Computer Network & Network Design

Module 0

Lecture 1

Prerequisite

Computer Network & Network Design

Course Code	Course Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Practical	Tutorial	Theory	Practical /Oral	Tutorial	Total
ITC402	Computer Network and Network Design	03	--	--	03	--	--	03

Course Code	Course Name	Examination Scheme						
		Theory Marks				Term Work	Pract. /Oral	Total
		Internal assessment			End Sem. Exam			
		Test1	Test 2	Avg.				
ITC402	Computer Network and Network Design	20	20	20	80	--	--	100

Networking Lab

Lab Code	Lab Name	Teaching Scheme (Contact Hours)			Credits Assigned			
		Theory	Practical	Tutorial	Theory	Practical	Tutorial	Total
ITL401	Network Lab	--	02	--	--	01	--	01

Lab Code	Lab Name	Examination Scheme						
		Theory Marks				Term Work	Pract. /Oral	Total
		Internal assessment			End Sem. Exam			
		Test1	Test 2	Avg.				
ITL401	Network Lab	--	--	--	--	25	25	50

Networking Lab

Term Work:

- Term Work shall consist of at least **10** to **12 practicals** based on the given list.
- Term work Journal must include at least **2 assignments**.
- **Term Work Marks:** 25 Marks
  - 15 Marks (Experiment)
  - 5 Marks (Assignments)
  - 5 Marks (Attendance)
- **Practical & Oral Exam: An Oral & Practical exam will be held based on the syllabus.**

Syllabus

Module 0	Prerequisite
Module 1	Introduction to Computer Networks
Module 2	Physical Layer & Data Link Layer
Module 3	Network Layer
Module 4	Transport Layer & Session Layer
Module 5	Presentation Layer & Application Layer
Module 6	Network Design Concepts

Bottom-up Approach

Course Outcomes

Sr. No.	Course Outcomes	Cognitive levels of attainment as per Bloom's Taxonomy
On successful completion, of course, learner/student will be able to:		
1	Describe the **functionalities of each layer of the models** and compare the Models.	L1
2	Categorize the types of transmission media and explain **data link layer concepts, design issues and protocols**.	L2, L3, L4
3	Analyze the **routing protocols** and assign **IP address to networks**.	L4
4	Explain the **data transportation** and **session management** issues and related protocols used for end to end delivery of data.	L1, L2
5	List the **data presentation** techniques and illustrate the client/server model in **application layer** protocols.	L1, L3
6	Use of networking concepts of IP address, Routing, and application services to design a network for an organization	L3

Books

Text Books:

1. Andrew S Tanenbaum, Computer Networks -, 4th Edition, Pearson Education.
2. **Behrouz A. Forouzan, Data Communications and Networking, 4th Edition, Mc Graw Hill education.**

References:

1. S. Keshav, An Engineering Approach to Computer Networks, 2nd Edition, Pearson Education.
2. B. A. Forouzan, “TCP/IP Protocol Suite”, Tata McGraw Hill edition, Third Edition.
3. Ranjan Bose, Information Theory, Coding and Cryptography, Ranjan Bose, Tata McGrawHill , Second Edition.
4. Khalid Sayood, Introduction to Data Compression, Third Edition, Morgan Kaufman.

DATA COMMUNICATION

- *Telecommunication -* Communication at a distance.

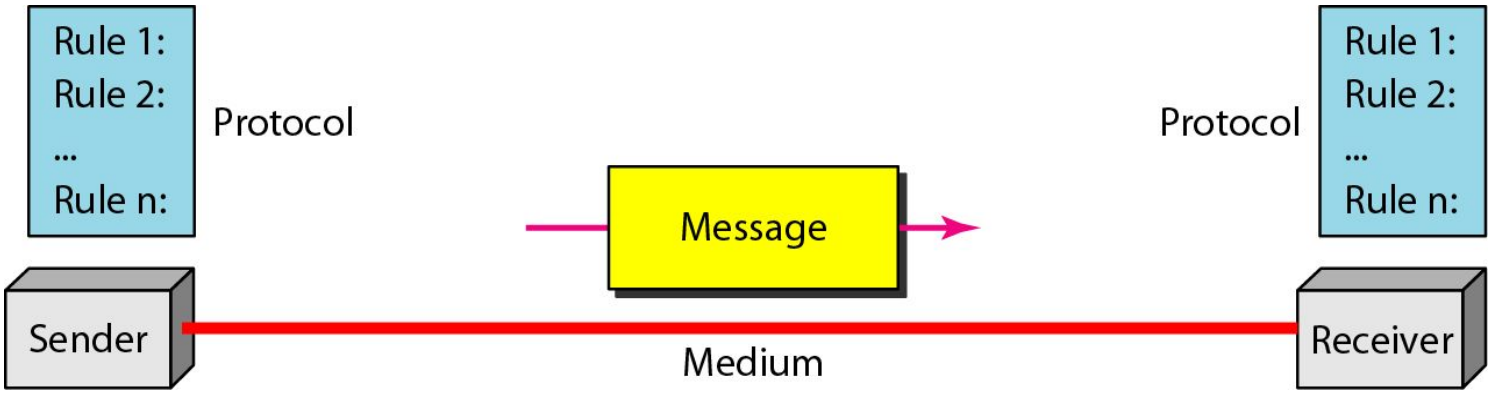
- *Data* – Information, presented in whatever form is agreed upon by the parties creating and using the data.

- *Data communications - E*xchange of data between two devices via some form of transmission medium such as a wire, cable.

Topics discussed in this section:

Components of Data Communication
Data Representation
Data Flow

Five components of data communication

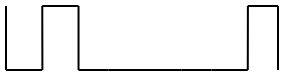


- Message: The information (data) to be communicated.

  E.g. Text, Numbers, Pictures, Audio and Video
- Sender: A device that sends the data message.
- Receiver: A device that receives the message.
- Transmission medium: A physical path by which a message travels from sender to receiver
- Protocol: A set of rules that governs data communications.

Data Representation

- Text:
  - Can be a bit pattern
  - A set of bit patterns can represent different text symbols
  - Each set of bit pattern is called a “Code”. E.g.- 0100 0001- A
  - Process of representing symbol is called “Coding”. E.g.-
  - Popular Coding system is ASCII.



- Numbers:
  - Also represented by bit patterns
  - Different numbering systems are used to convert a number in a bit pattern
- Images:
  - It is a matrix of pixels (a small dot)
  - Number of pixels decide resolution of image
  - Each pixel is assigned a bit pattern
  - Size of bit pattern is decided by type of image (B&W, Gray, color)

Computer Network & Network Design

Module 0

Lecture 2

Prerequisite

Let's Revise

- What are different ways of representing information(data) for communication purpose?

- A color image is represented by 60 pixels each of 32 bits. What is the memory storage required in bytes?

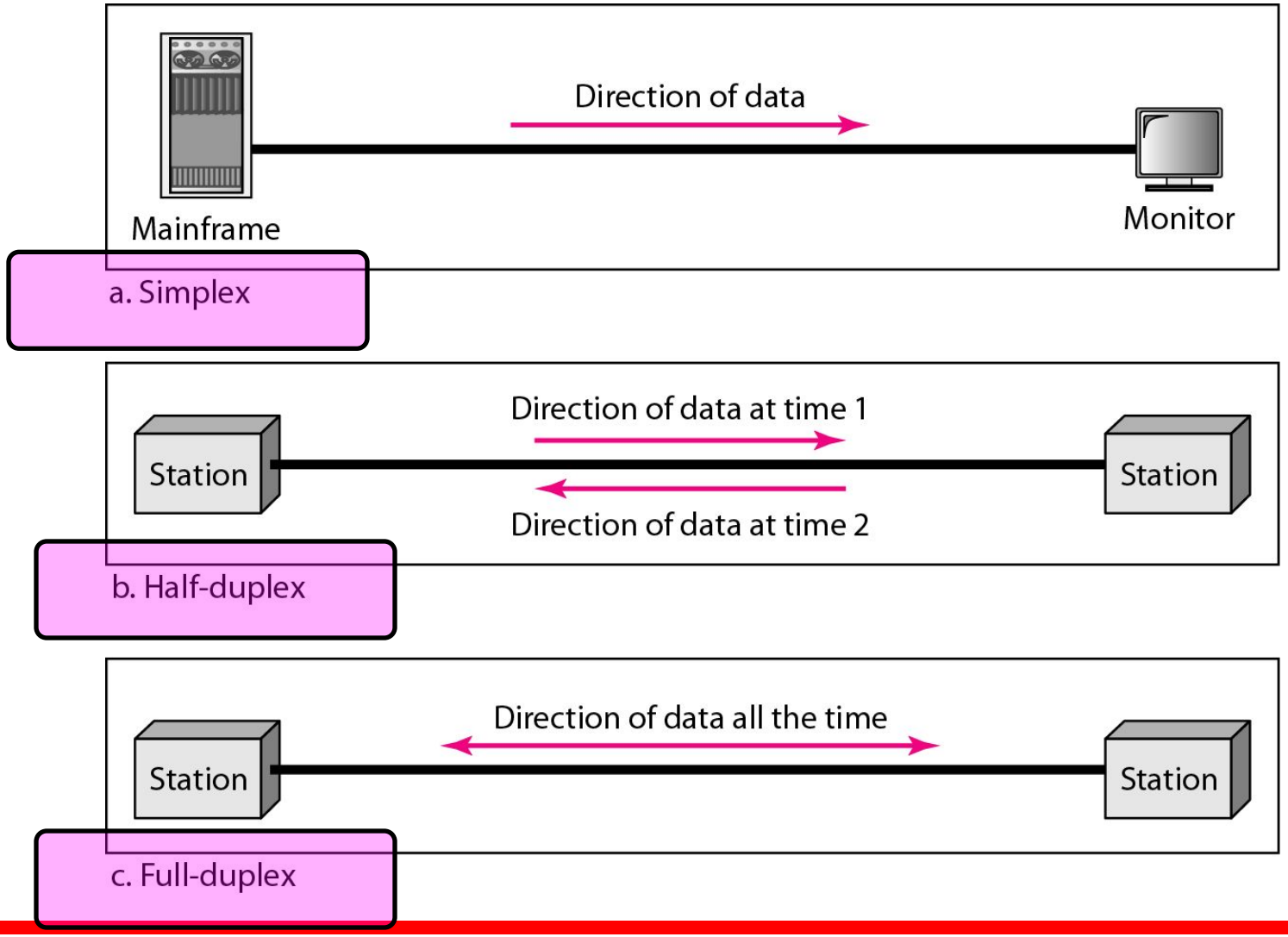
Ans: 240 bytes

Data Representation

- Audio:
  - A recording or broadcasting of sound or music
  - Its a continuous electric signal
  - Can be represented by analog or digital data

