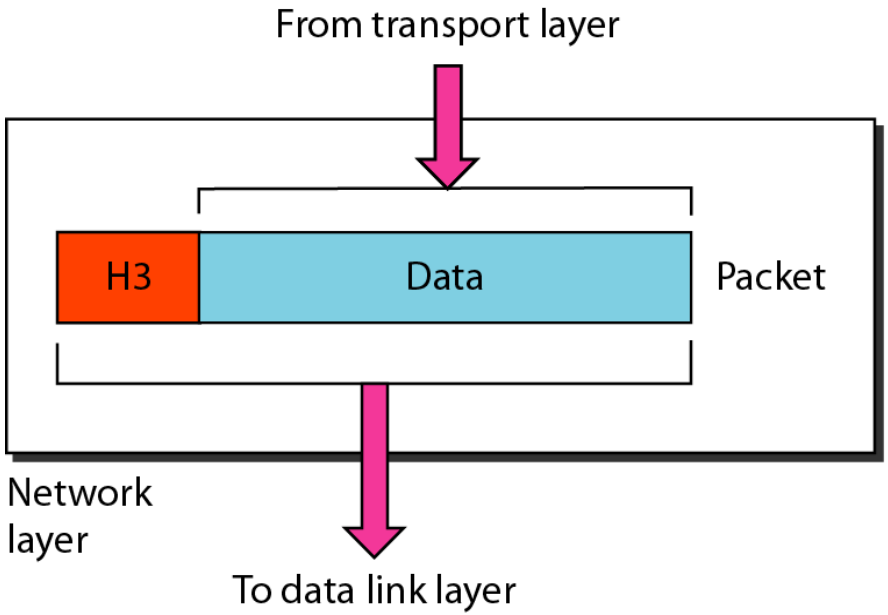


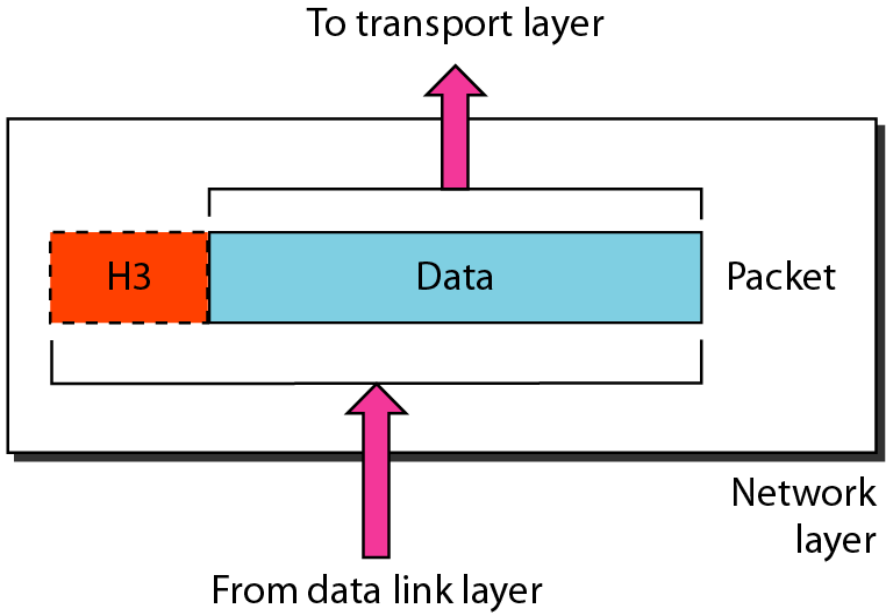
Hop to Hop Delivery



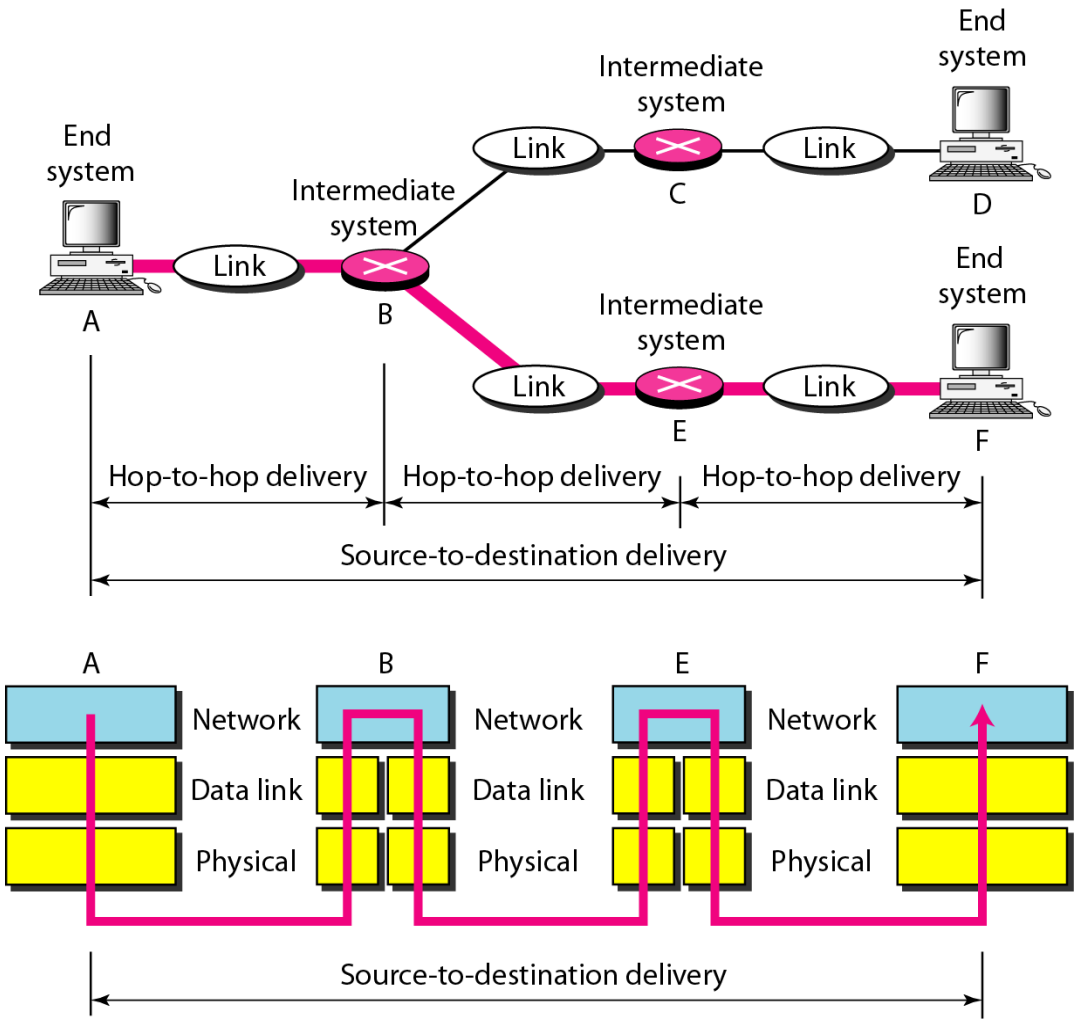
Network Layer

The network layer is responsible for the delivery of individual packets from the source host to the destination host.



