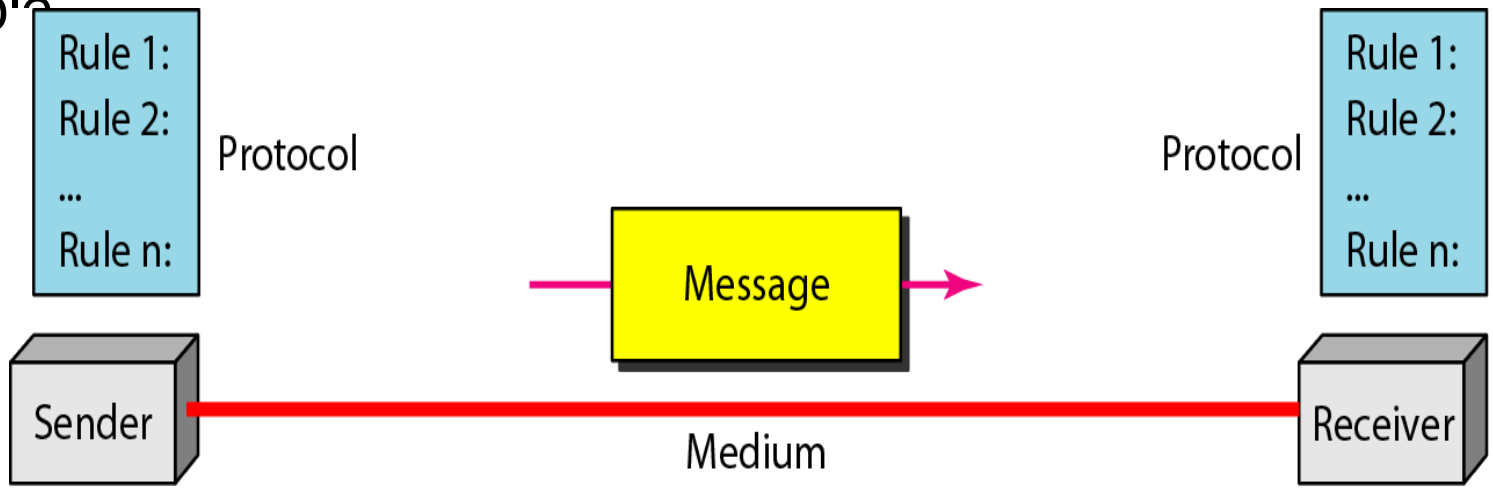
Computer Network and Distributed Systems

PART 1

Data Communications

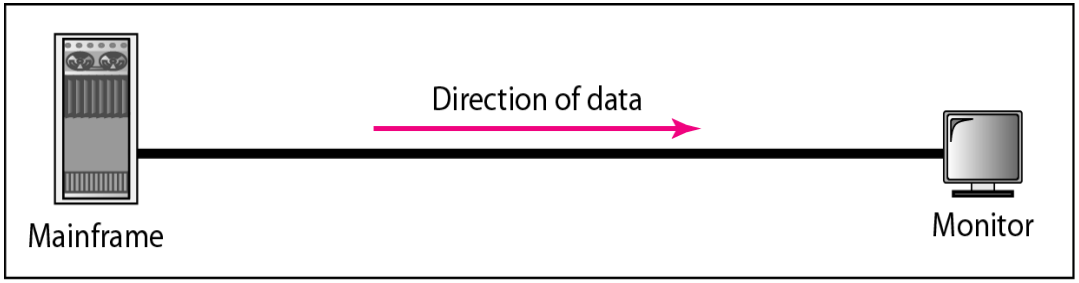
- The term telecommunication means communication at a distance.
- The word data refers to information presented in whatever form is agreed upon by the parties creating and using the data.
- Data communications are the exchange of data between two devices via some form of transmission medium such as a wire cable.



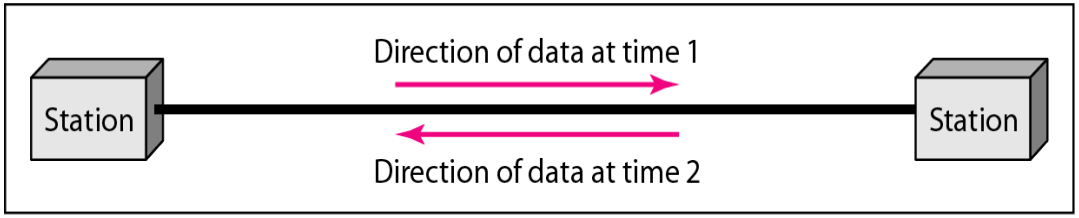
Types of transmissions

Types of transmission

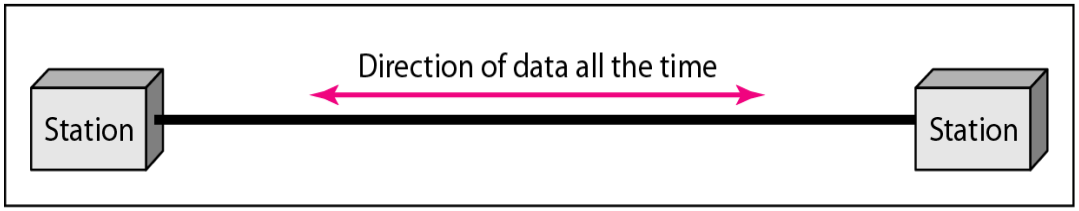
a. Simplex
b. Half-duplex
c. Full-duplex



a. Simplex



b. Half-duplex



c. Full-duplex

Networks

A 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.

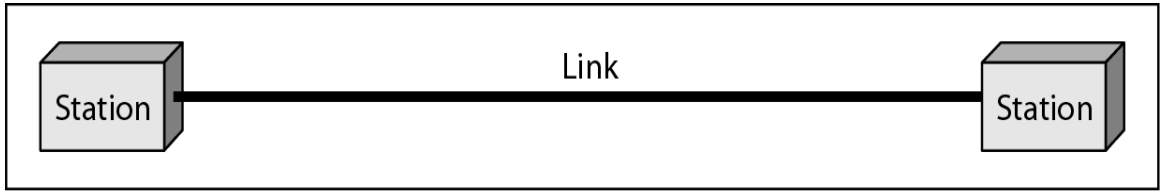
Network Criteria

- 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

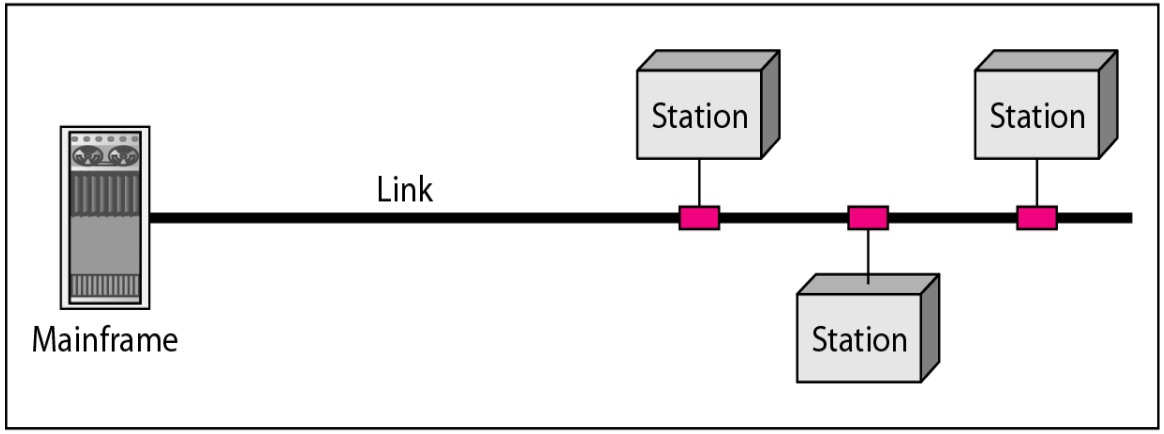
Physical Structures

Type of Connection

a. Point to Point - single transmitter and receiver
b. Multipoint (multidrop) - multiple recipients of single transmission