- Video:
  - A recording or broadcasting of image or movie
  - Either can be a continuous signal (TV signal) or can be a combination of images arranged to convey motion
  - Can be represented by analog or digital data

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



NETWORKS

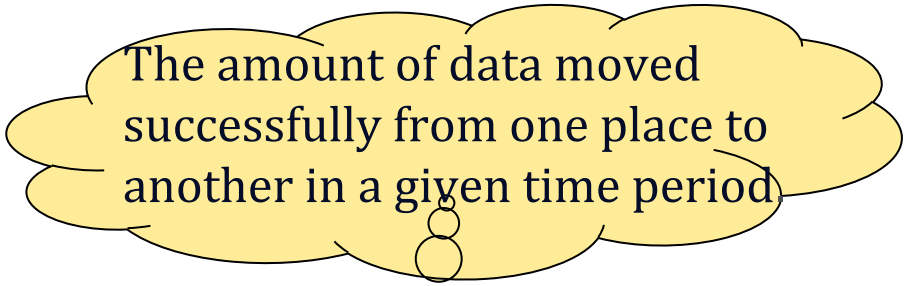
- A **network** is a set of devices (often referred to as nodes) connected by communication links.

- 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.

Topics discussed in this section:

Network Criteria
Physical Structures
Network Models
Categories of Networks
Interconnection of Networks: Internetwork

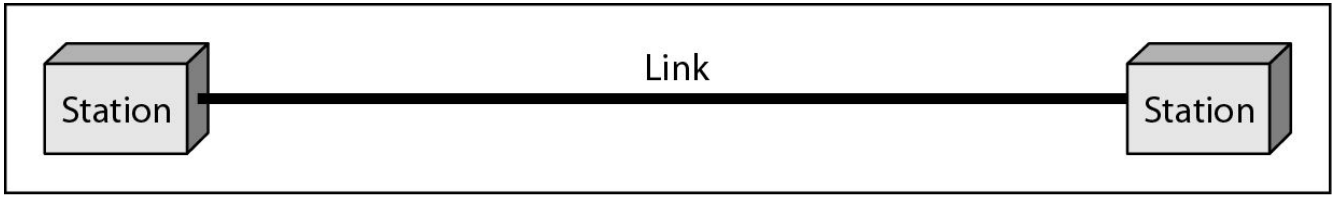
Network Criteria



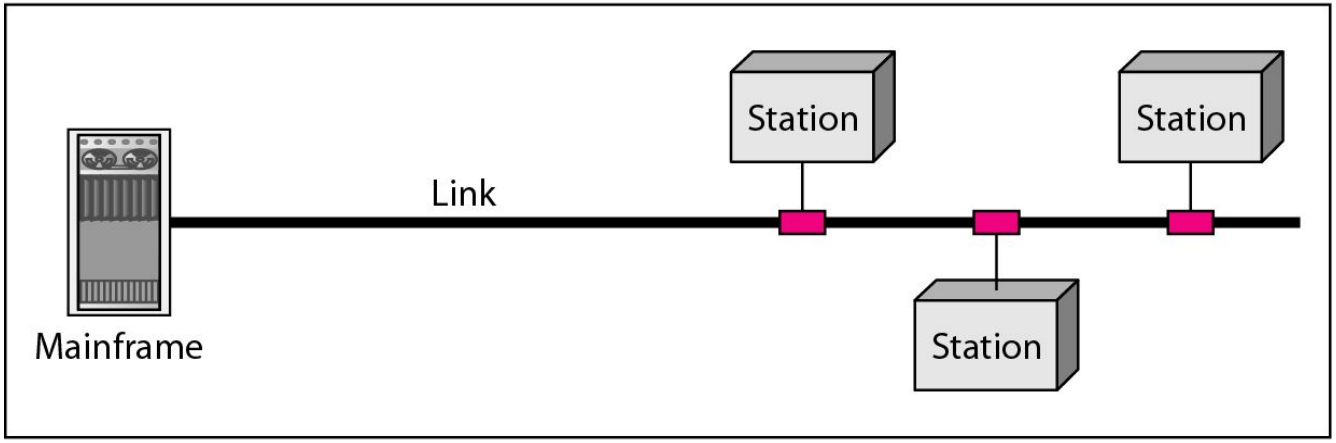
- **Performance**: more throughput and less delay
- **Reliability:** A measure of frequency of failure and the time it takes to recover from it
- **Security:** Protection of data from unauthorized access, damage, loss and implementation of procedures for recovery of such data

Physical Structures

- Type of Connection
  - Point to Point
  - Point to Multipoint



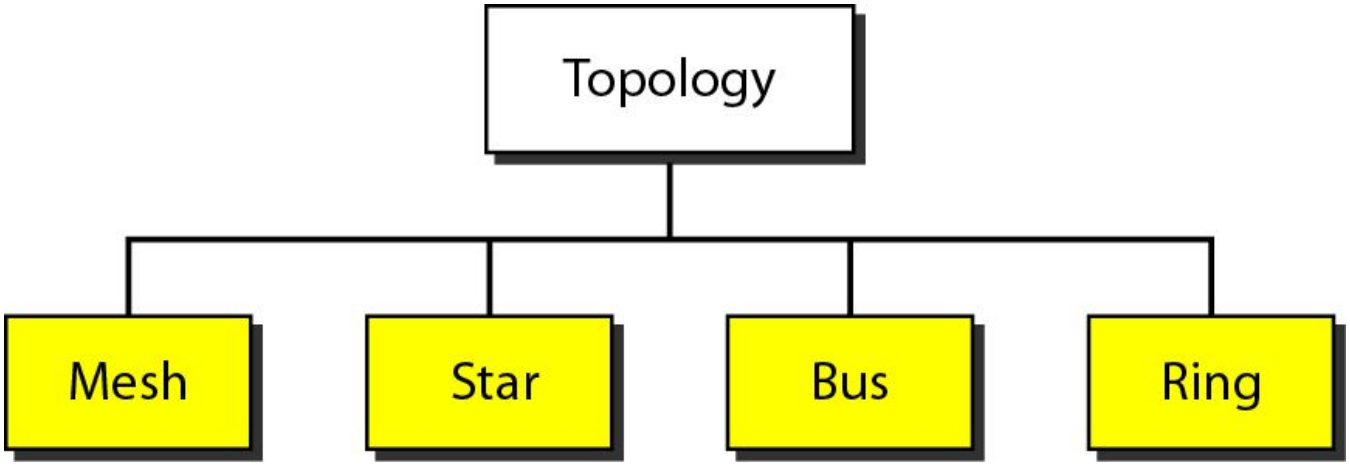
a. Point-to-point



b. Multipoint

Physical Structures

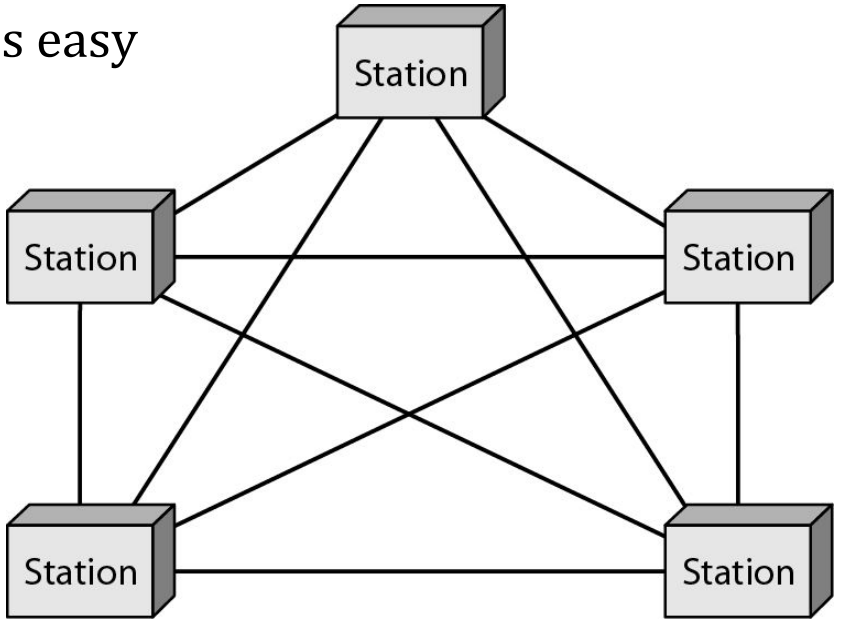
- Physical Topology
  - Topology is the geometric representation of the relationship of all the links and nodes to one other.