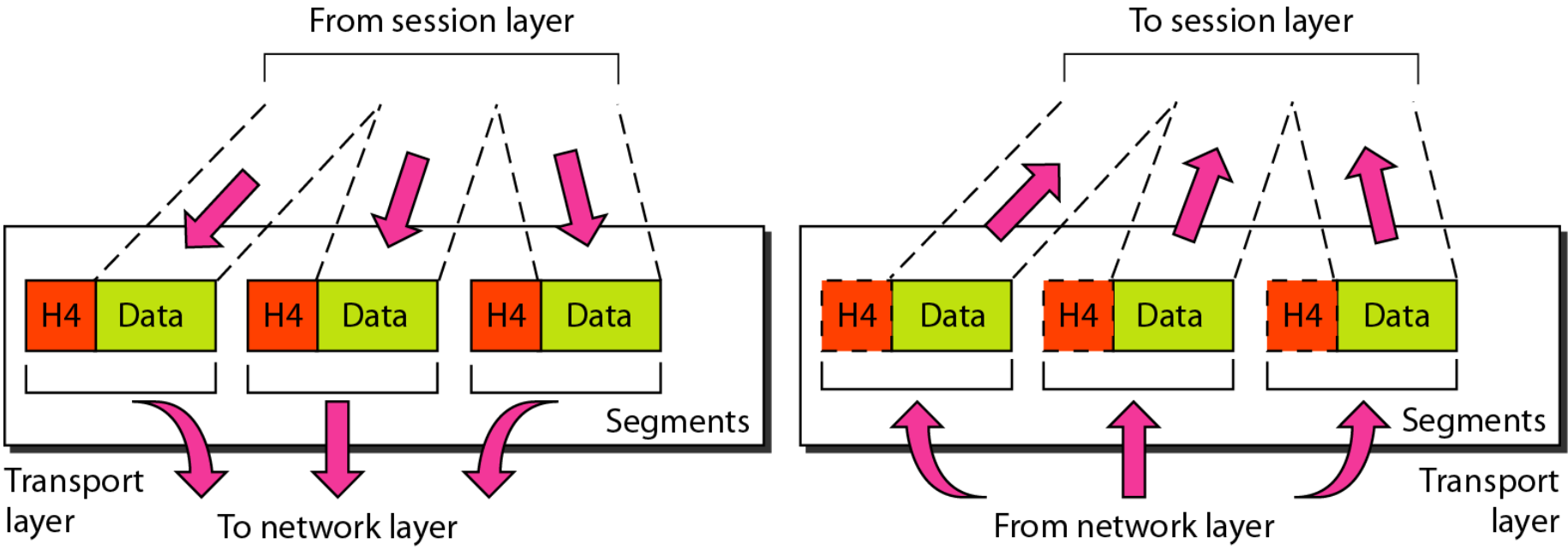


Source to destination delivery

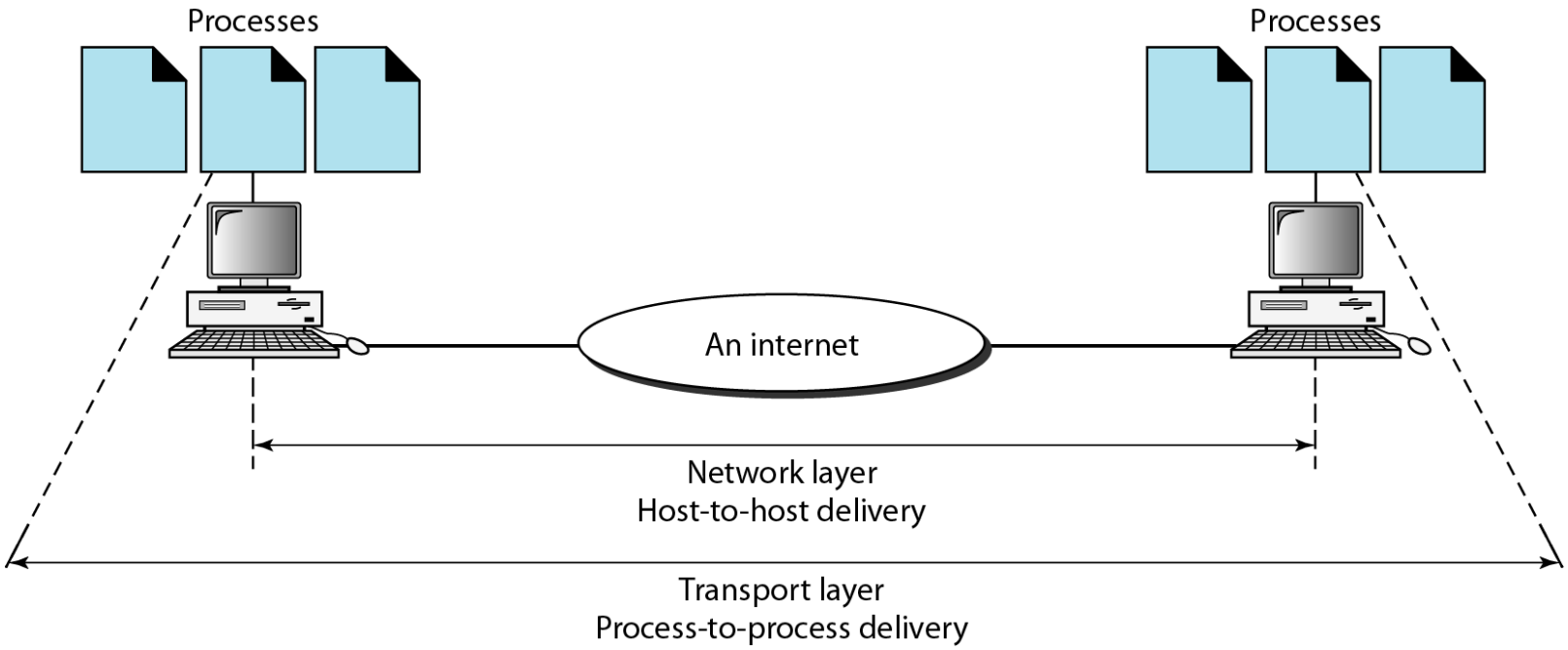


Transport Layer

- The transport layer is responsible for the delivery of a message from one process to another.