a. Point-to-point

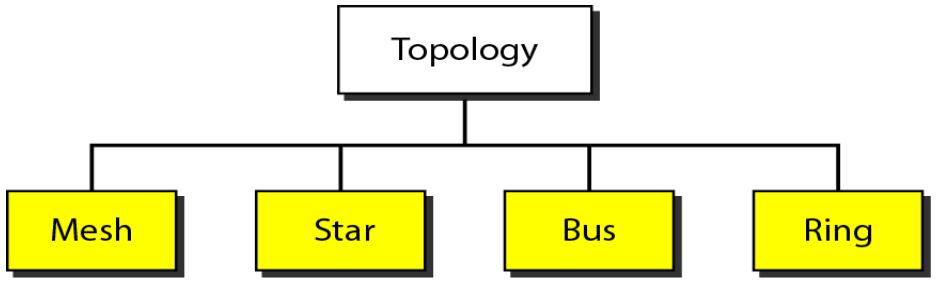


b. Multipoint

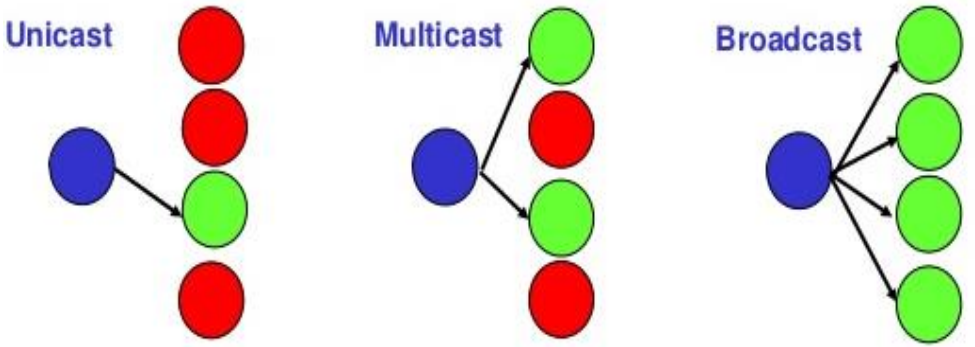
Physical Structures

Physical Topology

- Connection of devices

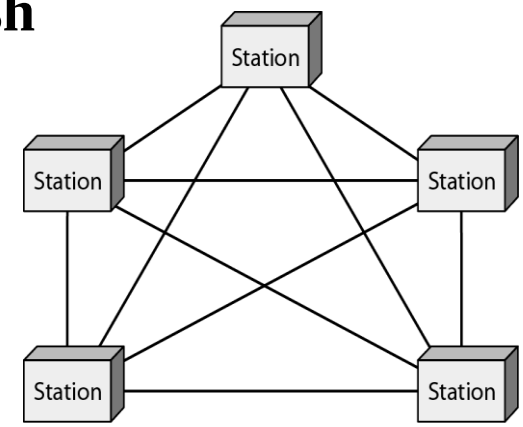


- Type of transmission
  - Unicast,
  - Mulitcast
  - Broadcast

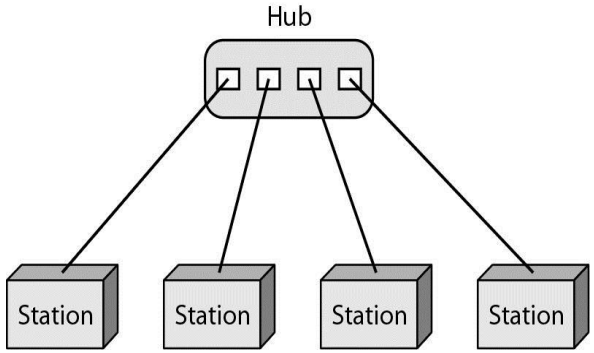


Physical Topology

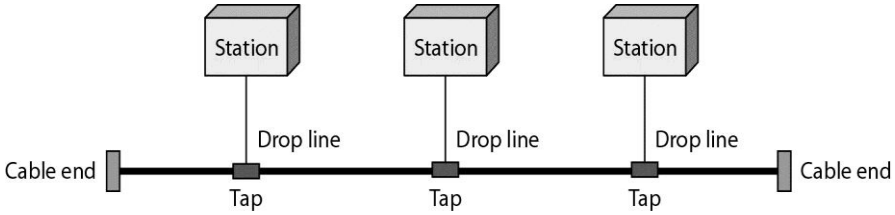
Mesh



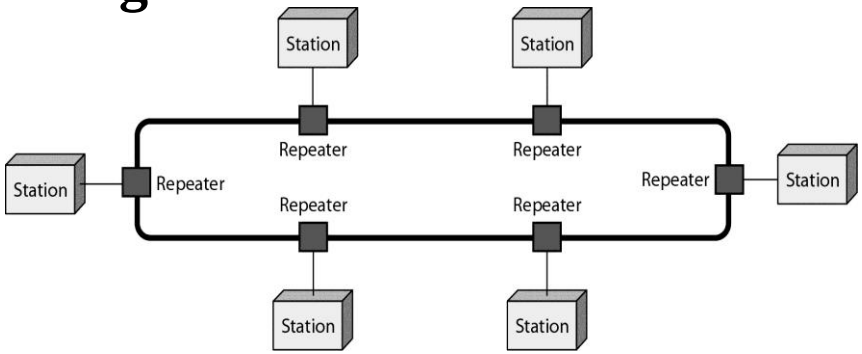
Star



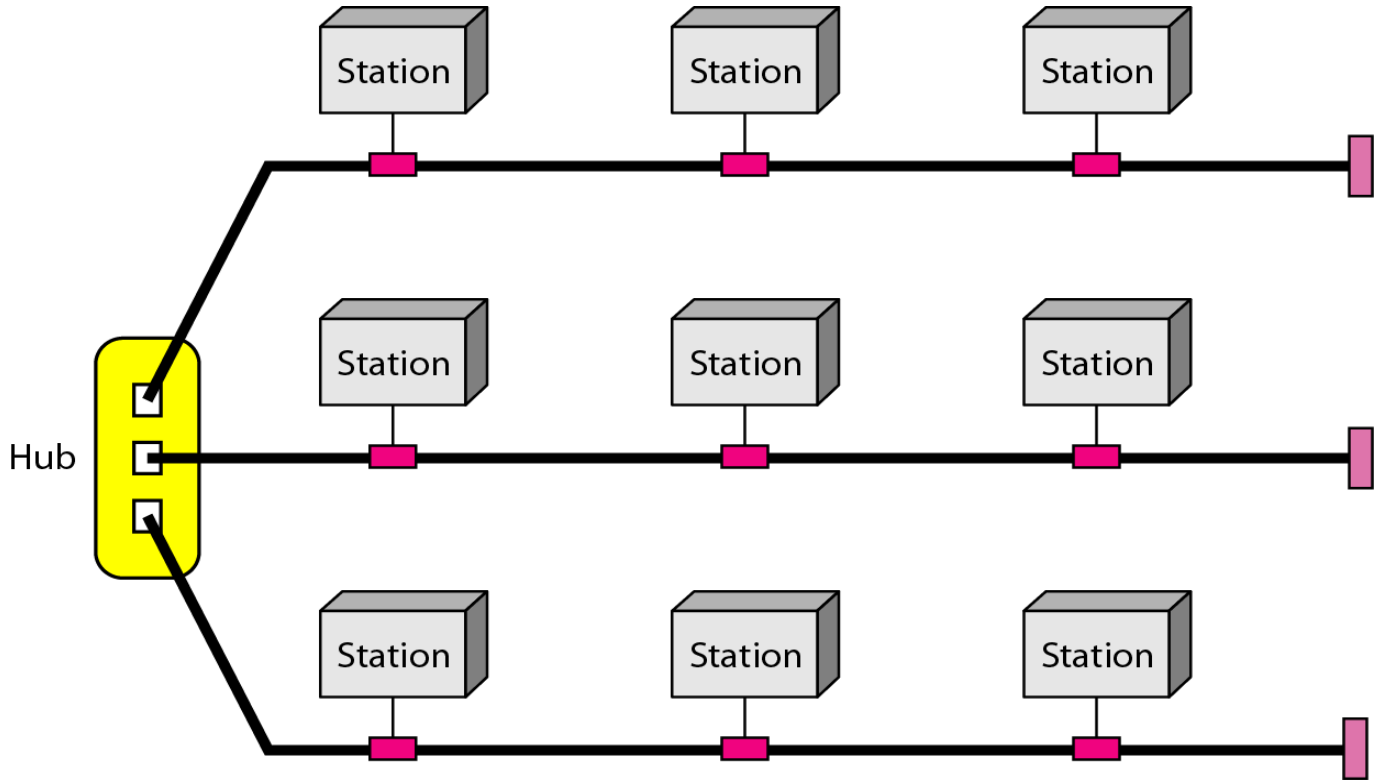
Bus



Ring



A hybrid topology: a star backbone with three bus networks



Categories of Networks

Local Area Networks (LANs)

- Short distances
- Designed to provide local interconnectivity – office, a building or a campus
- Interconnects **hosts**

Wide Area Networks (WANs)

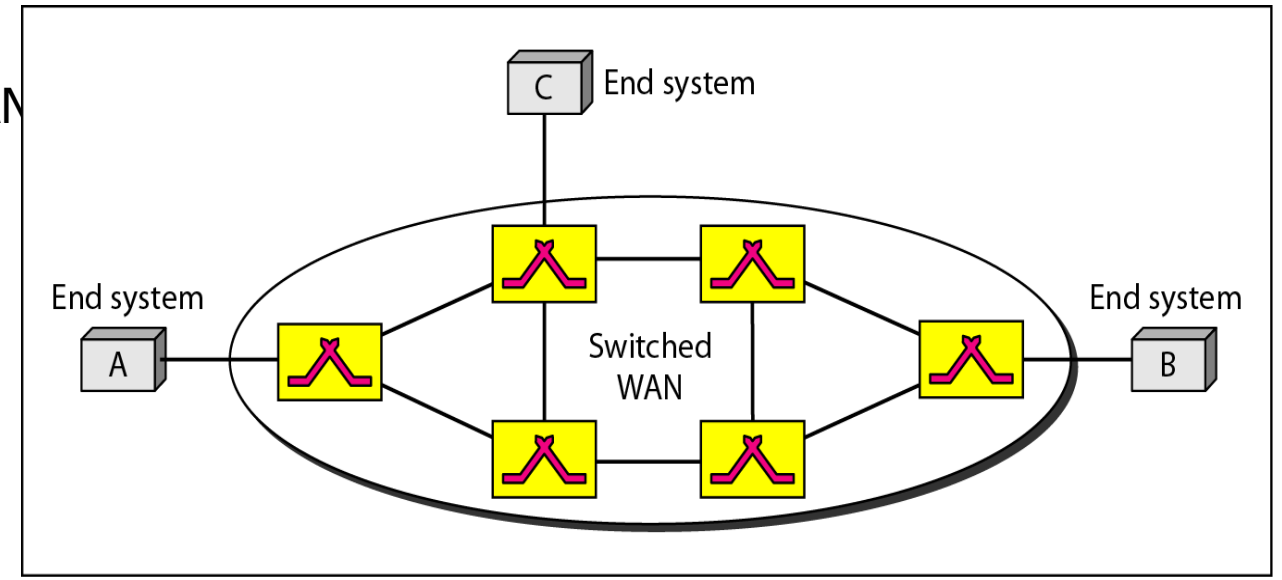
- Long distances
- Provide connectivity over large areas – a town, a state, a country or even world
- Interconnects connecting devices, i. e. **switches, routers, or modem**.