Categories of topology

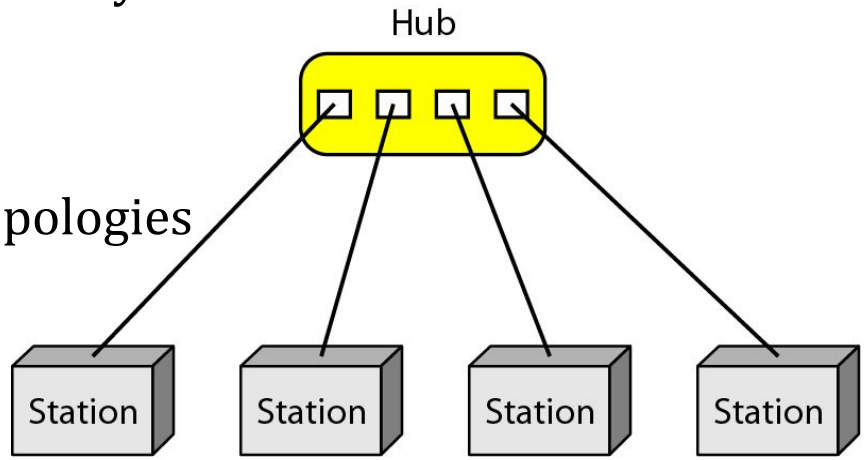
Mesh topology

- Every device has a dedicated point to point link to every other device
- Advantages
  - Less traffic problems due to dedicated links
  - Robust topology. Failure in one link do not affect entire network
  - More Secure and privacy is maintained
  - Fault identification and resolution is easy
- Disadvantages
  - Complex cabling
  - Reconnection and installation is complex
  - Expensive
- Example
  - telephone regional offices

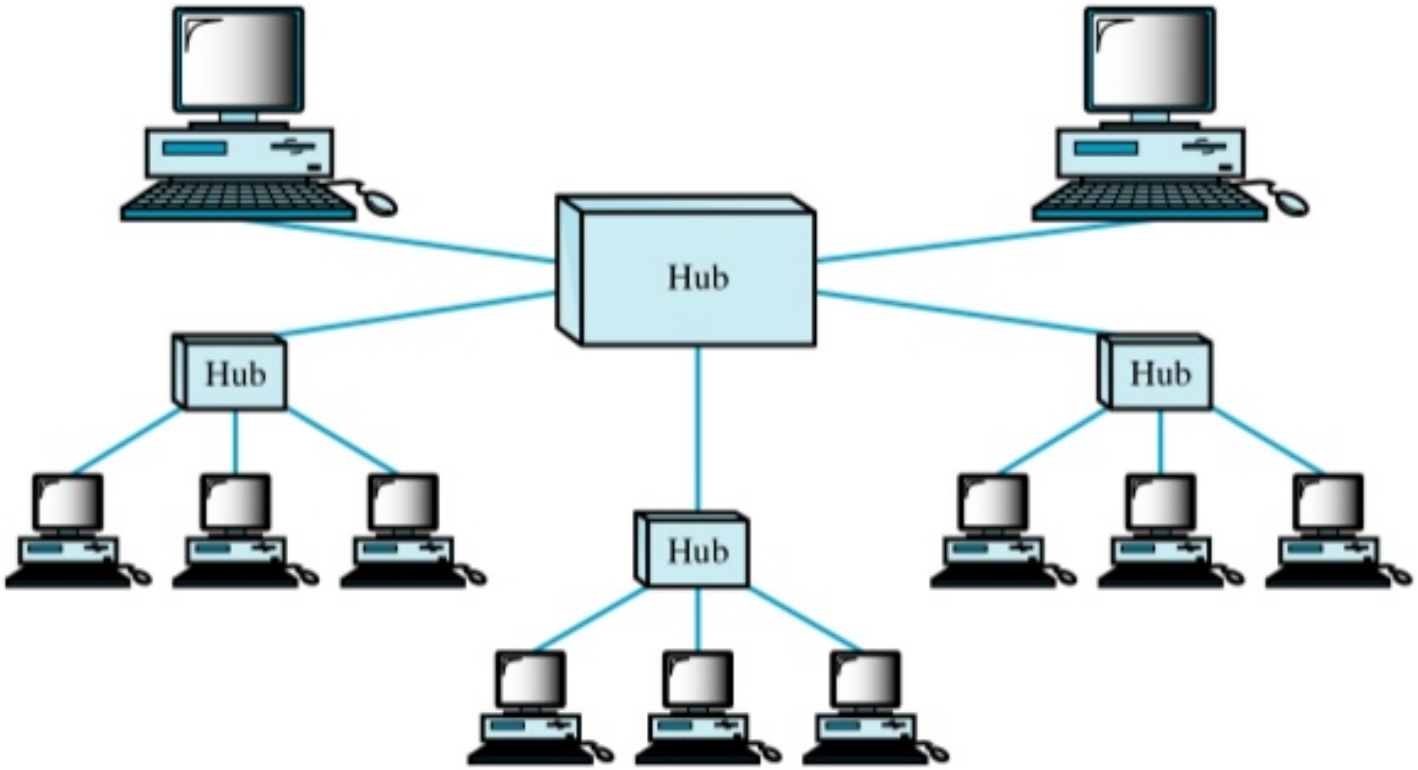


Star topology

- Each device has a dedicated point to point link only to a central controller, called **Hub**
- Advantages
  - Less expensive
  - Each device needs only one i/o port and one link, thus reconfiguration and installation is easy
  - Robust, failure in one link do not affect entire network
  - Fault identification and isolation is easy
- Disadvantages
  - Dependency on Hub
  - More cabling than ring and bus topologies
- Example
  - Used widely in LAN networks

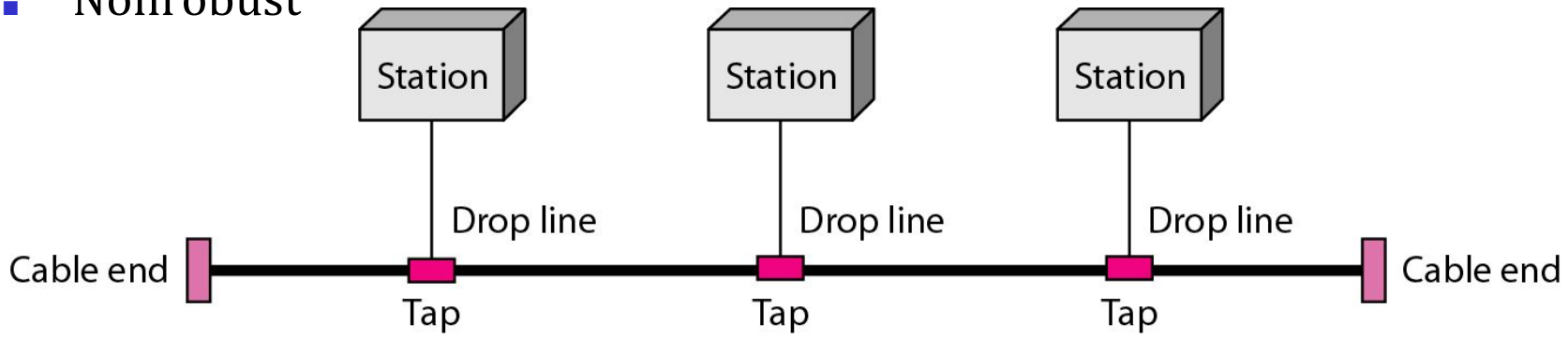


Tree Topology



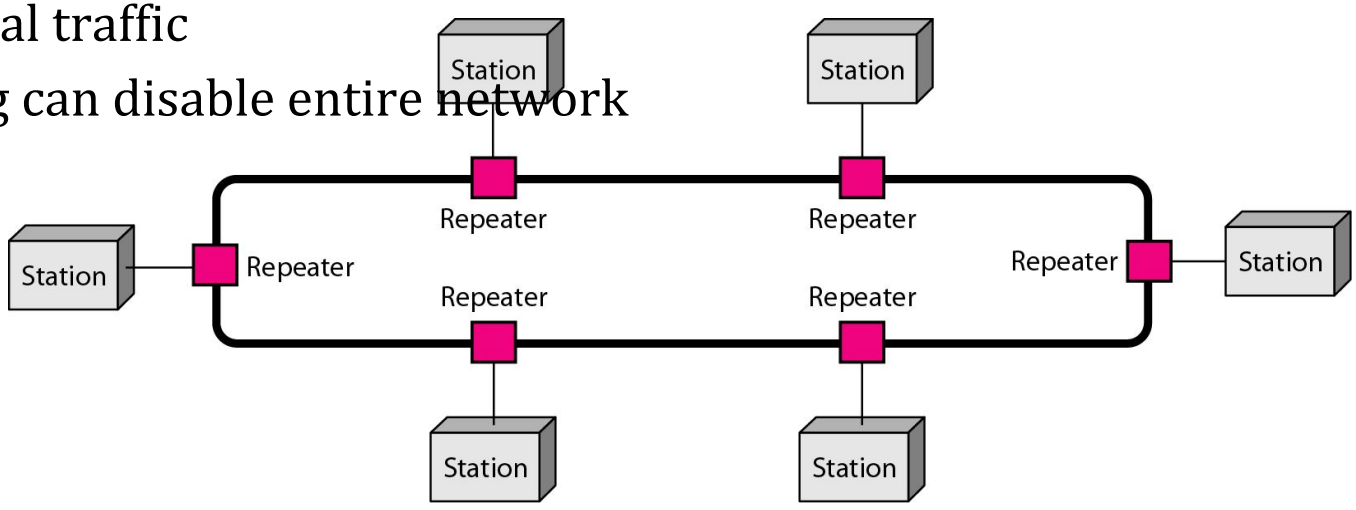
Bus topology

- Use multipoint connections
- One long cable act as a backbone to link all other devices
- Nodes are connected through drop lines and taps
- Advantages
  - Less cables, easy installation
- Disadvantages
  - Difficult fault detection and isolation
  - Taps degrades the quality of signal
  - Nonrobust