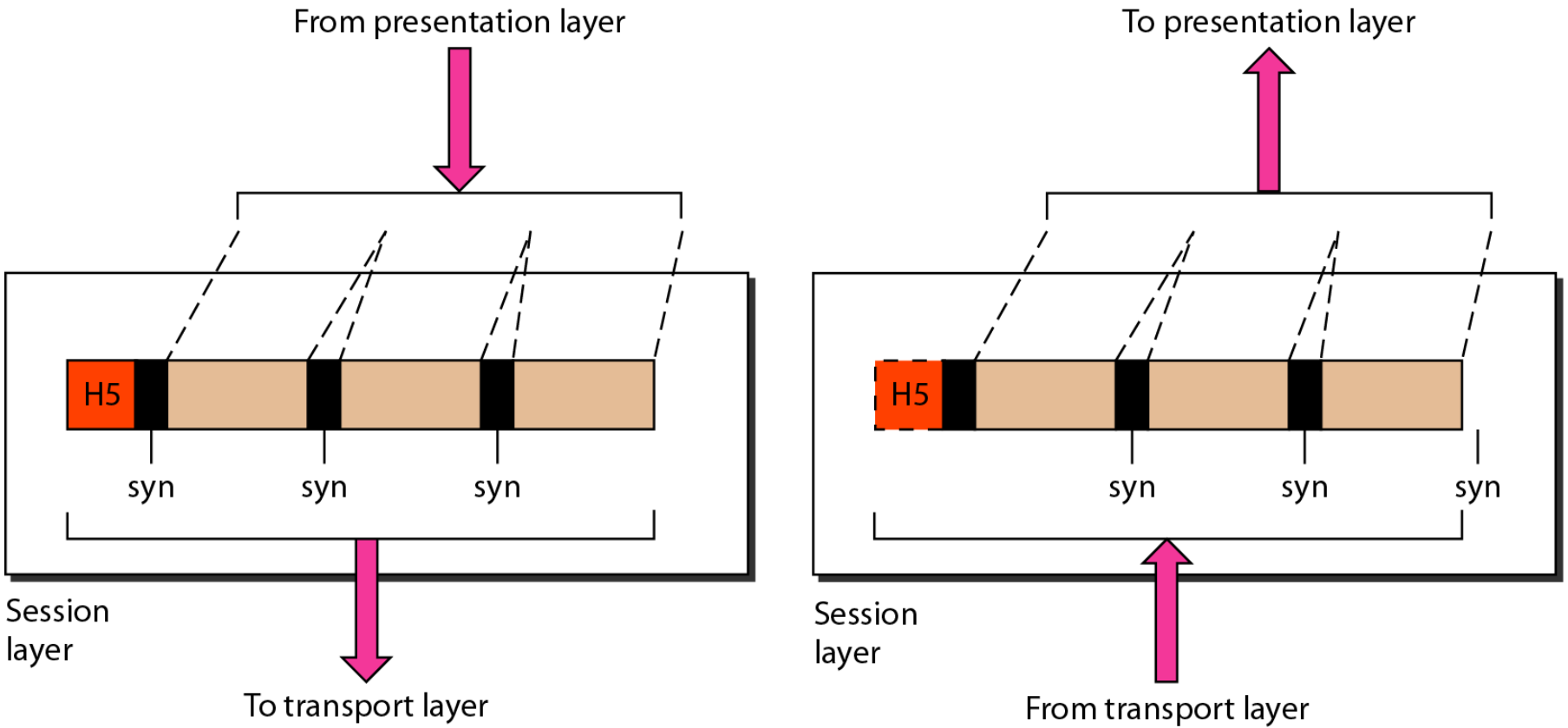


Reliable process-to-process delivery of a message



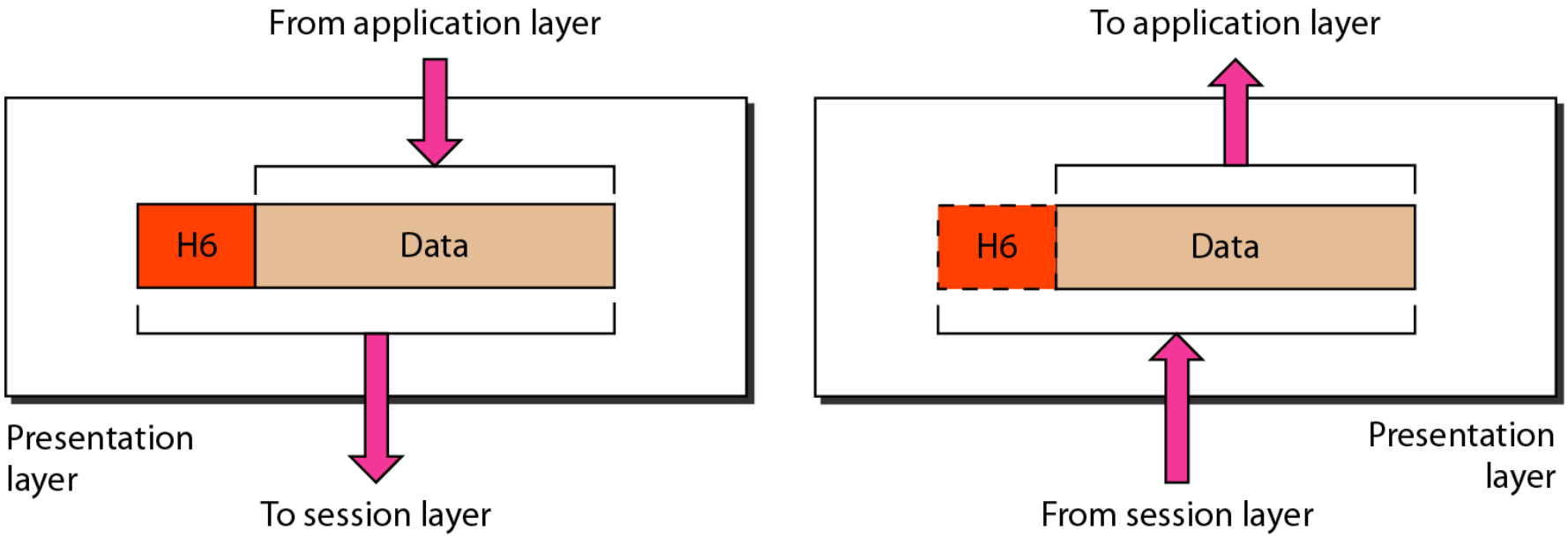
Session Layer

- The session layer is responsible for dialog control and synchronization.



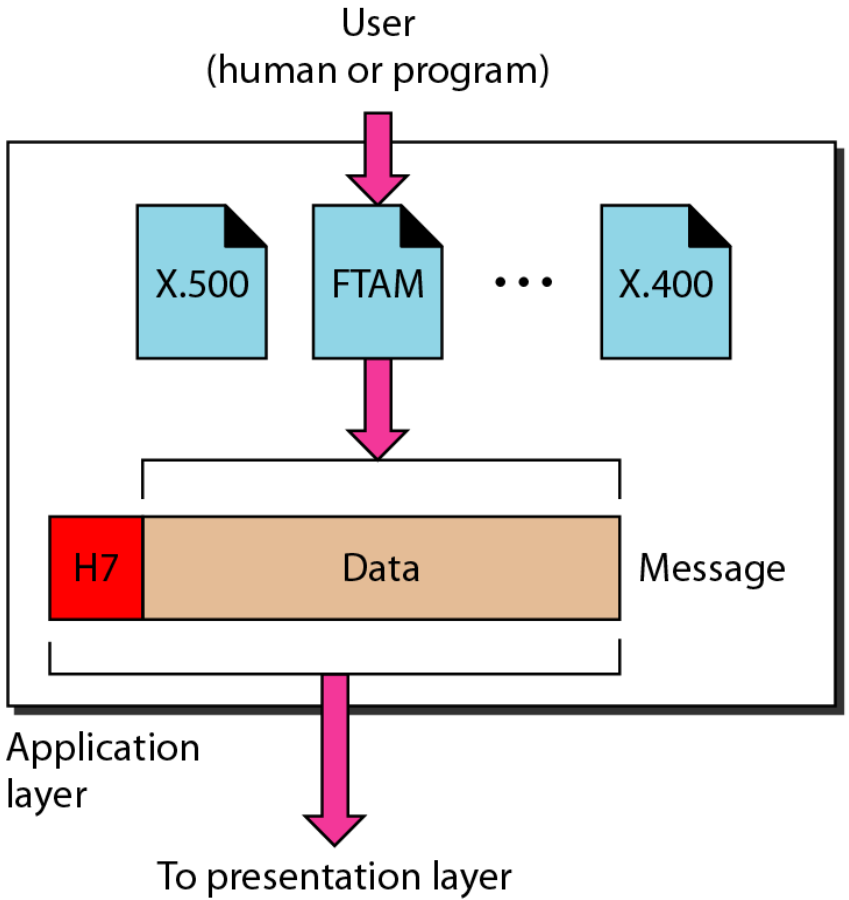
Presentation layer

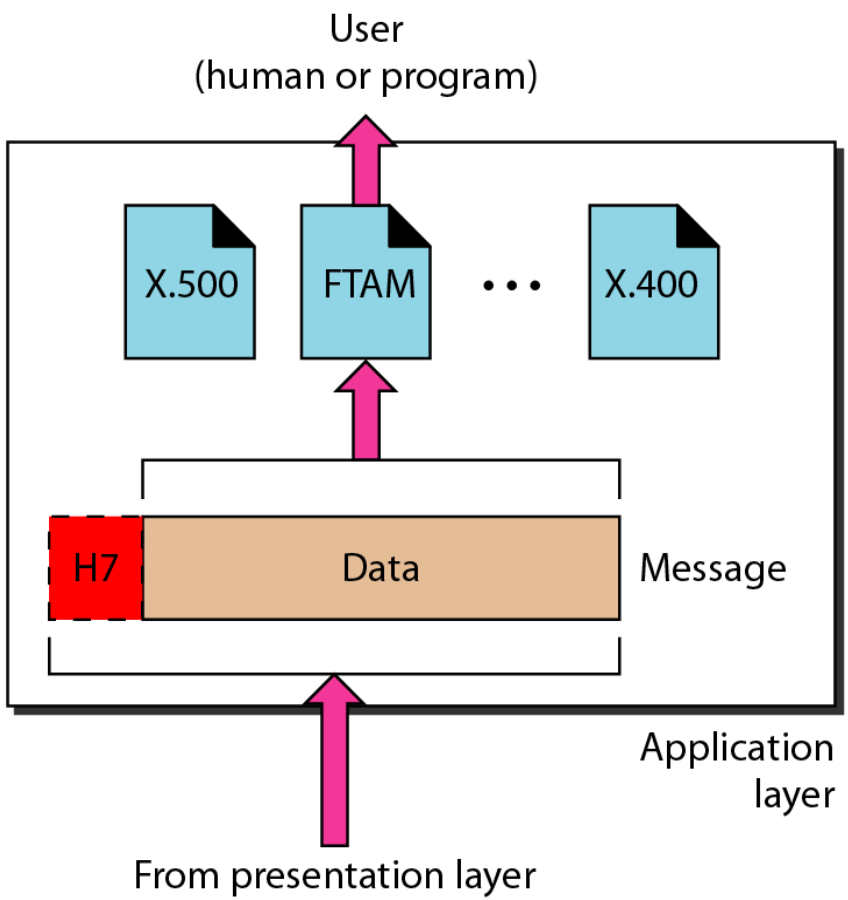
- The presentation layer is responsible for translation, compression, and encryption.