Metropolitan Area Networks (MANs)

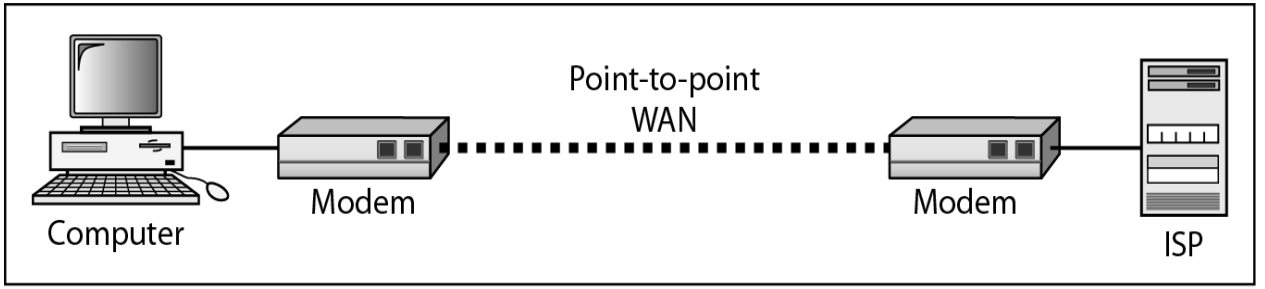
- *Provide connectivity over areas such as a city, a campus*

Type of WAN

a. Switched WAN
b. Point-to-point WAN



a. Switched WAN

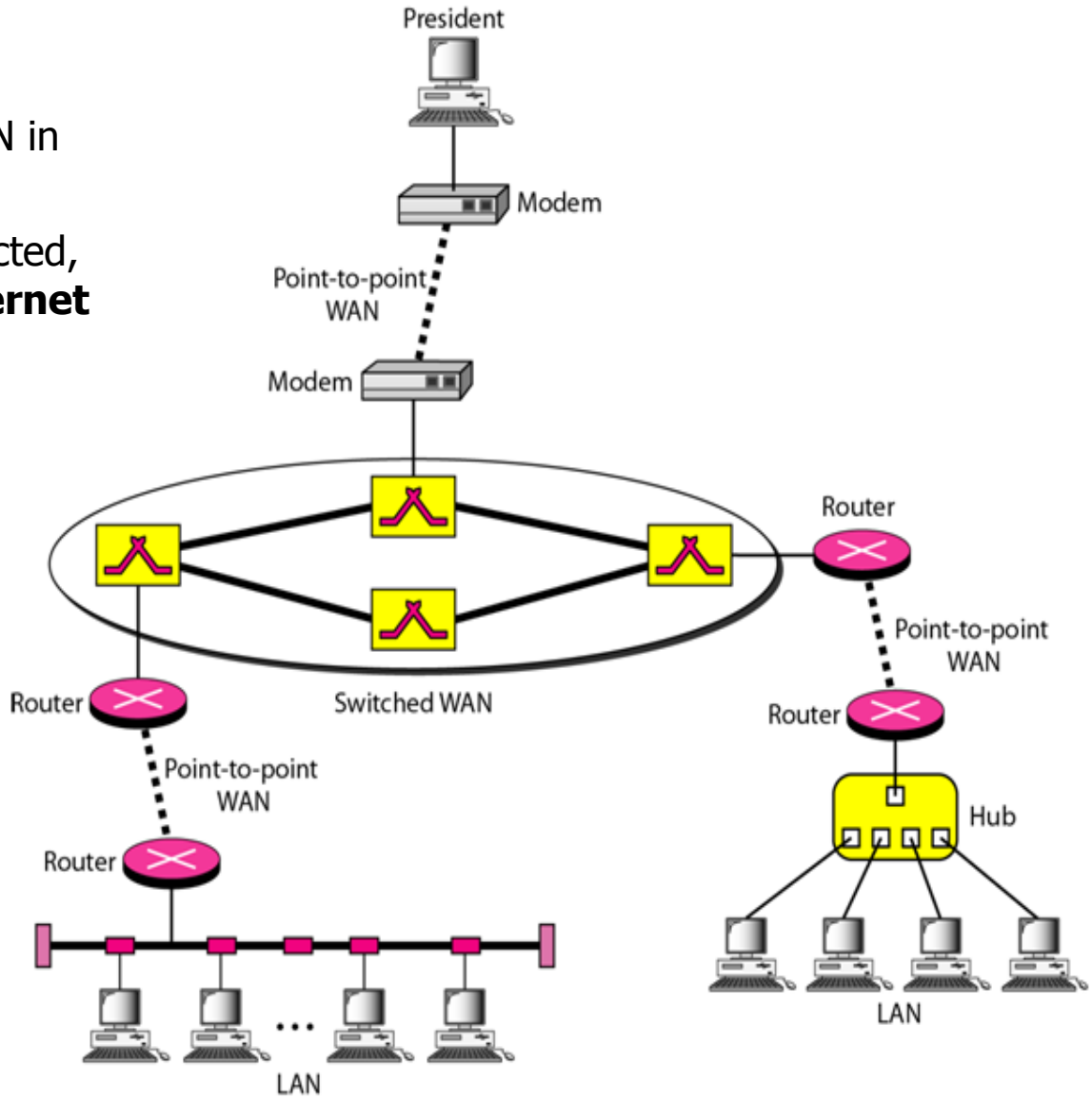


b. Point-to-point WAN

A typical heterogeneous network

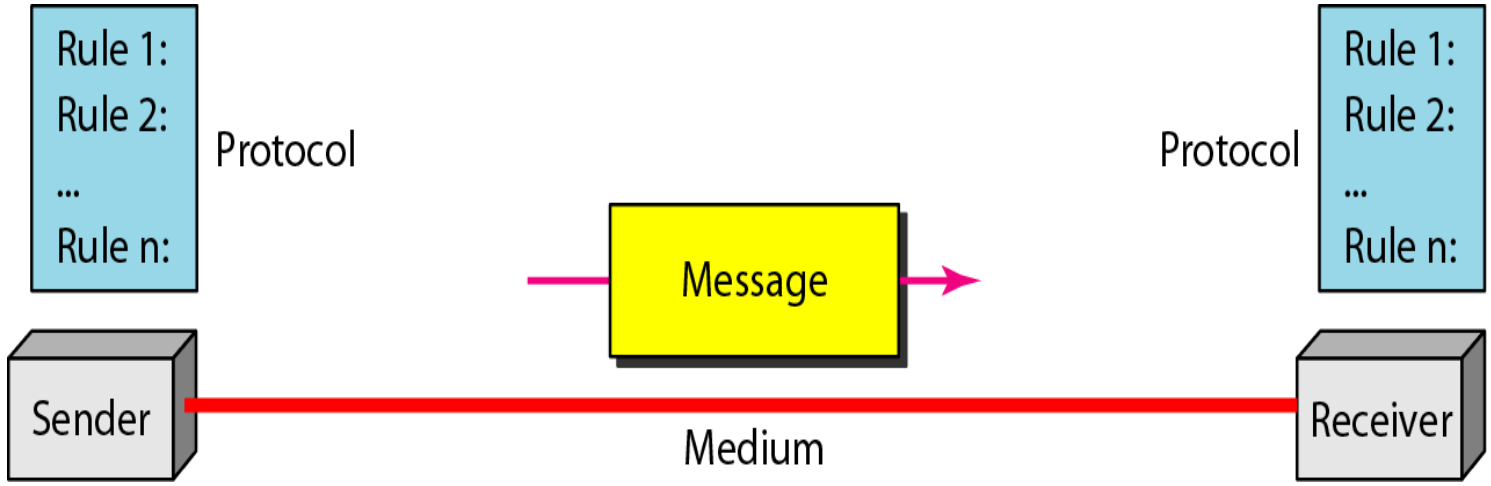
Internetwork

- Very rare to see LAN and WAN in isolation
- Two or more networks connected, forms **internetwork**, or **internet** (with lower case *i*).



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
  - 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
- Speed at which data should be sent or speed at which it is being received.

Few important terms in Networking

- Modem
- Repeater
- Hub
- Bridge
- Switch
- Router
- Gateways

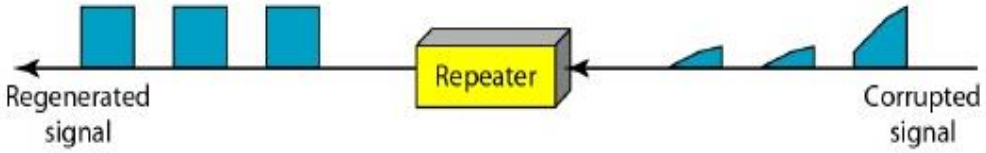
Modem, Repeater

❑ Modem (modulator-demodulator)

- Hardware device works on physical layer
- Can be used with any means of transmitting analog signals
- Modulates one or more carrier wave signals to encode digital information for transmission
- Demodulates signals to decode the transmitted information

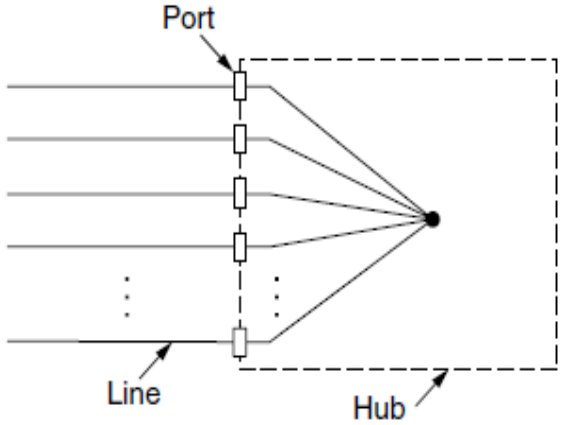
❑ Repeater

- Electronic device that receives a signal and retransmits it
- Used to extend transmissions so that the signal can cover longer distances



Hub

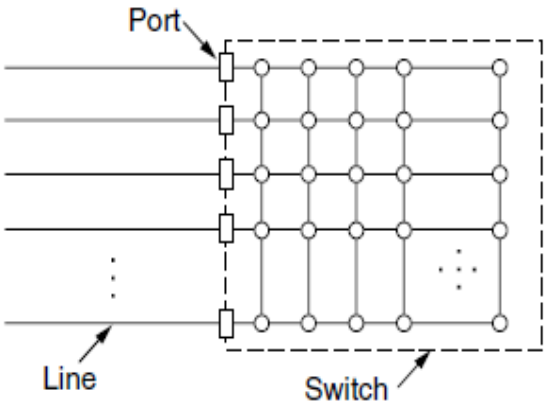
- **Hub (Ethernet hub, network hub, repeater hub, multiport repeater)**
  - Network hardware device for connecting multiple Ethernet devices together
  - Multiple Information Outlet (I/O) ports, in which a signal introduced at the input of any port appears at the output of every port except the original incoming
  - Acts as repeater also