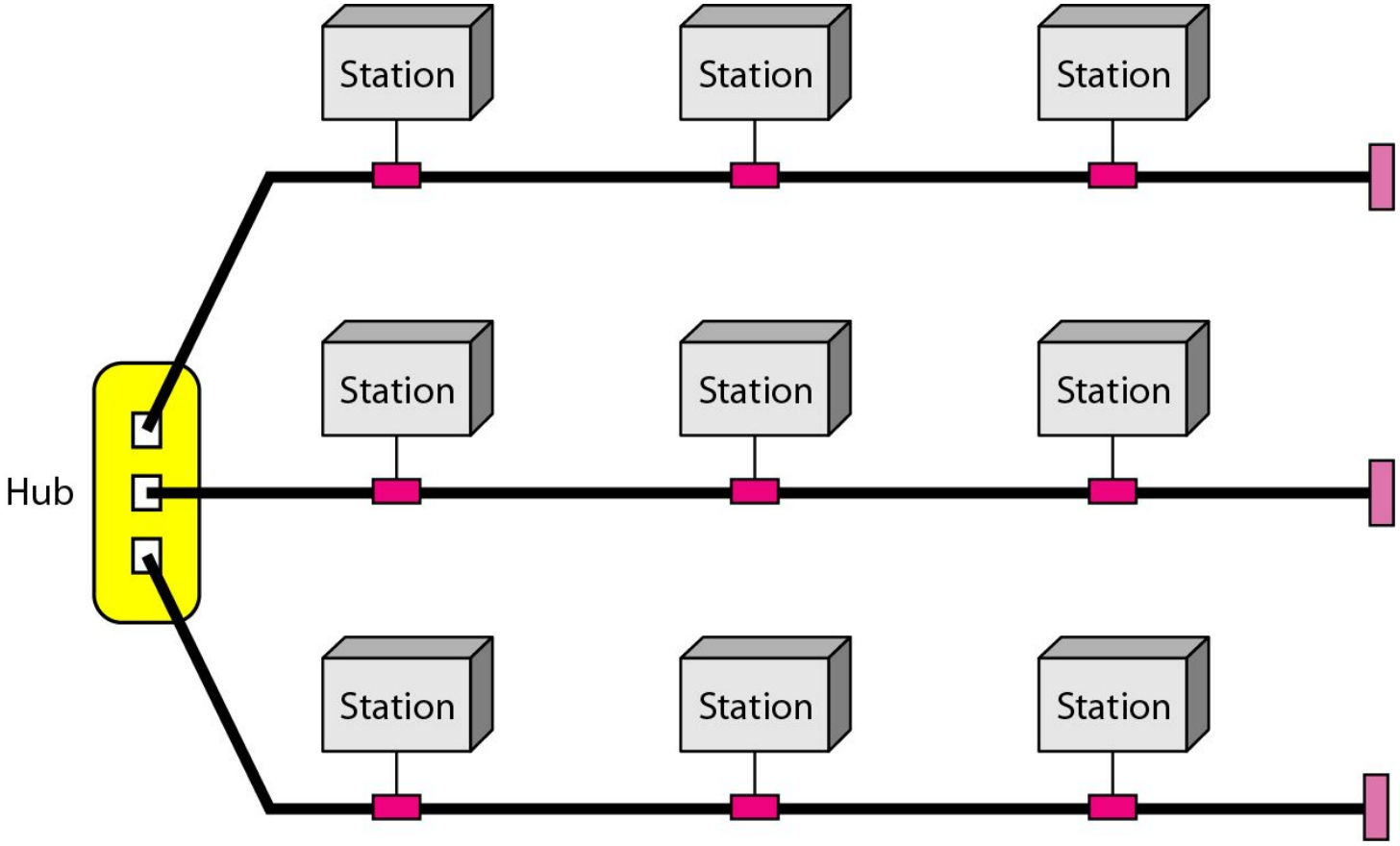


Ring topology

- Each device has a dedicated point to point connection with only the two devices on either side of it
- Each device incorporates a repeater
- Advantages
  - Easy to install and reconfigure
- Disadvantages
  - Unidirectional traffic
  - Break in ring can disable entire network
- Example
  - Token ring



A hybrid topology: a star backbone with three bus networks



Revision

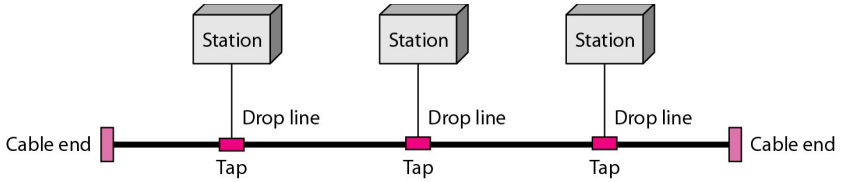
- For n devices in a network, what is the number of cable links required for a mesh, ring, bus and star topology?

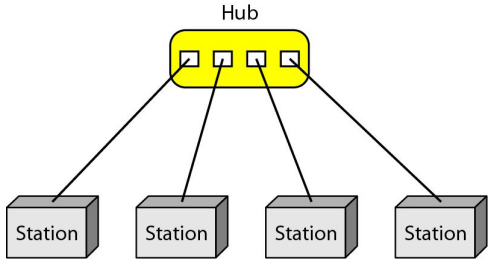
Ans: mesh –> n(n-1)/2

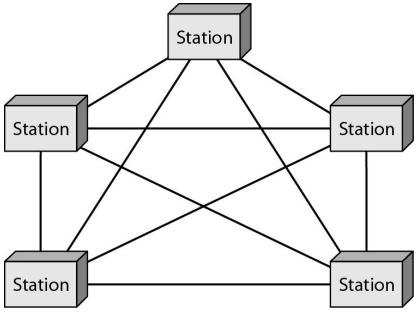
ring –> n

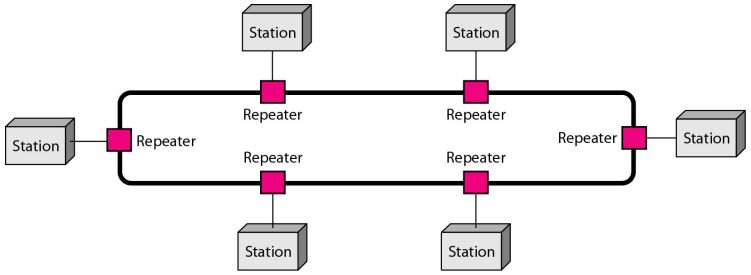
bus –> (n+1)

star -> n









Computer Network & Network Design

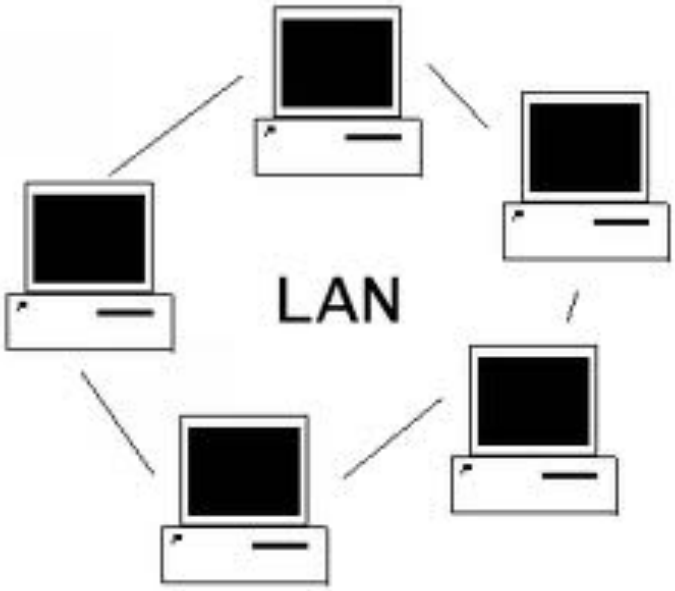
Module 0

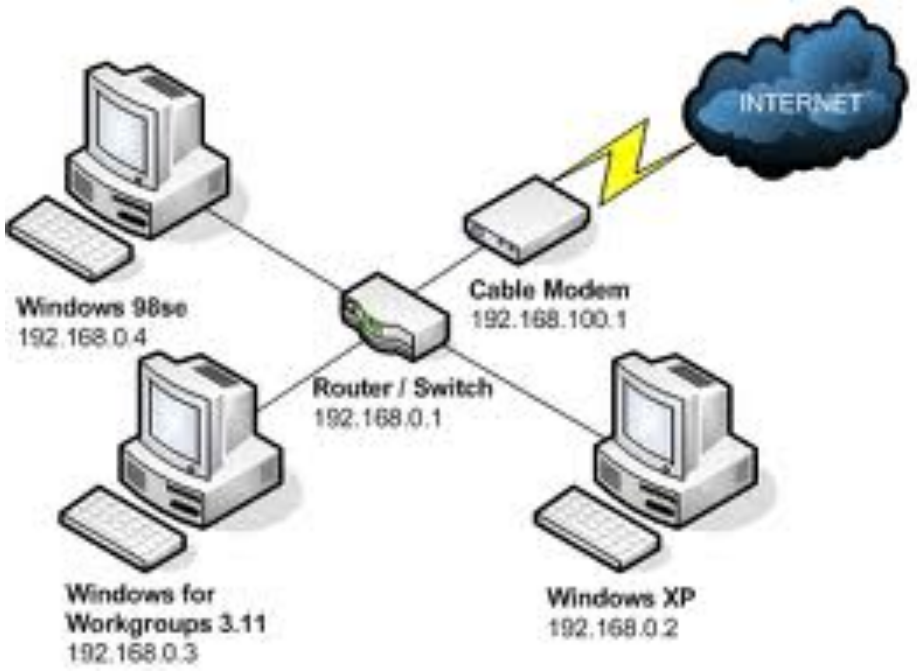
Lecture 3

Prerequisite

Categories of Networks

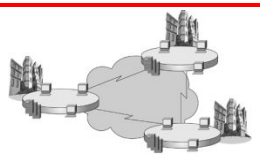
- LAN (Local Area Network)
  - Normally covers an area few kilometers
  - Used to connect devices in single office, building or campus