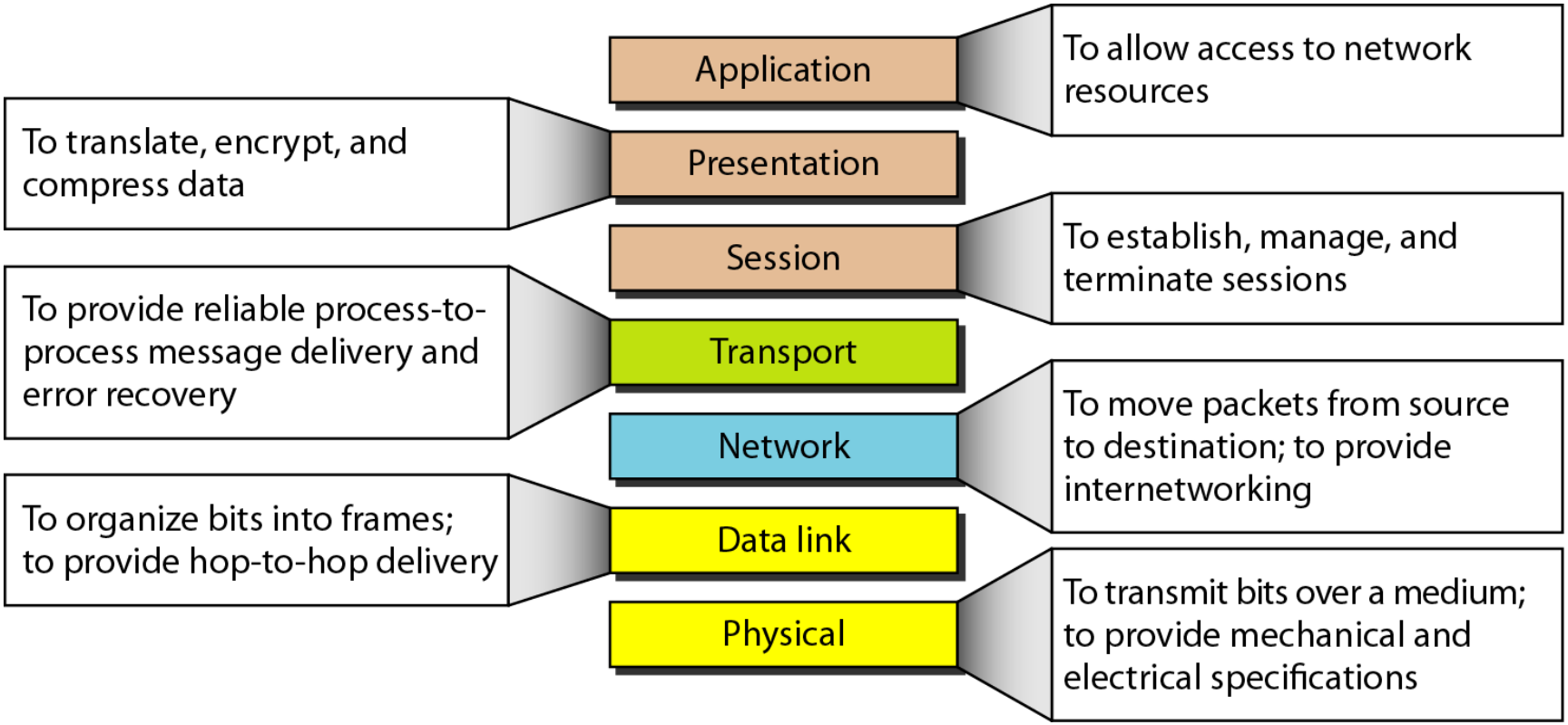
Application layer

- The application layer is responsible for providing services to the user.