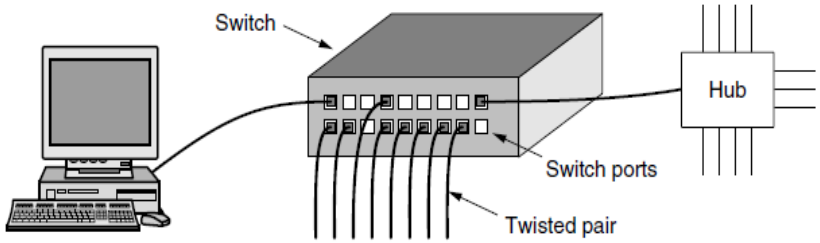


Switch / Bridge

❑ Switch (or Bridge /switching hub, bridging hub, MAC bridge)

- Unlike **Hub**, it forwards data only to one or multiple devices that need to receive it, rather than broadcasting the same data out of each of its ports
- Process and forward data to the destination device on using hardware addresses (at Layer 2)

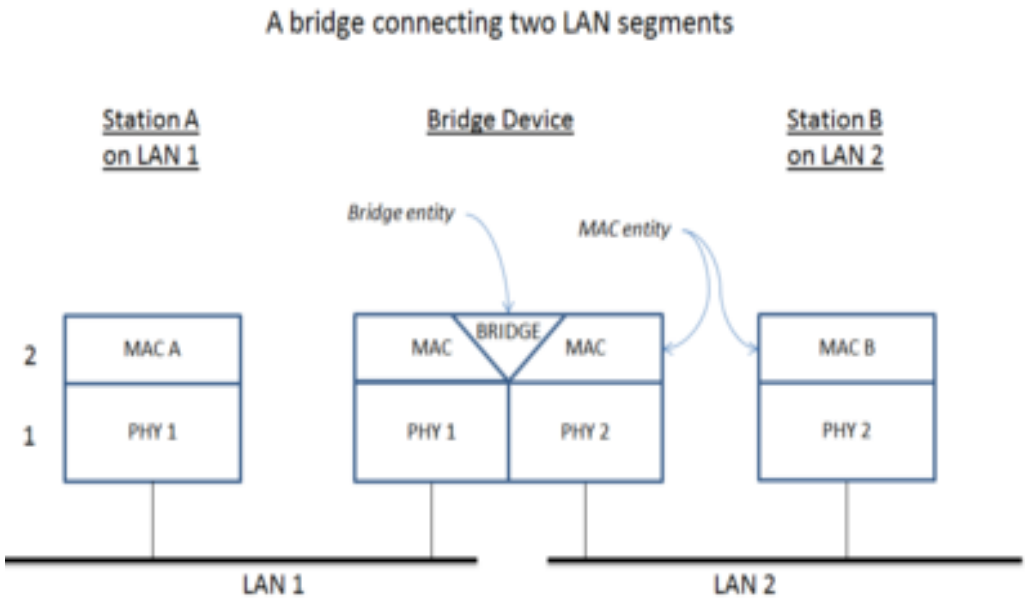




Switch / Bridge (contd)

❑ Switch (or Bridge /switching hub, bridging hub, MAC bridge)

- Creates a single aggregate network from multiple network segments
- Allows multiple different networks (of same type) to communicate independently while remaining separate
- It can perform error checking before forwarding data



Router, Gateways

❑ Router

- Networking device that forwards data packets between computer networks.
- Perform the traffic directing (routing) functions on the Internet.
- A data packet is typically forwarded from one router to another through the networks that constitute the internetwork until it reaches its destination node
- Regulates traffic between similar networks (having same transport protocols like TCP, UDP, SCTP)

❑ Gateway

- Unlike Router, it regulates traffic between dissimilar networks (TCP ←→ SCTP etc)

Protocol Architecture

- Task of communication broken up into modules or layers
- Each layer has specific responsibilities

- Reason for layering – if one layer's implementation changed, other layers not affected if interface remains unchanged

OSI Layers

- OSI Layers (Open Systems Interconnection)

- Developed by International Organization for Standardization (ISO)

- Seven Layers (depending on the complexity of the functionality each of these layers provide.)
  - Application
  - Presentation
  - Session
  - Transport
  - Network
  - Data Link
  - Physical

OSI Layers (contd.)

- Physical Layer
  - Physical interface between data transmission device (e.g. computer) and transmission medium or network
  - Specifies raw transmission details like connectors, medium, voltage levels, encodings used, data rate, etc.

- Data Link Layer
  - Ensures reliable communication between two directly connected nodes
  - Sends blocks of data (frames) with the necessary synchronization, error control, flow control
  - Medium Access Control (MAC)

OSI Layers (contd. 2)

- Network Layer
  - Deals with **routing**: sending packets from source to destination nodes that are not directly connected
  - Packets may not reach in order, can get lost (does not guarantee reliable communication)
  - Congestion Control and Internetworking
  - Some other functions (like fragmentation)

- Transport layer
  - Ensures reliable, in-order delivery between any two applications ensures no frame loss, no error, no duplicate (Error Control, Flow Control)
  - Segmentation & Reassembly
  - Connection Establishment / Release

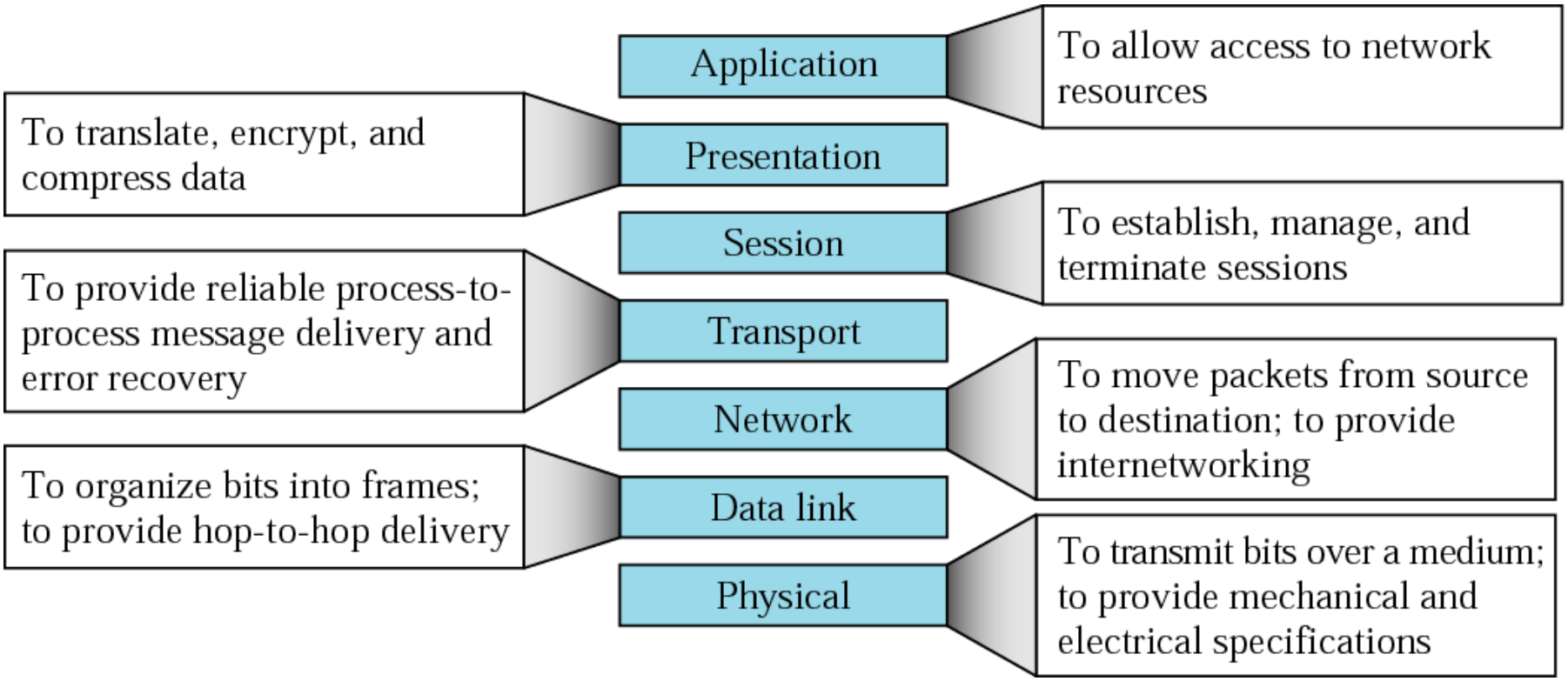
OSI Layers (contd. 3)

- Session layer
  - It deals with the concept of Sessions
  - Controls the dialogues (connections) between computers
  - Synchronization

- Presentation layer
  - Compression and encryption
  - Independence from data representation (Endianness, Basic Encoding Rules(BER) of ASN.1)

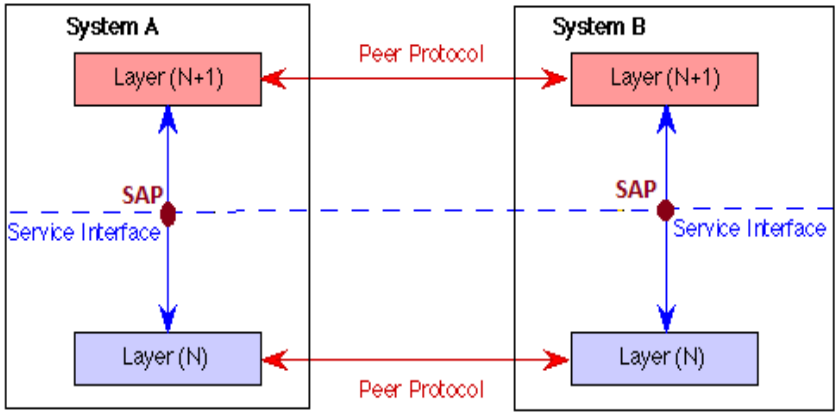
- Application layer
  - Supports user applications (e.g. http, ftp)

OSI Layers in brief



Interface, Protocol & Addressing

- Interface between two layers
  - A Service Access Point (SAP) is a conceptual location at which one OSI layer can request the services of another OSI layer
  - Each layer expects some service from lower layer and provides some service to its higher layer
    - ✓ e.g. application layer expects reliable communication from transport layer (no errors in frames, no lost frames, etc)