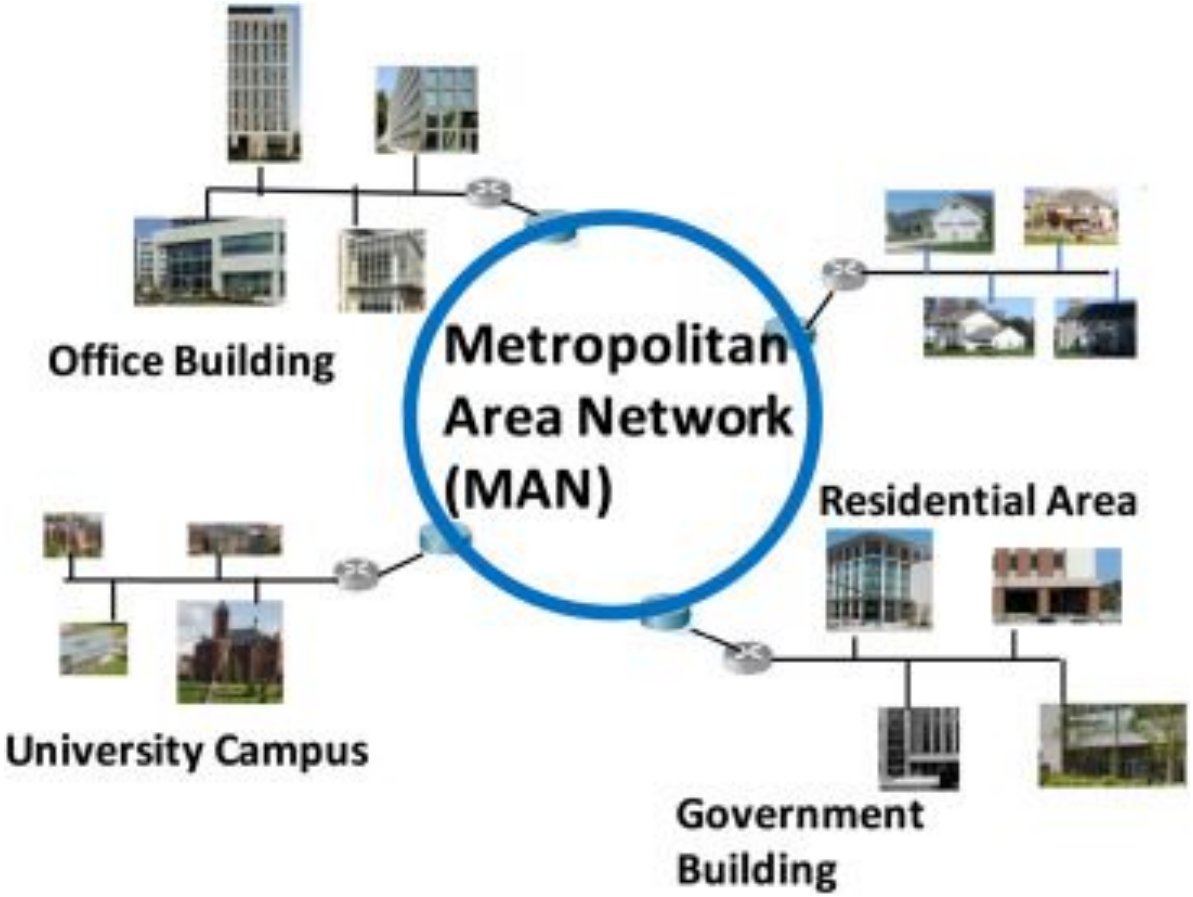




Categories of Networks

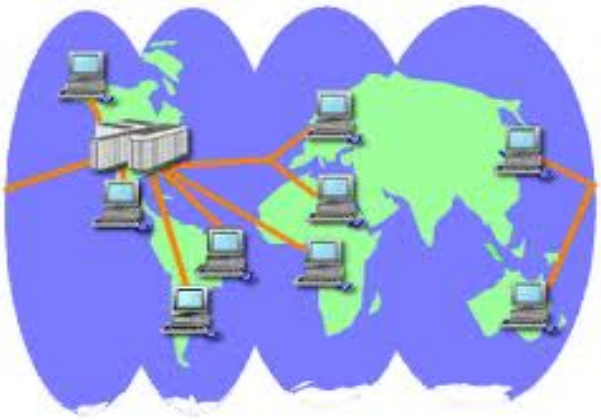
- MAN (Metropolitan Area Network)
  - Covers area inside a town or a city
  - Cable TV network, DSL line network of any telephone company

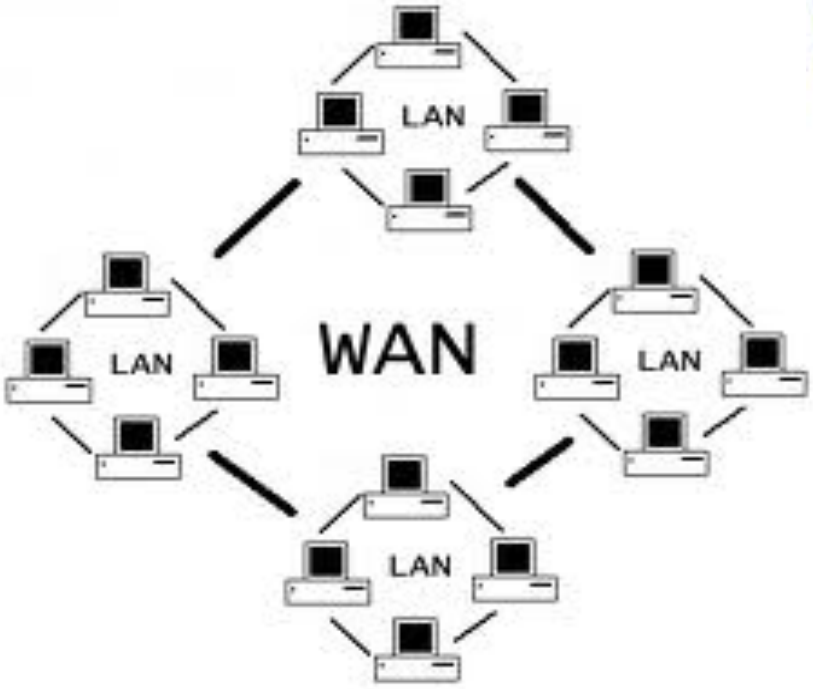


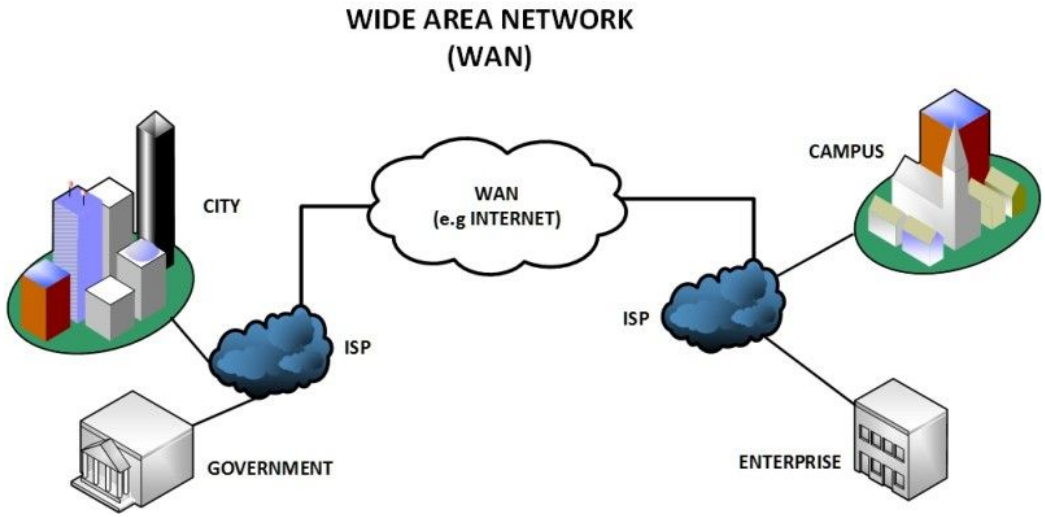


Categories of Networks

- WAN (Wide Area Network)
  - Can be worldwide
  - Used in internet







THE INTERNET

The Internet has revolutionized many aspects of our daily lives.
It has affected the way we do business as well as the way we spend our leisure time.
The Internet is a communication system that has brought a wealth of information to our fingertips and organized it for our use.