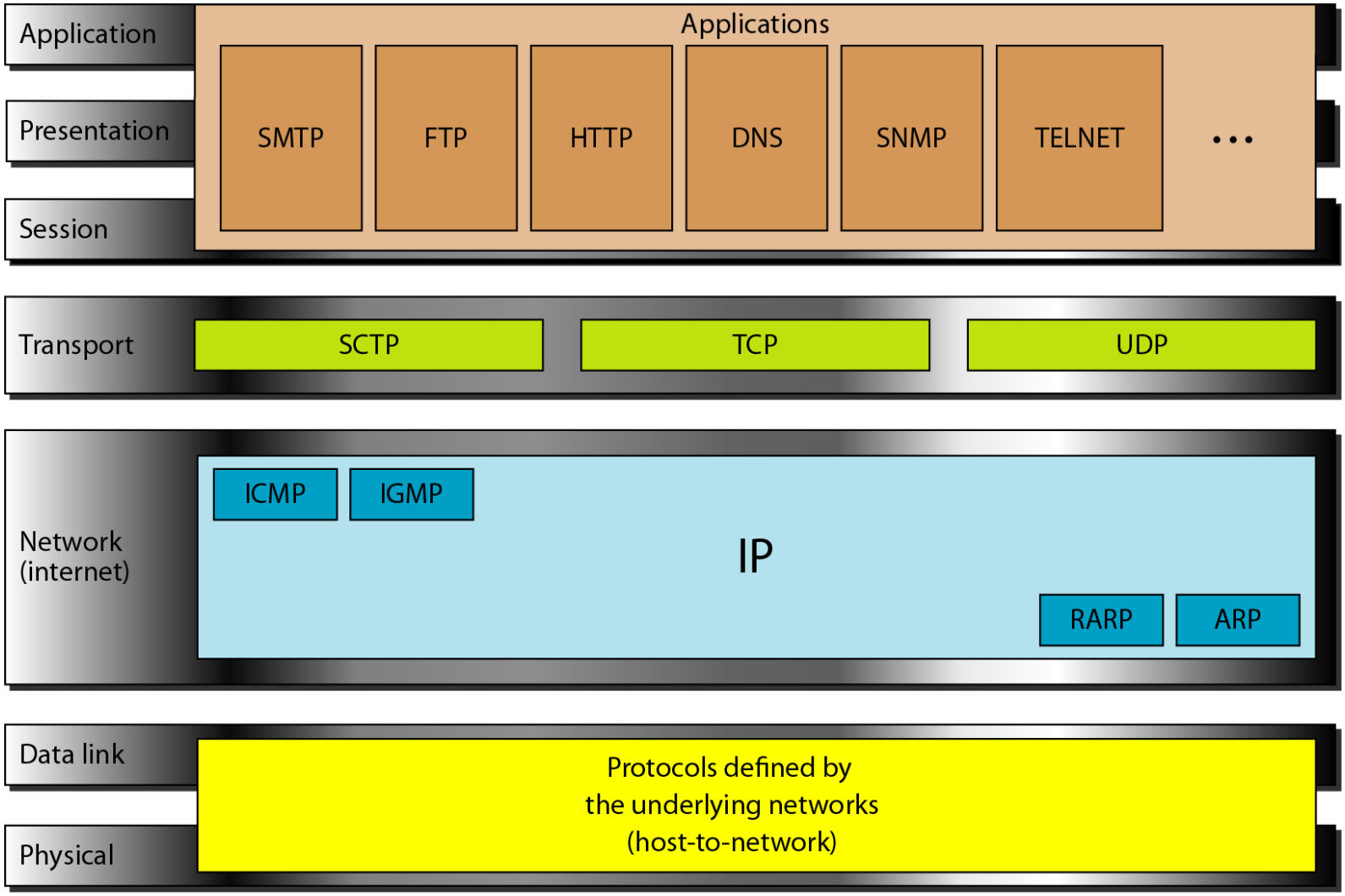
Summary of layers



TCP/IP protocol suite

- The layers in the TCP/IP protocol suite do not exactly match those in the OSI model. The original TCP/IP protocol suite was defined as having four layers: host-to-network, internet, transport, and application. However, when TCP/IP is compared to OSI, we can say that the TCP/IP protocol suite is made of five layers: physical, data link, network, transport, and application.