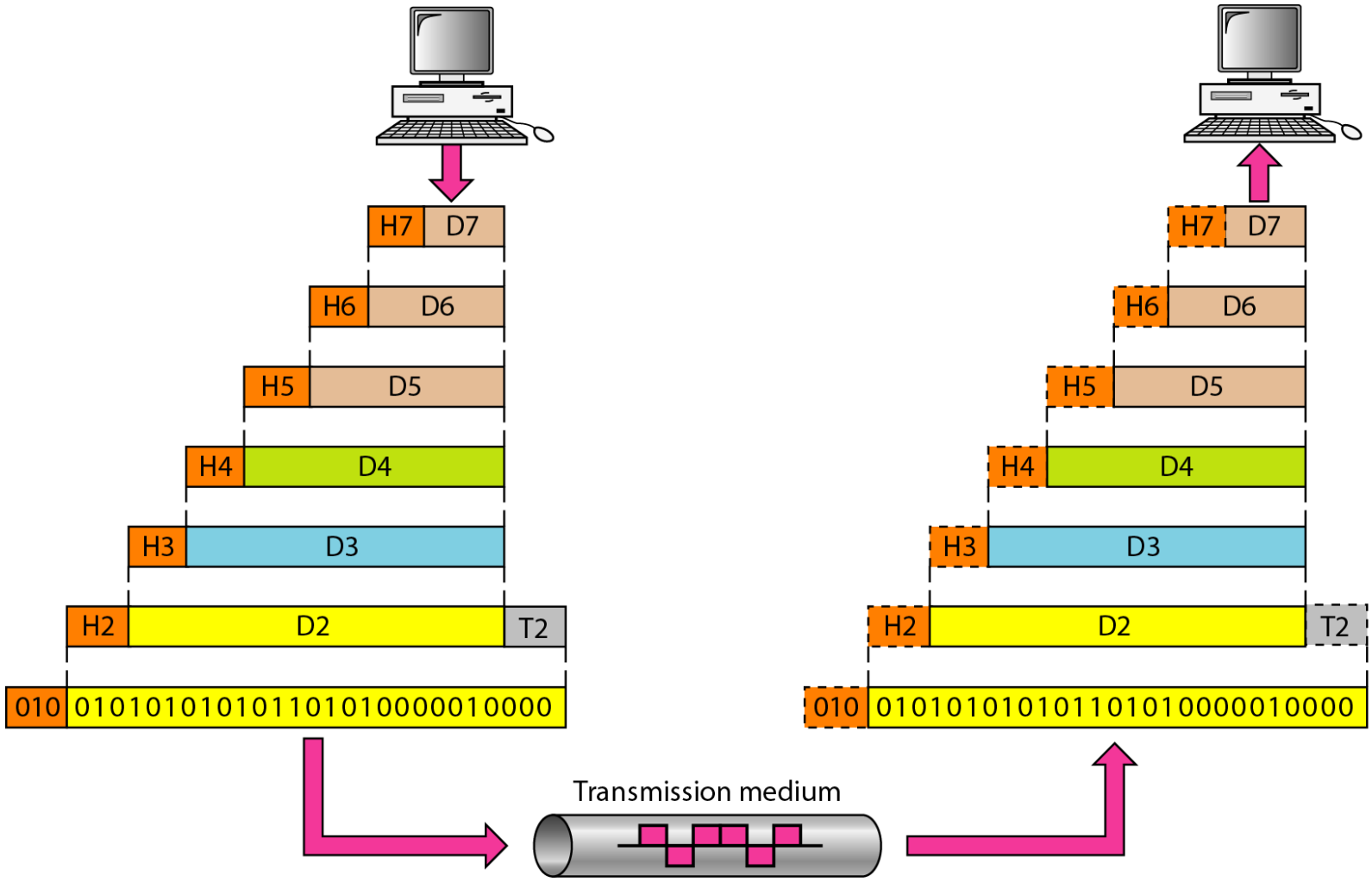
- Protocol – set of rules followed by same layer at different nodes e.g. between the transport layer of Tx and Rx

Protocol Data Units (PDUs)

- Control information added to data at each layer (in the form of header / trailer)
  - Destination node address, sequence number, error detection code, etc
  - Control information added by layer i at transmitter is used by layer i at receiver node

- PDUs called differently at different layers
  - frame in data link layer, packet/datagram in network layer, packet/segment in transport layer, message in application layer

Operation of a Protocol Architecture



PDUs (contd.)

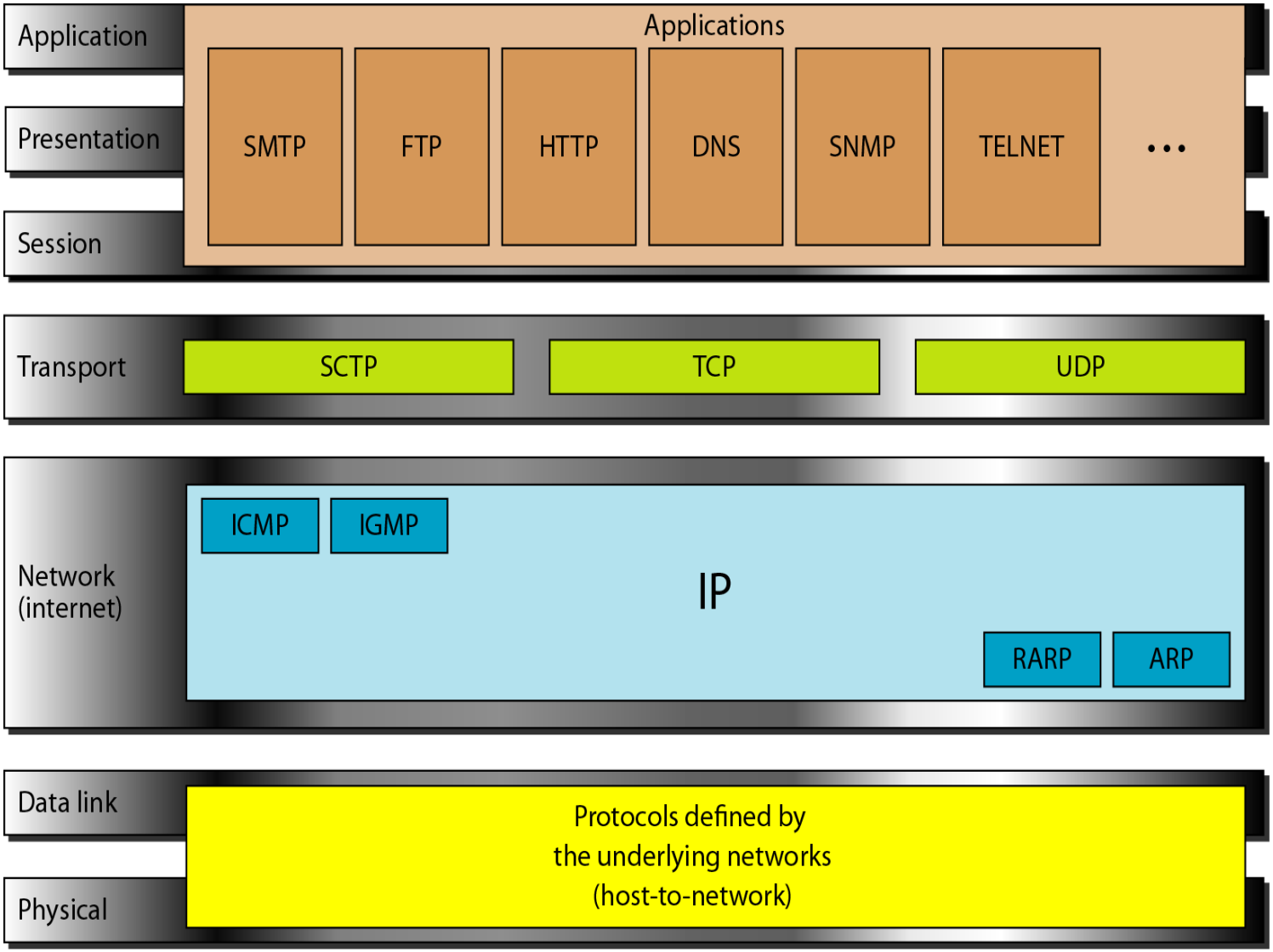
- Encapsulation
  - At Tx: as data goes down, each layer adds header
  - At Rx: as data goes up, each layer takes out its own header, carries out checks, hands up rest to higher layers if ok

- Number of layers to be used
  - More the no. of layers, more headers added as the data goes downwards, more wastage
  - Too few layers – defeats the purpose of layering (isolating functionalities in layers) itself