Topics discussed in this section:

History
The Internet Today (ISPs)

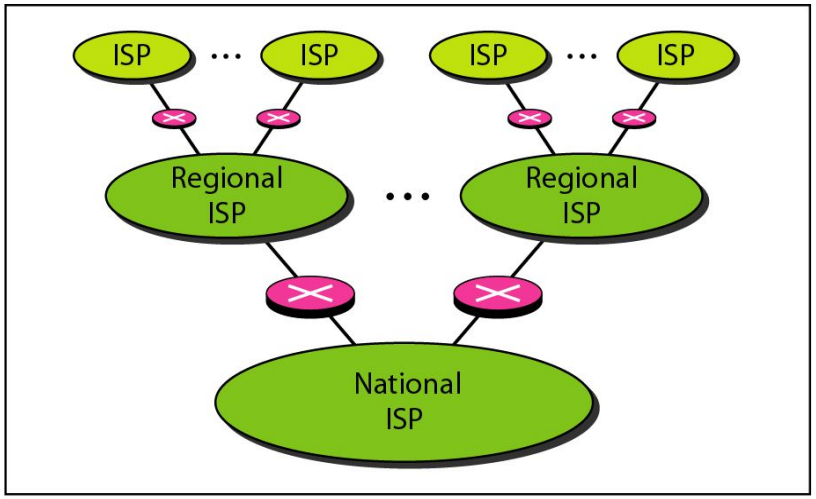
History

- In **1967**, Advanced Research Projects Agency (ARPA) from Defense Department of US presented first small network called "**ARPANET**"
- The idea was to attach each host computer from different manufacturer to a specialized device called an 'interface message processor(IMP)'. The IMP's, in turn, would be connected to one another.
- In **1969**, four nodes, at university of California at LA, the university of California at Santa Barbara, Stanford research institute and university of Utah were connected via IMPs (now called as Router)
- Software called the ***Network Control Protocol*** ***(NCP)*** provided communication between the nodes

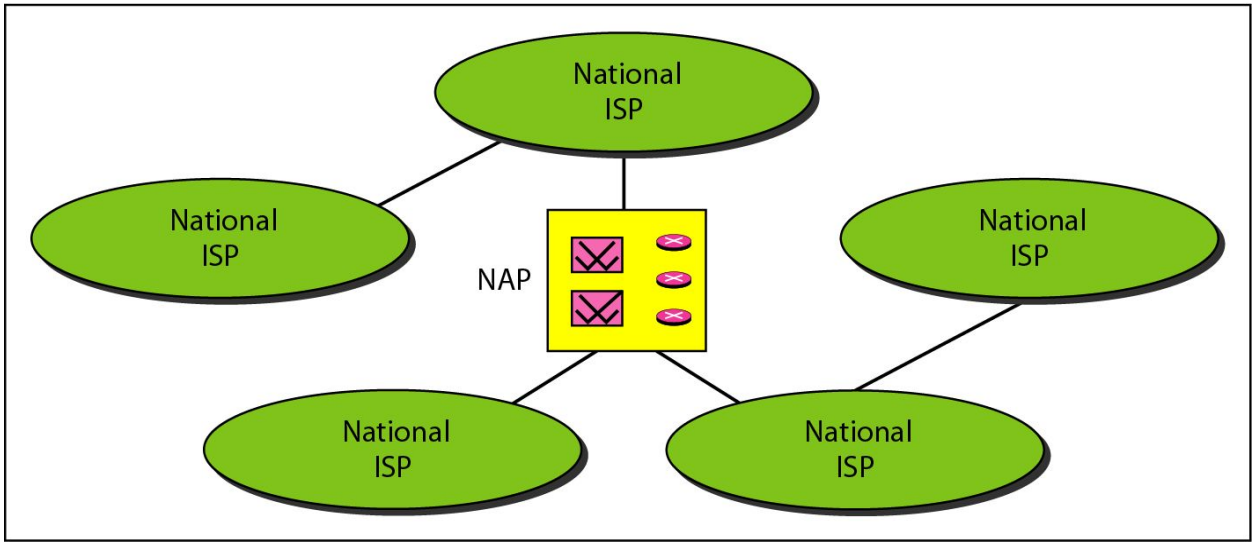
The Internet

- Internet today is a complex structure made up of many **wide** and **local** area networks joined through switching and connecting devices
- Today most end users get internet connection through services of "**Internet Service Providers(ISPs)**"

Hierarchical organization of the Internet



a. Structure of a national ISP



b. Interconnection of national ISPs

The Internet

- International ISP
  - Connects nations together
- National ISP
  - Backbone networks within the country maintained by specialized companies
  - Connected to each other through a complex switching stations called “NAPs” (network access points)
  - Also can use private switching stations called “peering points” to connect to each other
  - The data rates are high up to 600 Mbps
- Regional ISP
  - Cover smaller area and are connected to one or more national ISPs
  - Use smaller data rates
- Local ISP
  - Provides direct service to the end users
  - Can be a company, a corporation, a college or university etc

PROTOCOLS AND STANDARDS

In this section, we define two widely used terms: protocols and standards.

First, we define protocol, which is synonymous with rule.

Then we discuss standards, which are agreed-upon rules.

Topics discussed in this section:

Protocol
Standards
Standards Organisations

Protocol

- A set of rules that governs data communication
- Key elements
  - Syntax:- A structure or format of data
  - Semantics:- meaning of each section of bits
  - Timing:- when data should be sent and how fast it should be sent

Standards

- De facto (by fact or by convention)
  - A standard that is widespread by tradition, enforcement or market dominance
  - May not have received a formal approval by way of standardization process
  - E.g. DOS, band-aid
- De jure (by law or by regulation)
  - Legislated (approved) by an officially recognized body
  - E.g. Ethernet 802.3, ISO products

Standards' Organizations

- **ISO** (International Organization for Standardization): A multinational standard creation committee
- **ITU-T** (International telecommunication Union- Telecommunication Standard Sector)- concerns with international compatibility
- **ANSI** (American National Standards Institute)- private non-profit corporation contributing US government
- **IEEE** (Institute of Electrical and Electronics Engineers)- largest professional engineering society, aims at advancement in all engineering fields
- **EIA** (Electronic Industries Association)- concerns electronic manufacturing
- **FCC** (Federal Communications Commission)- communication technology regulatory agency in US

Computer Network & Network Design

Module 1

Lecture 4

Introduction to Computer Networks

Network Models

LAYERED TASKS :

We use the concept of layers in our daily life.

Example:

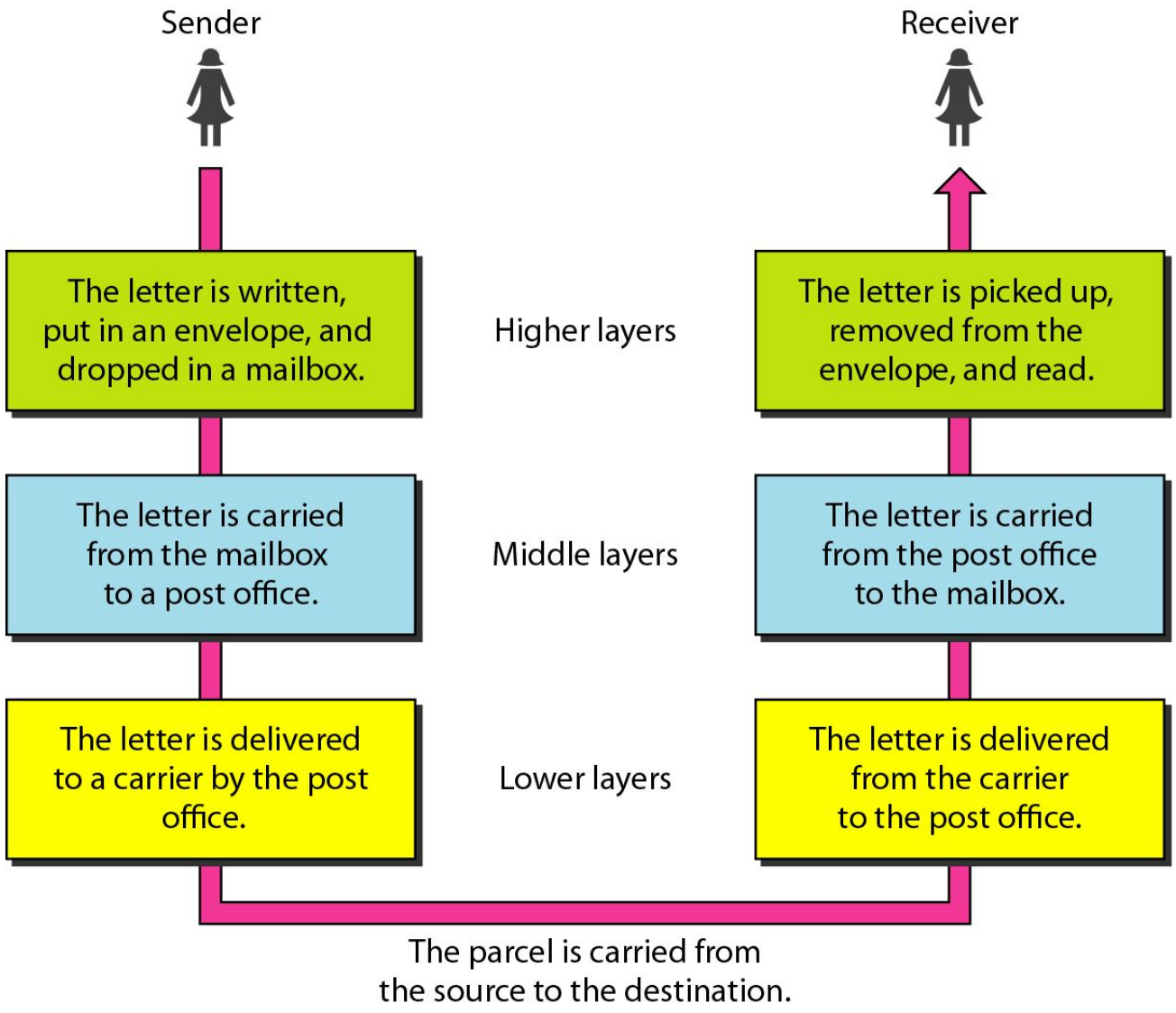
- Communication between two entities **Sender** and **Receiver**

Consider two friends who communicate through postal mail.