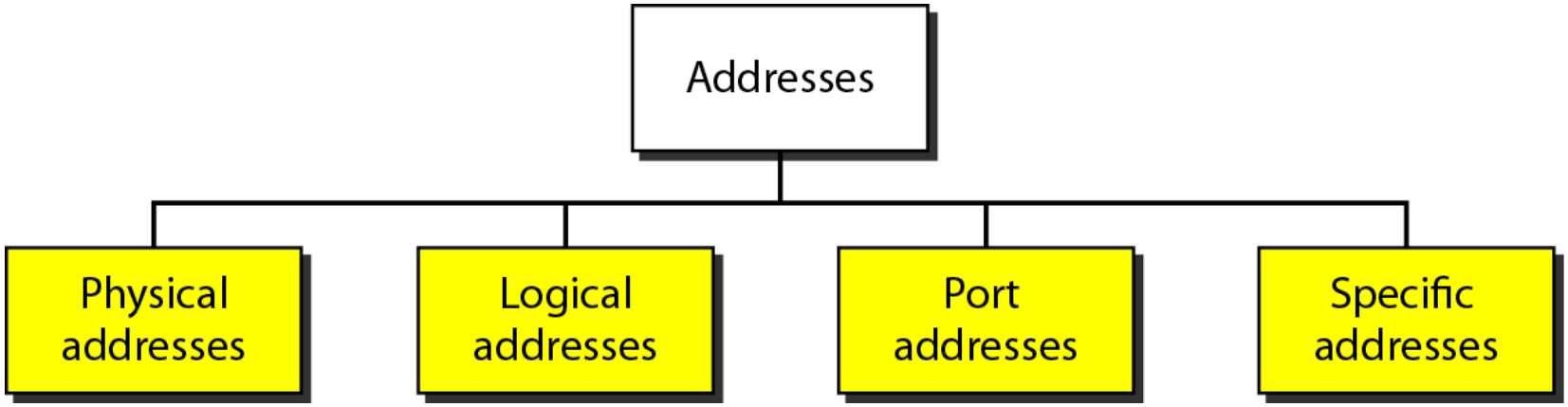
TCP/IP and OSI model



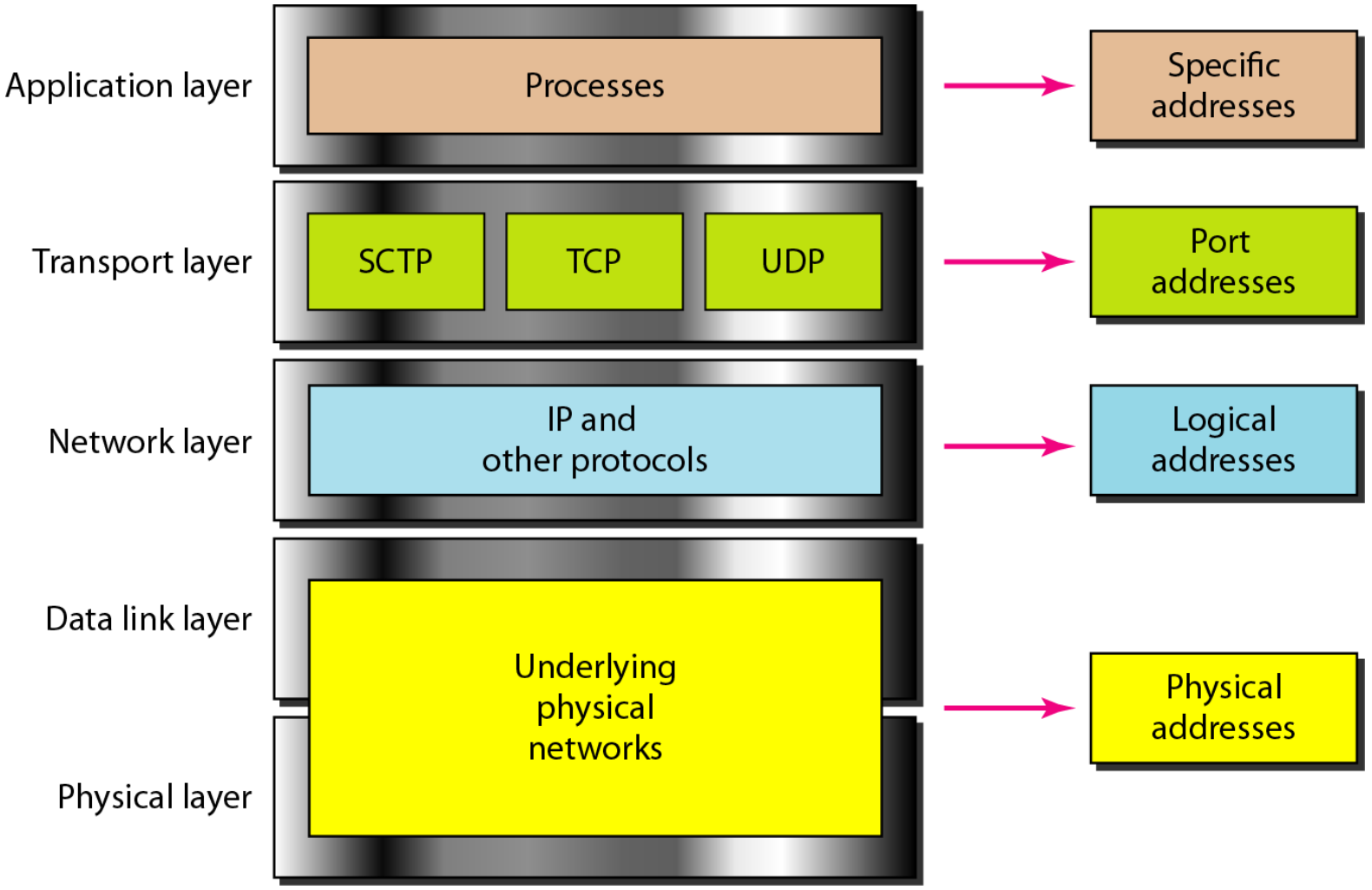
Addressing

- Physical Addresses
- Logical Addresses
- Port Addresses
- Specific Addresses

Addresses in TCP/IP

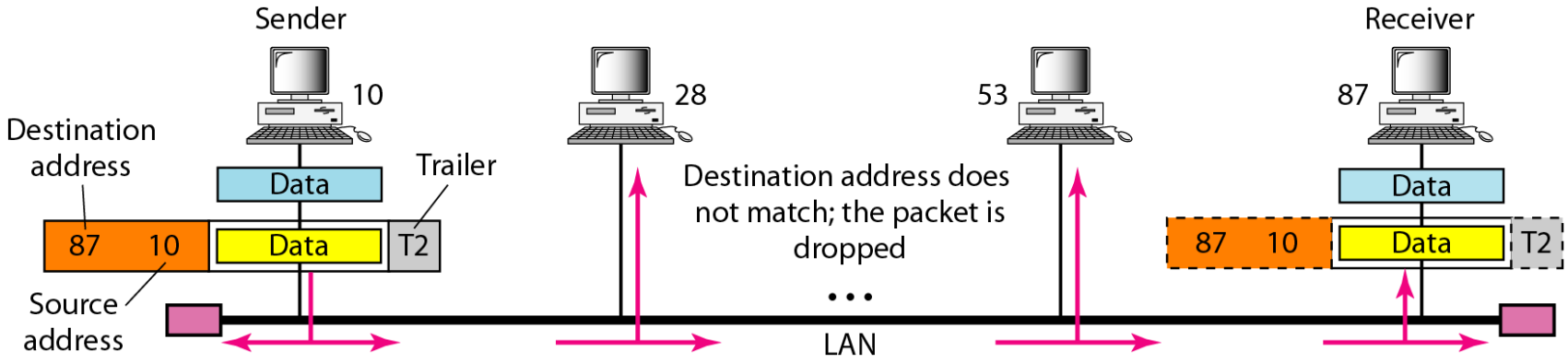


Relationship of layers and addresses in TCP/IP



Physical Addresses

- Here a node with physical address 10 sends a frame to a node with physical address 