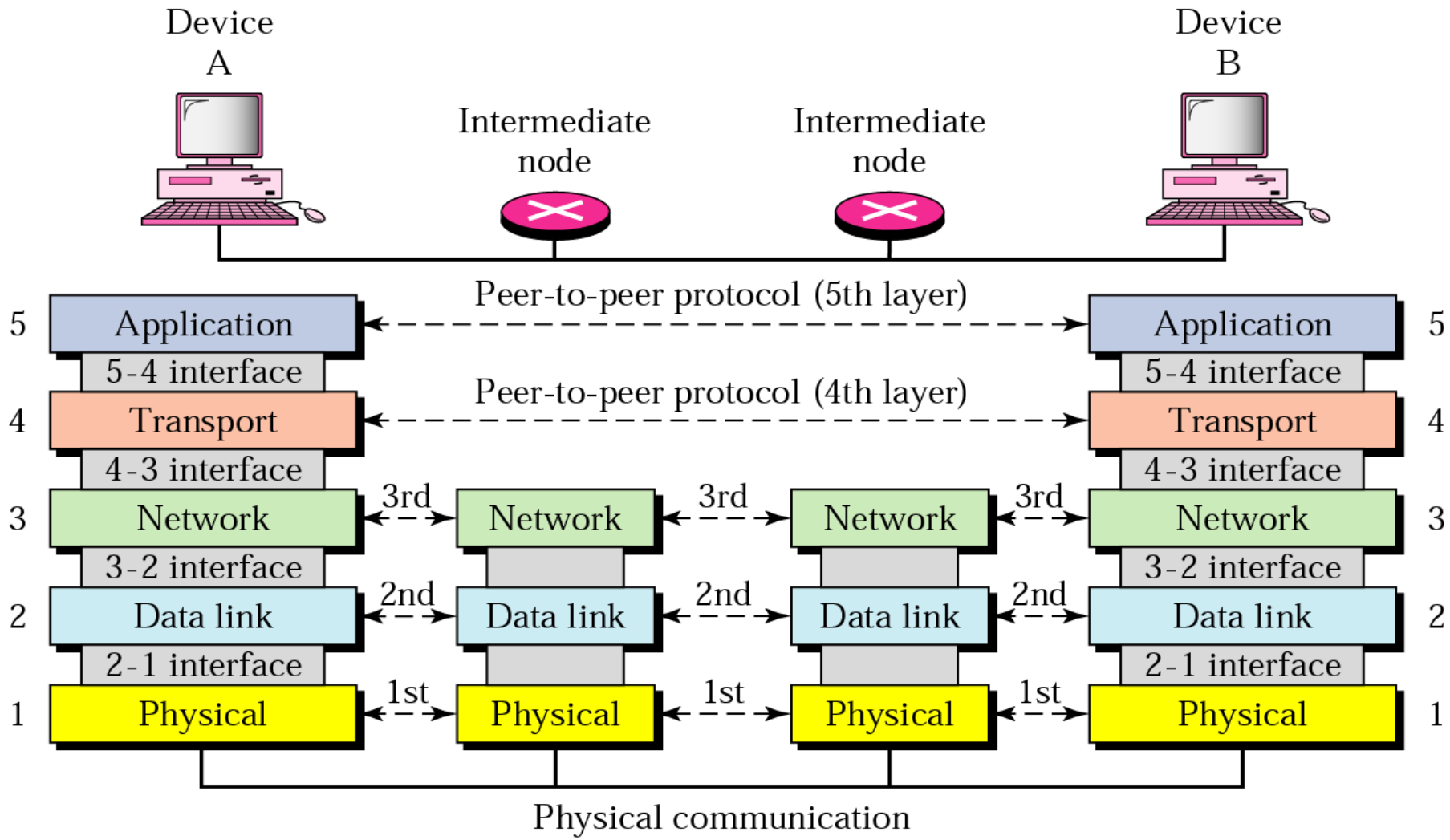
TCP/IP layers

- TCP layers – by US Defense Agency
- De-facto standard (not official, but working model)
- Used by the global Internet
- Five Layers
  - Application
  - Transport
  - Network (Internet)
  - Data Link
  - Physical

OSI model and TCP/IP

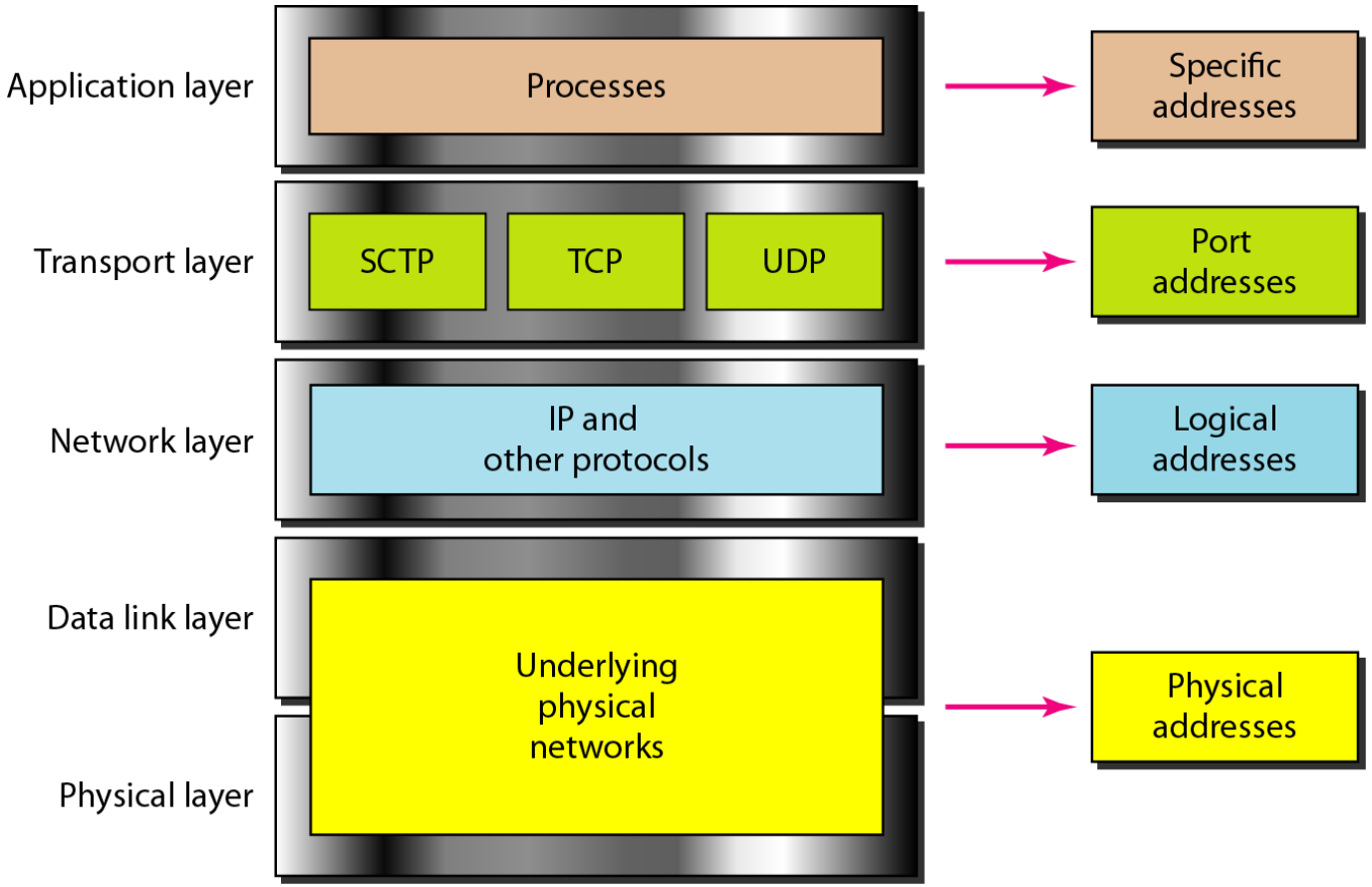


Protocols & Interfaces in TCP/IP stack



Relationship of layers and addresses in TCP/IP

Four levels of addresses are used in an internet employing the TCP/IP protocols: physical, logical, port, and specific.



Physical Address / MAC Address

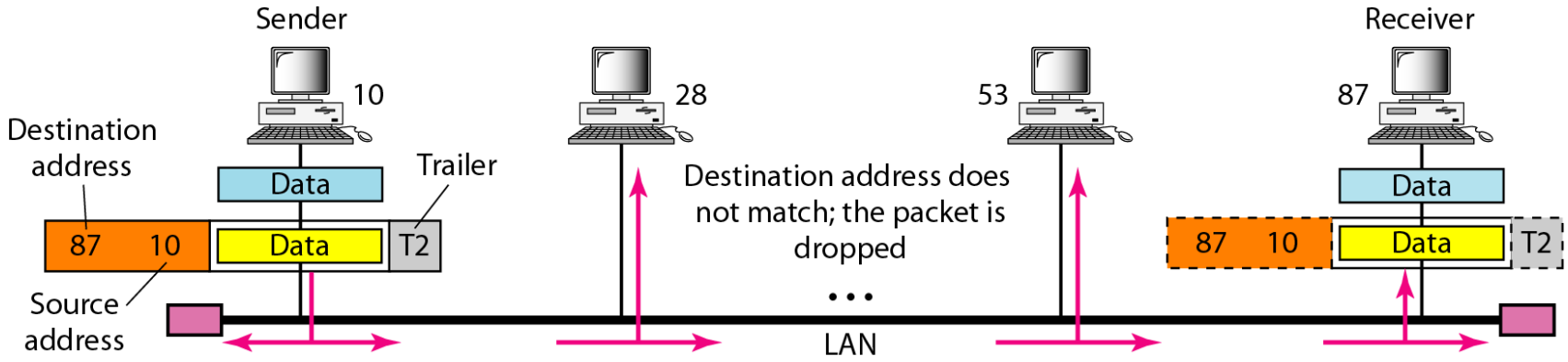
Most local-area networks use a 48-bit (6-byte) physical address written as 12 hexadecimal digits; every byte (2 hexadecimal digits) is separated by a colon, as shown below:

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

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

Data communication within a LAN

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.



Logical Address /IP Address

An Internet Protocol address (IP address) is a numerical label assigned to each node participating in a computer network that uses the Internet Protocol for communication

Two principal functions: host or network interface identification and location addressing