- A **carrier** for transport of letter

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



Note: Hierarchy Services

Network Models

- Network includes different entities. These entities need to communicate with each other.
- Some standards are required to set.
- Common standards are
  - **OSI Model**
  - **TCP/IP (internet) Model**

THE OSI MODEL

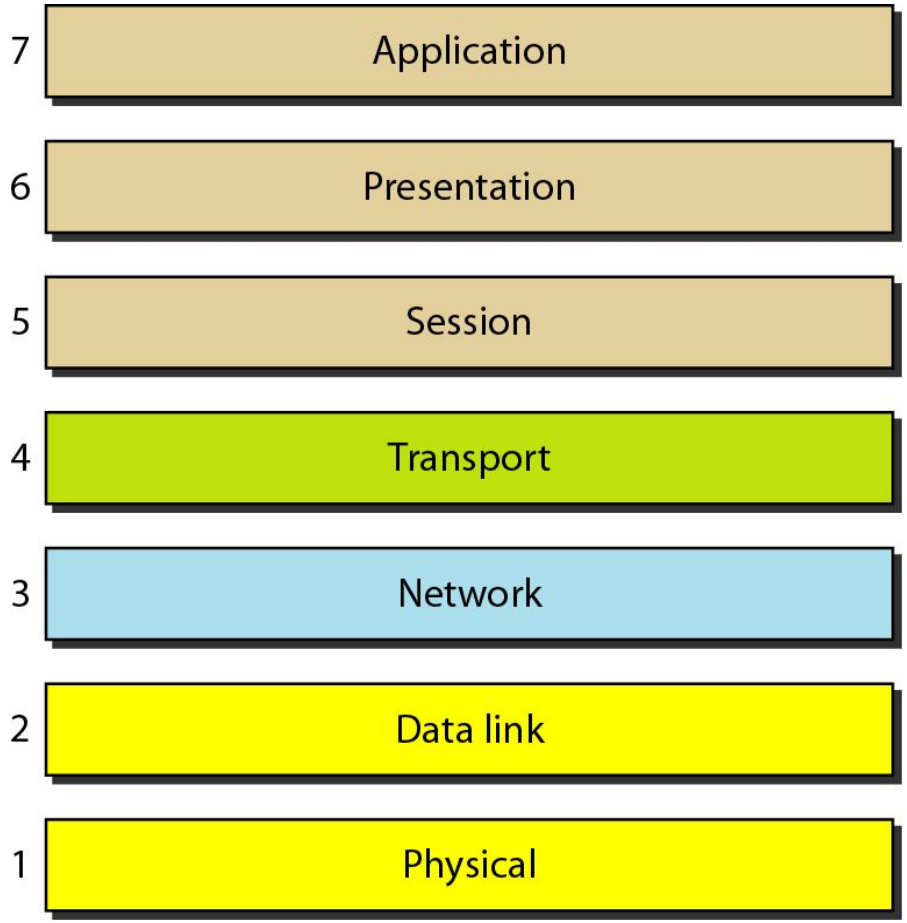
An ISO standard that covers all aspects of network communications is the Open Systems Interconnection (OSI) model. It was introduced in late 1970s.

Note

ISO is the organization.
OSI is the model.

- OSI model is not a protocol
- It is flexible, robust and interoperable, thus called “Open System”
- Consist of 7 layers, related to each other

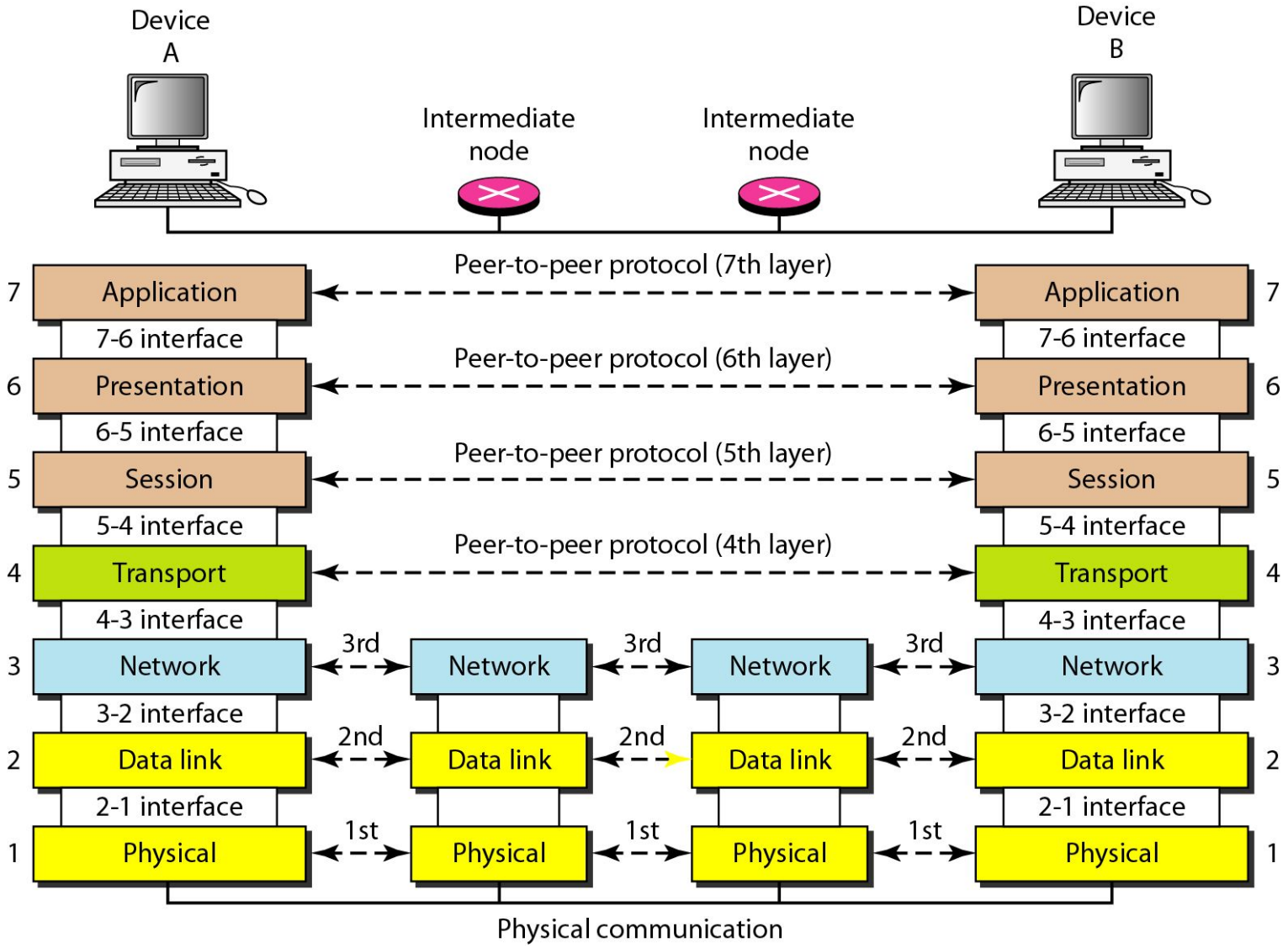
Seven layers of the OSI model



Layered Architecture

- The process of transmitting data is distilled to its most fundamental elements.
- The related networking functions are identified and grouped together
- These groups are called "**Layers**"
- Layered architecture provides flexibility, easy fault detection and correction
- Within a single machine, each layer uses the services of lower layer and provides services for higher layer
- Between the machines, layer 'x' on one machine communicate with layer 'x' of other machine
- Communication is governed by an agreed upon series of rules called **"Protocols" or "Peer to peer protocols"** (as used at peer levels)