87. The two nodes are connected by a link (bus topology LAN). As the figure shows, the computer with physical address 10 is the sender, and the computer with physical *address 87 is the receiver.*



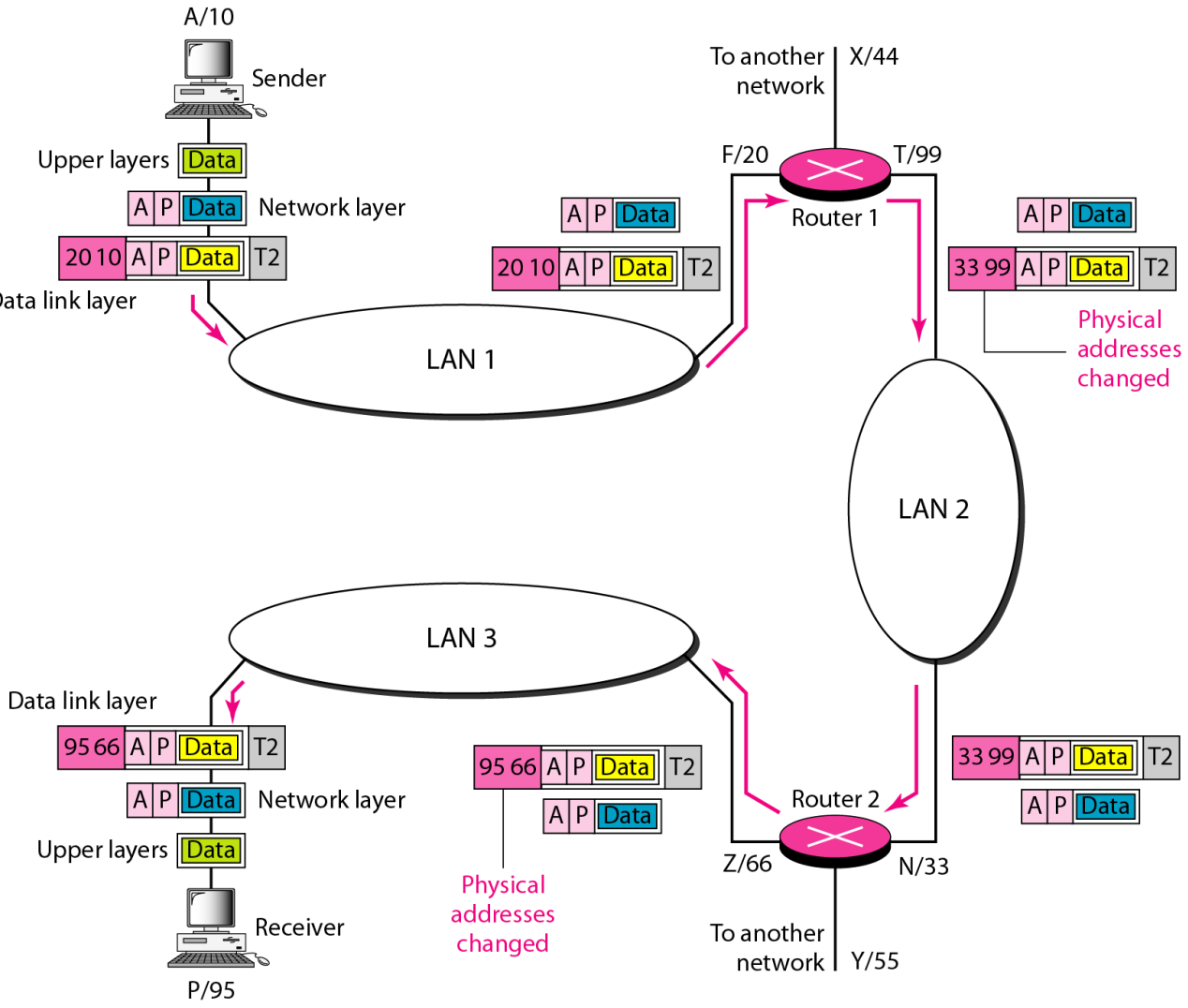
- Most local-area networks use a 48-bit (6-byte) physical address written as 12 hexadecimal digits; every byte (2 hexadecimal digits) is separated by a colon, as shown below:

07:01:02:01:2C:4B

A 6-byte (12 hexadecimal digits) physical address.

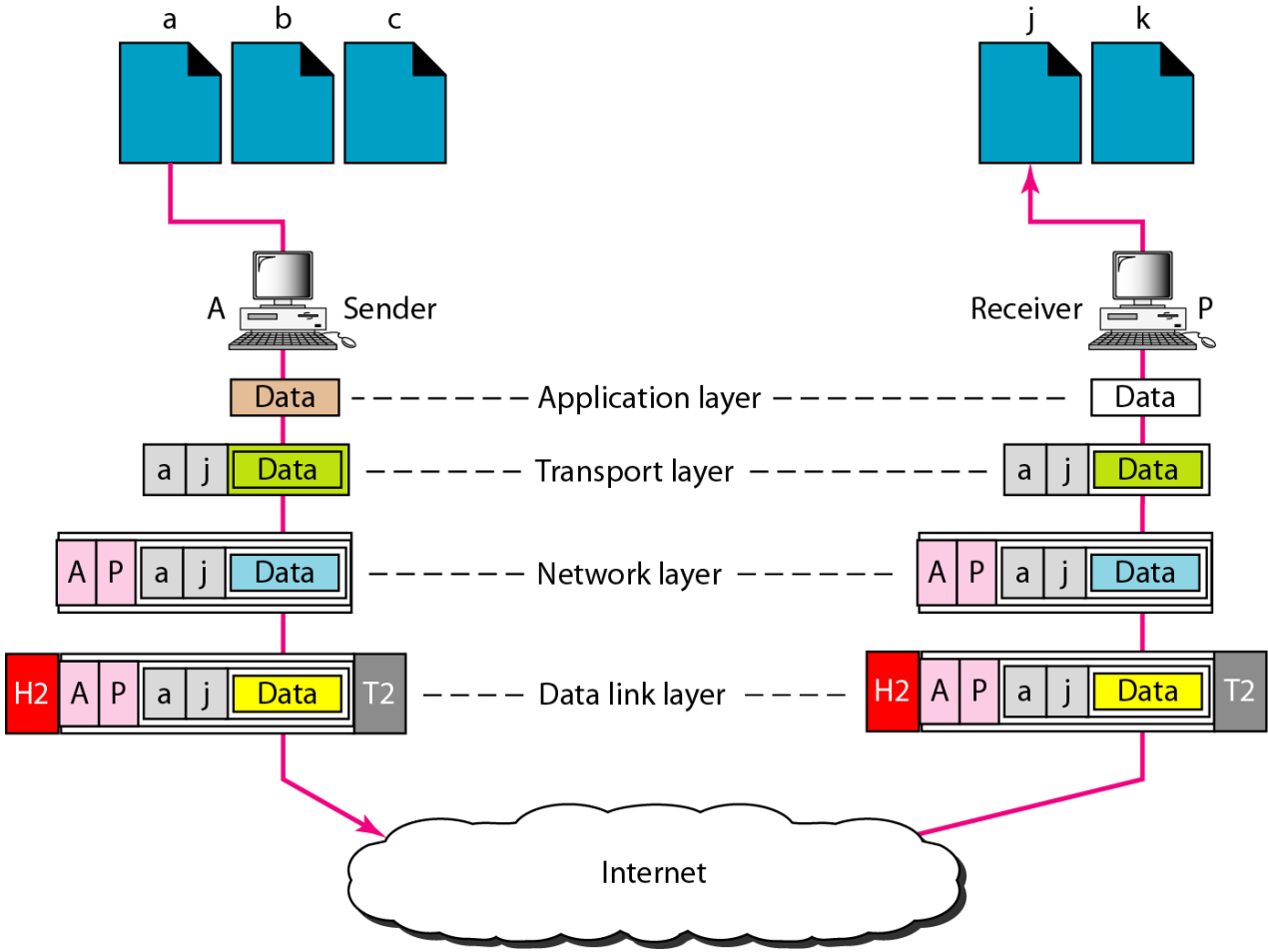
IP Addresses: A part of an internet with two routers connecting three LANs

- Each device (computer or router) has a pair of addresses (logical and physical) for each connection.
- In this case, each computer is connected to only one link and therefore has only one pair of addresses.
- Each router, however, is connected to three networks (only two are shown in the figure).
- So each router has three pairs of addresses, one for each connection.



Port addresses

- *The sending computer is running three processes at this time with port addresses a, b, and c.*
- *The receiving computer is running two processes at this time with port addresses j and k.*
- *Process a in the sending computer needs to communicate with process j in the receiving computer.*
- *Note that although physical addresses change from hop to hop, logical and port addresses remain the same from the source to destination.*



The physical addresses will change from hop to hop, but the logical addresses usually remain the same.

- *A port address is a 16-bit address represented by one decimal number as shown.*

753

- A 16-bit port address represented as one single number.