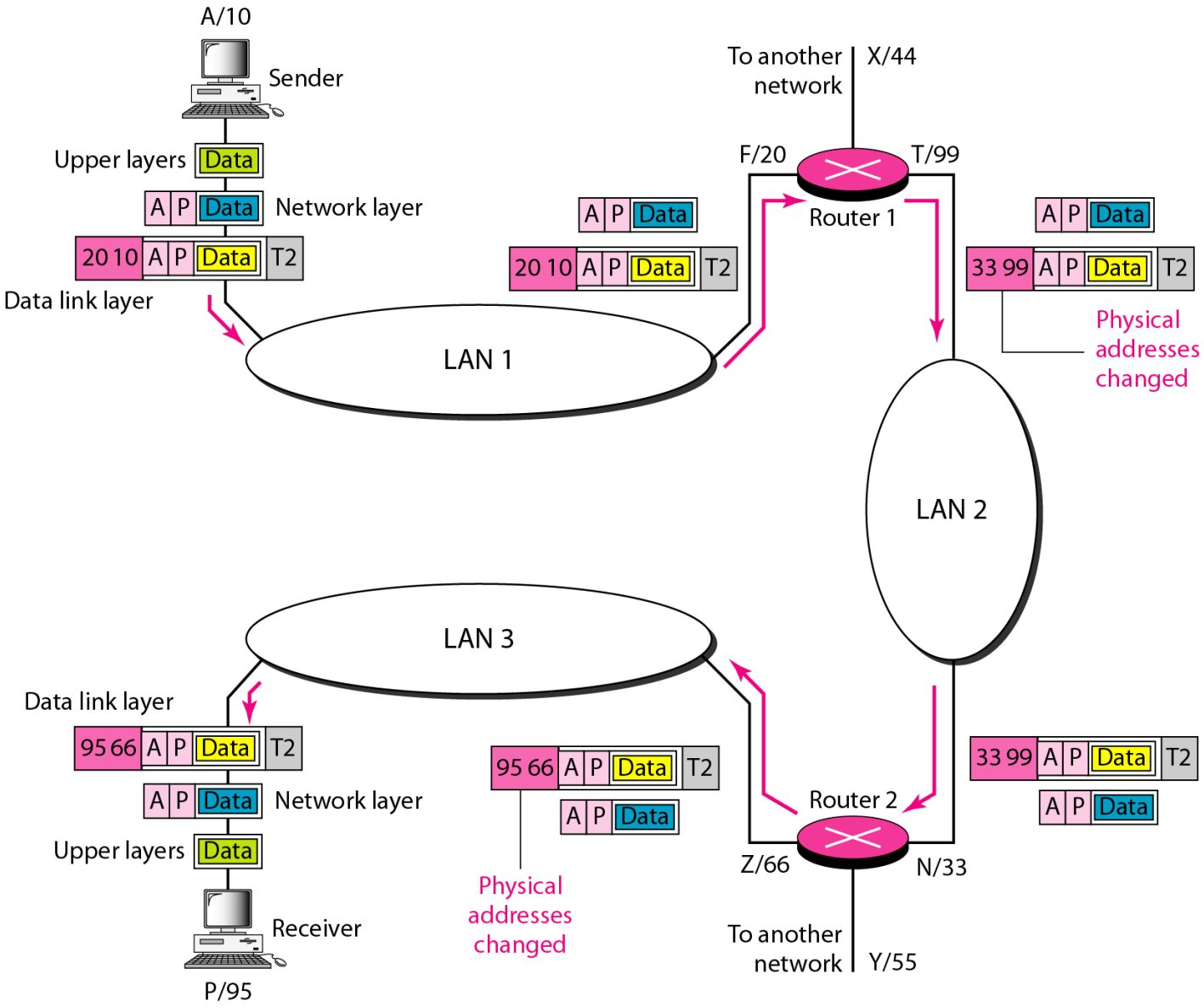
IPv4 : 10.2.1.40
A 4-byte logical address

IPv6 : 2001:db8:0:1234:0:567:8:1
A 16-byte logical address

Data communication across internet

Example shows 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.

Data communication across networks



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

Port addresses

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.

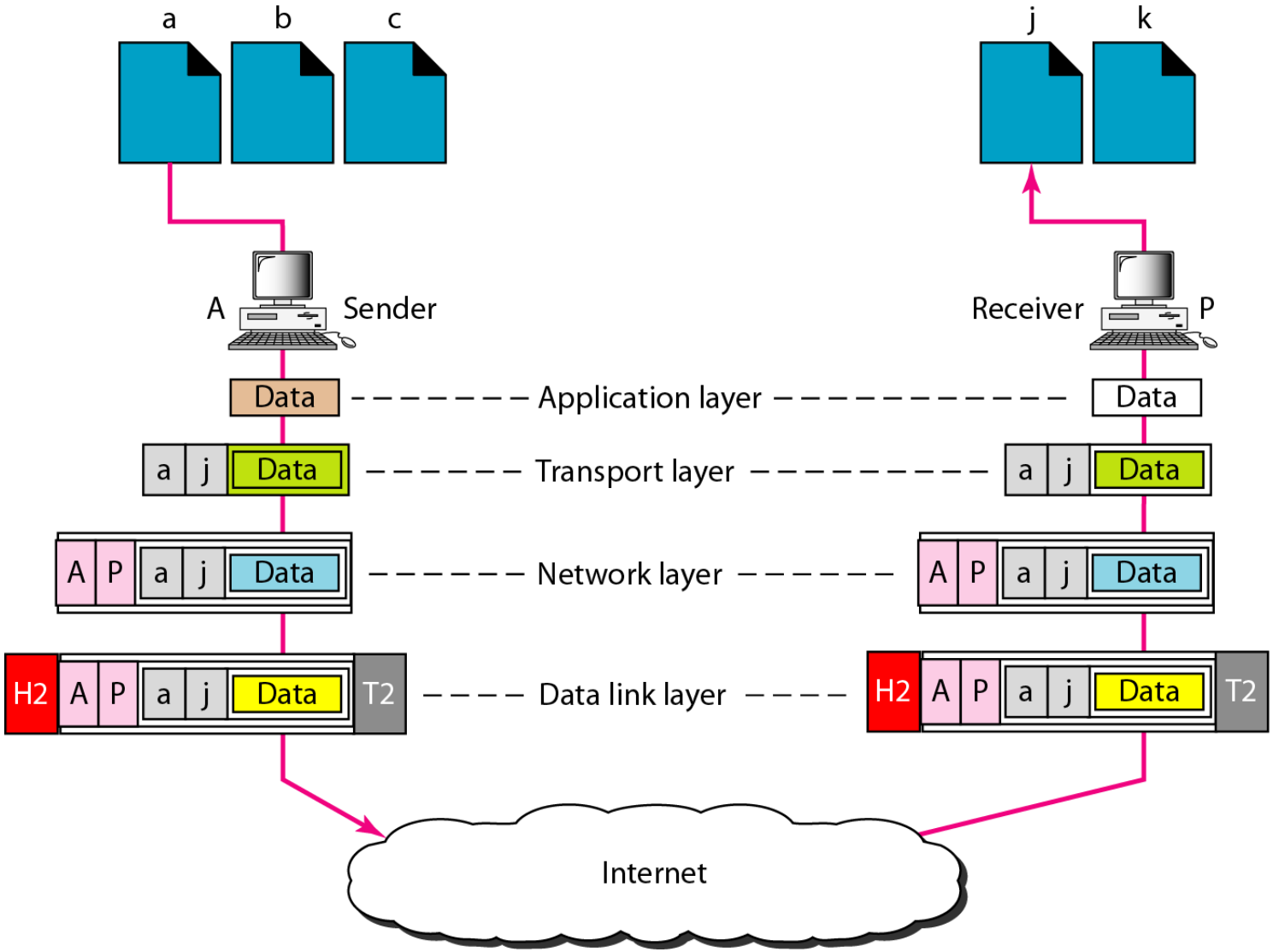
Well known port

```
ftp  : 20
Ssh  : 22
http : 80
```

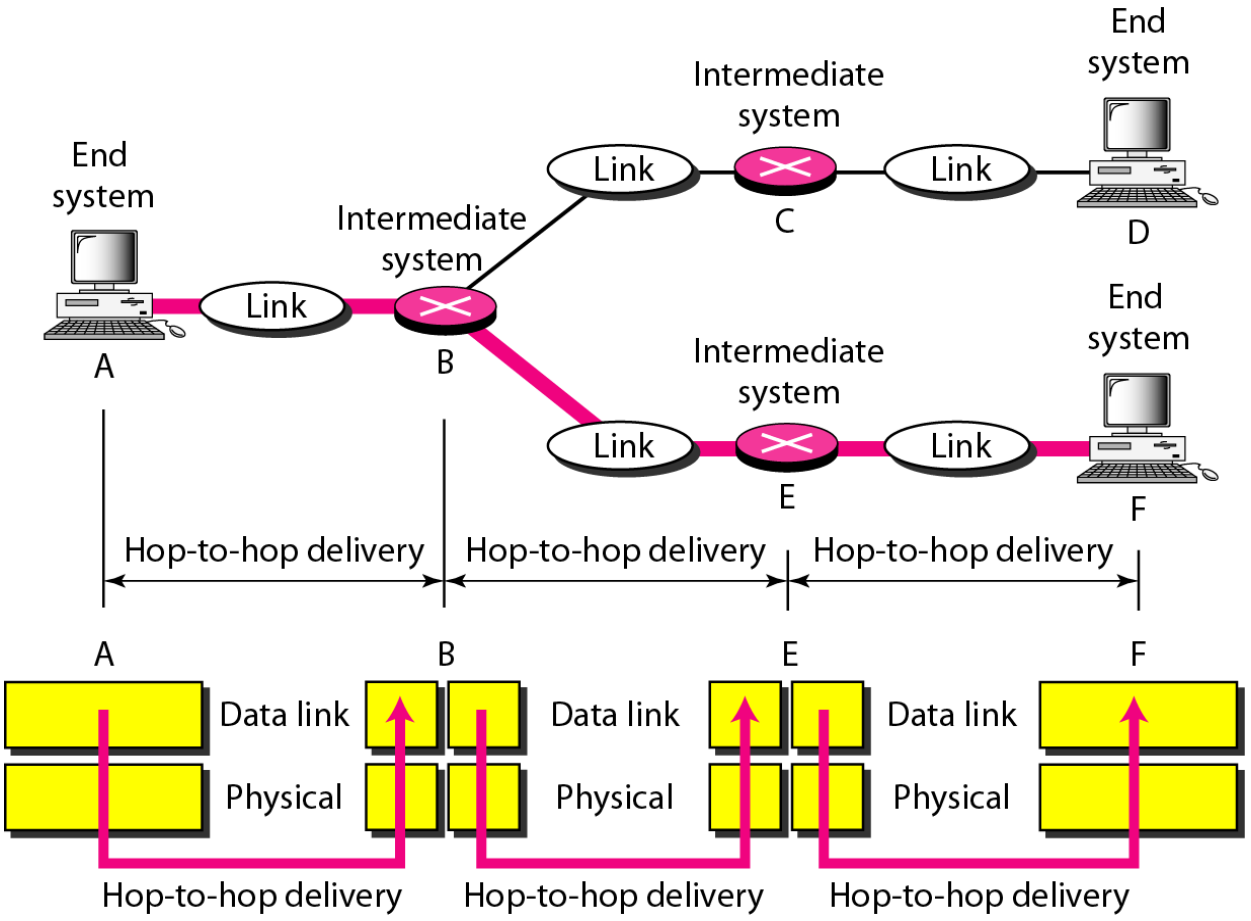
Data communicating via the Internet

Example shows two computers communicating via the Internet. 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.

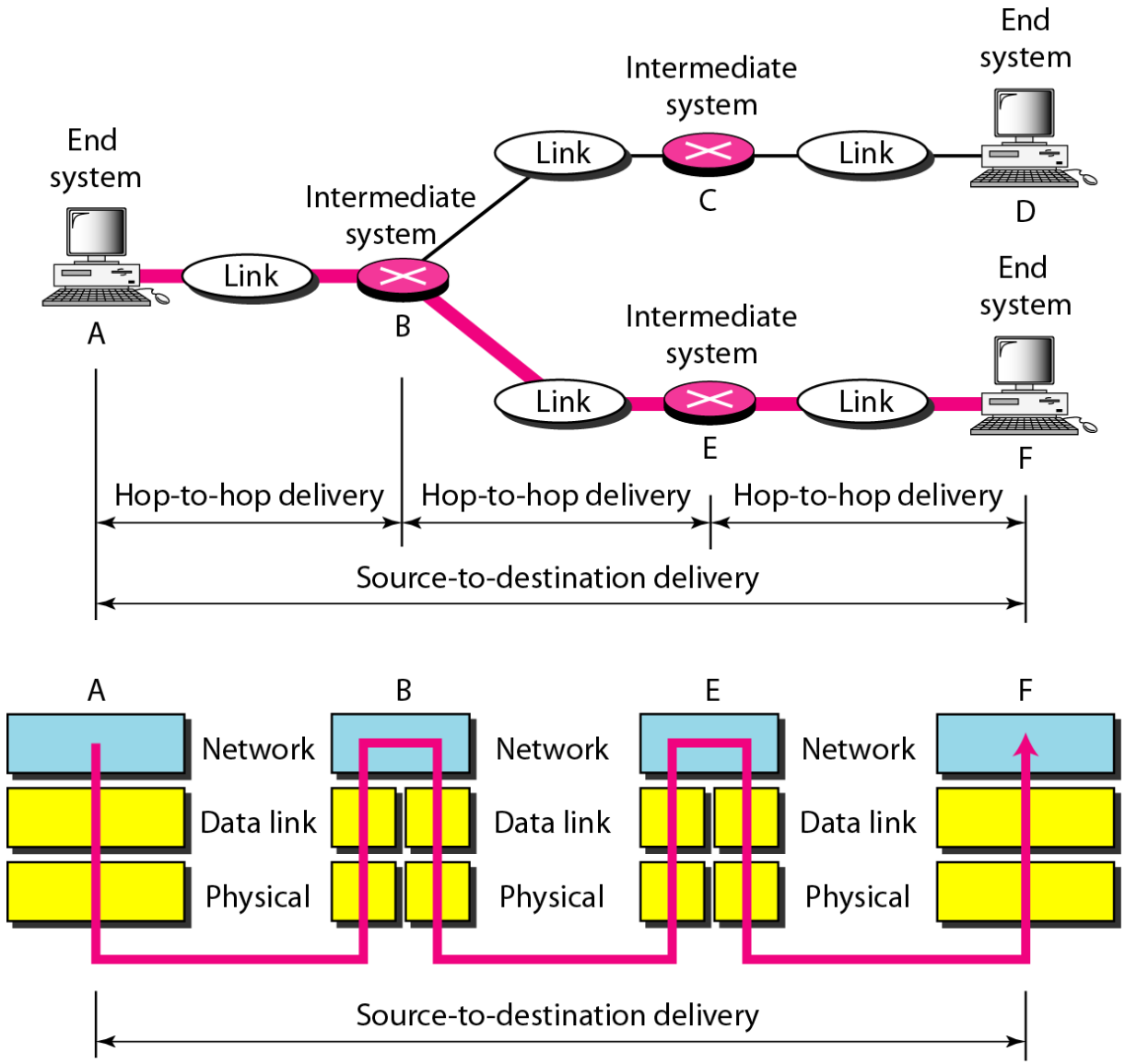
Port addresses



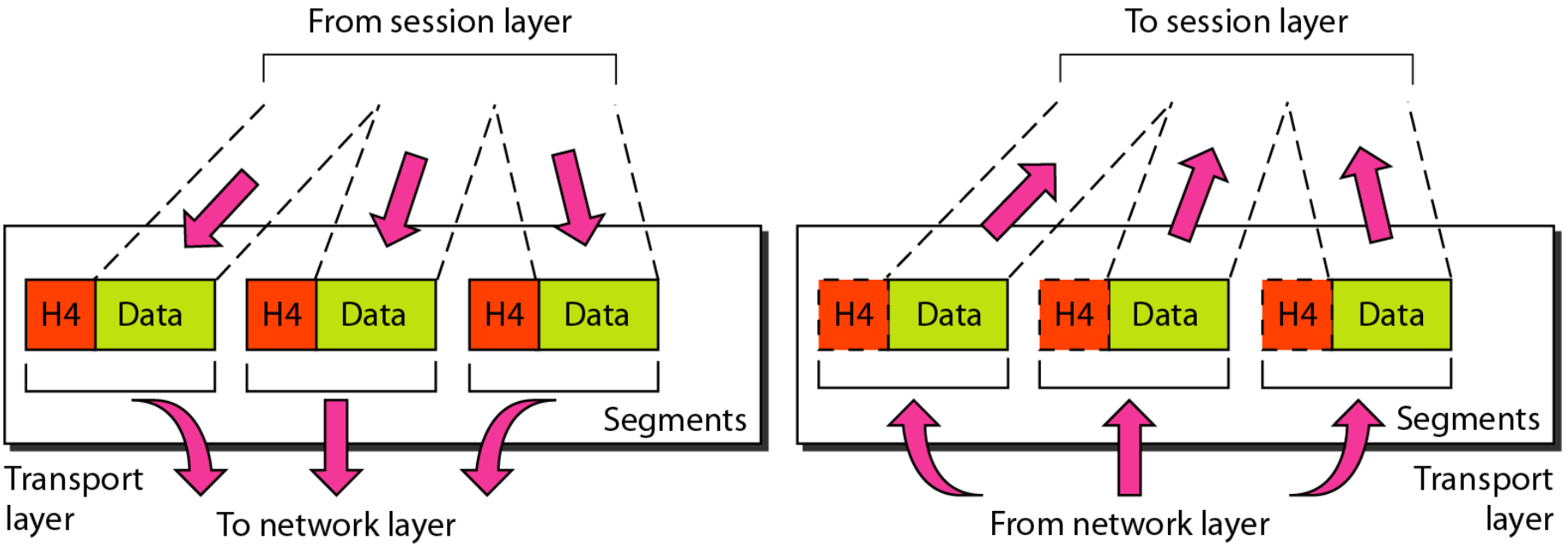
Appendix 1 : Hop-to-hop delivery (L2 switching)



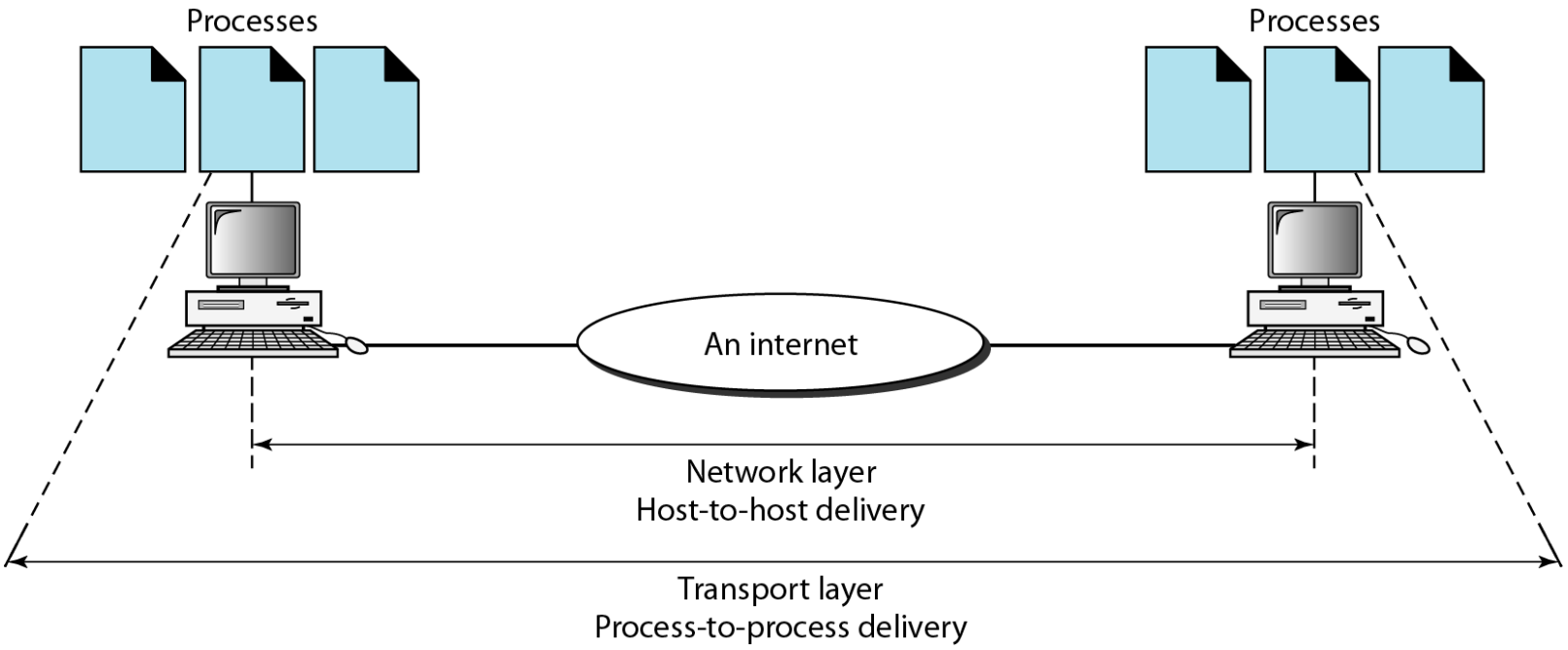
Appendix 2 : Source-to-destination delivery (L3 Switching)



Appendix 3 : Segmentation & Reassembly



Appendix 4: Reliable process-to-process delivery of a message



References

- *Data Communications & Networking, 5th Edition, Behrouz A. Forouzan*
- *Data and Computer Communication, William Stallings*
- *Computer Networks, Andrew S. Tanenbaum and David J. Wetherall*
- *Wikipedia*