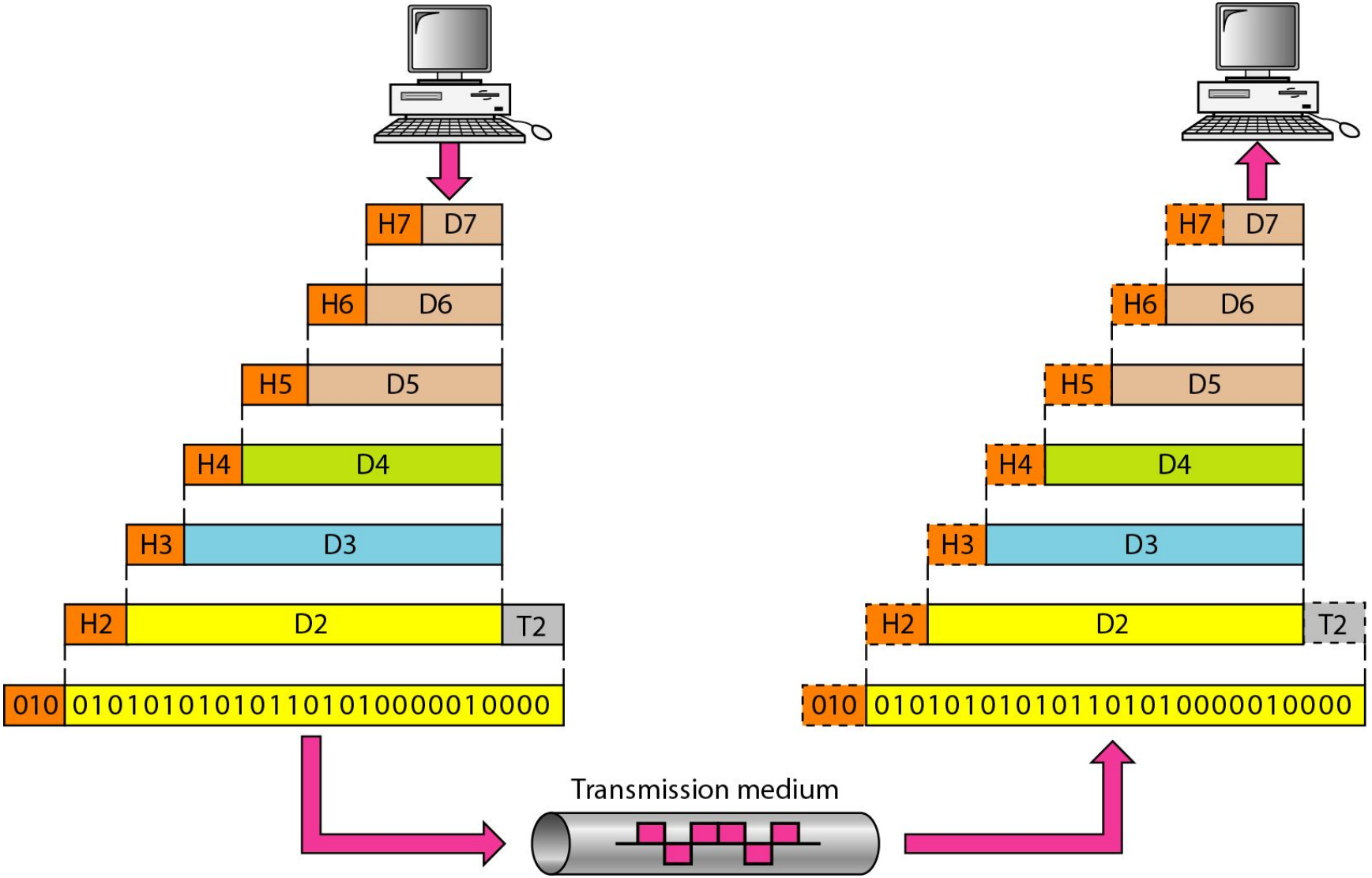
The interaction between layers in the OSI model



The interaction between layers in the OSI model- Observations

- At physical layer the communication is direct
- At higher layers, communication moves down through the layers of device A and moves up over to device B
- Each layer in sending device adds its own information to the message it receives from higher layer and pass it to the lower layer
- At the receiving machine, the message is unwrapped layer by layer
- Passing data between adjacent layers need interaction between the layers normally called **"Interfaces"**
- Interface defines the information and services a layer must provide for layer above it.
- Usually layers 1,2 & 3 are called "network support layers" and layer 5,6,& 7 are called "user support layers". Layer 4 links these two subgroups

An exchange using the OSI model- *using Encapsulation*



Computer Network & Network Design

Module 1

Introduction to Computer Networks

Lecture 5

Let's Revise

1. Name two Network Models.
2. Name of 6th Layer of OSI Model.
3. Name of 3rd Layer of OSI Model.
4. 'OSI is a protocol used for Network Design', True or False
5. 'Layer of OSI can communicate with peer layers', True or False
6. 'Layer of OSI support with each other via interface', True or False
7. What is Encapsulation?

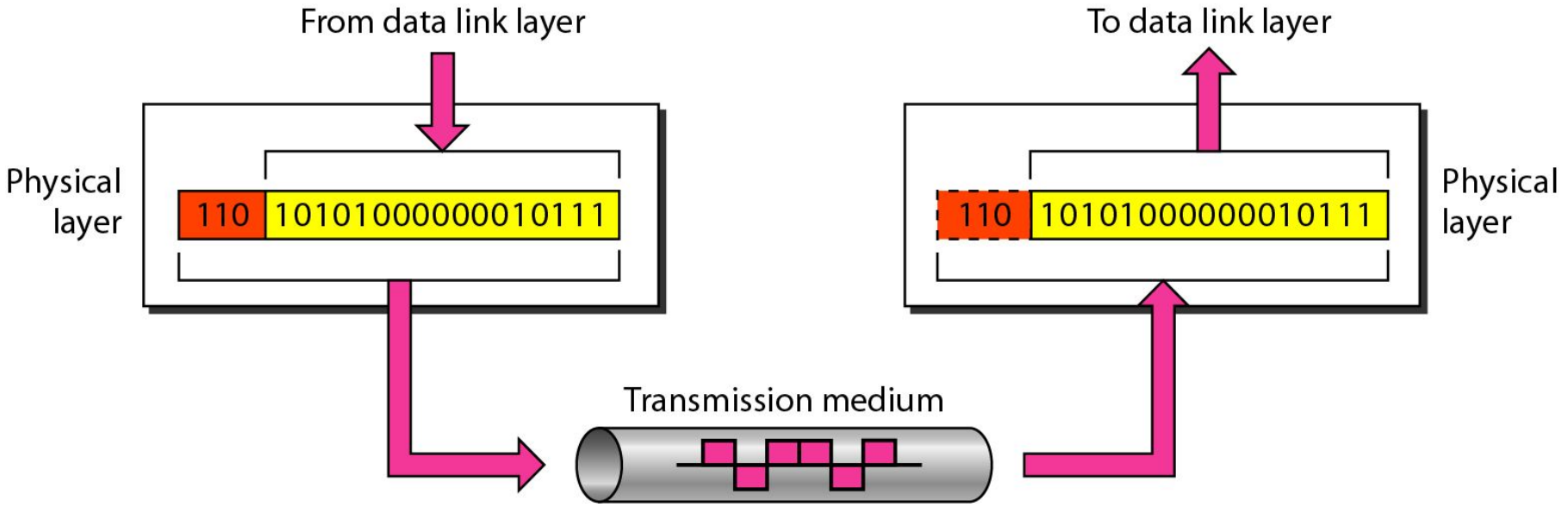
LAYERS IN THE OSI MODEL

In this section we briefly describe the functions of each layer in the OSI model.

Topics discussed in this section:

Physical Layer
Data Link Layer
Network Layer
Transport Layer
Session Layer
Presentation Layer
Application Layer

Physical layer



- Coordinates the functions required to carry a bit stream over a physical medium
- Deals with the mechanical and electrical specifications of the interface and transmission medium

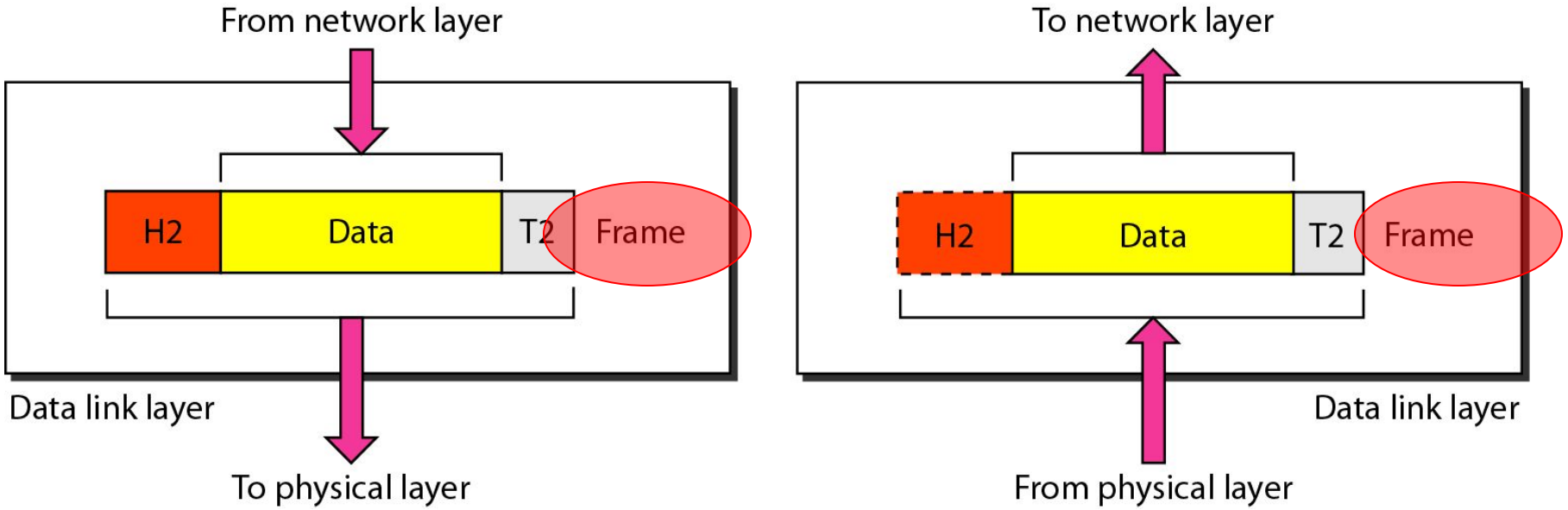
Physical layer

- Functions:
  - Physical characteristics of interfaces and medium
  - Representation of bits
  - Data rate
  - Synchronization of bits
  - Line configuration
  - Physical topology
  - Transmission mode

Note

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

Data link layer

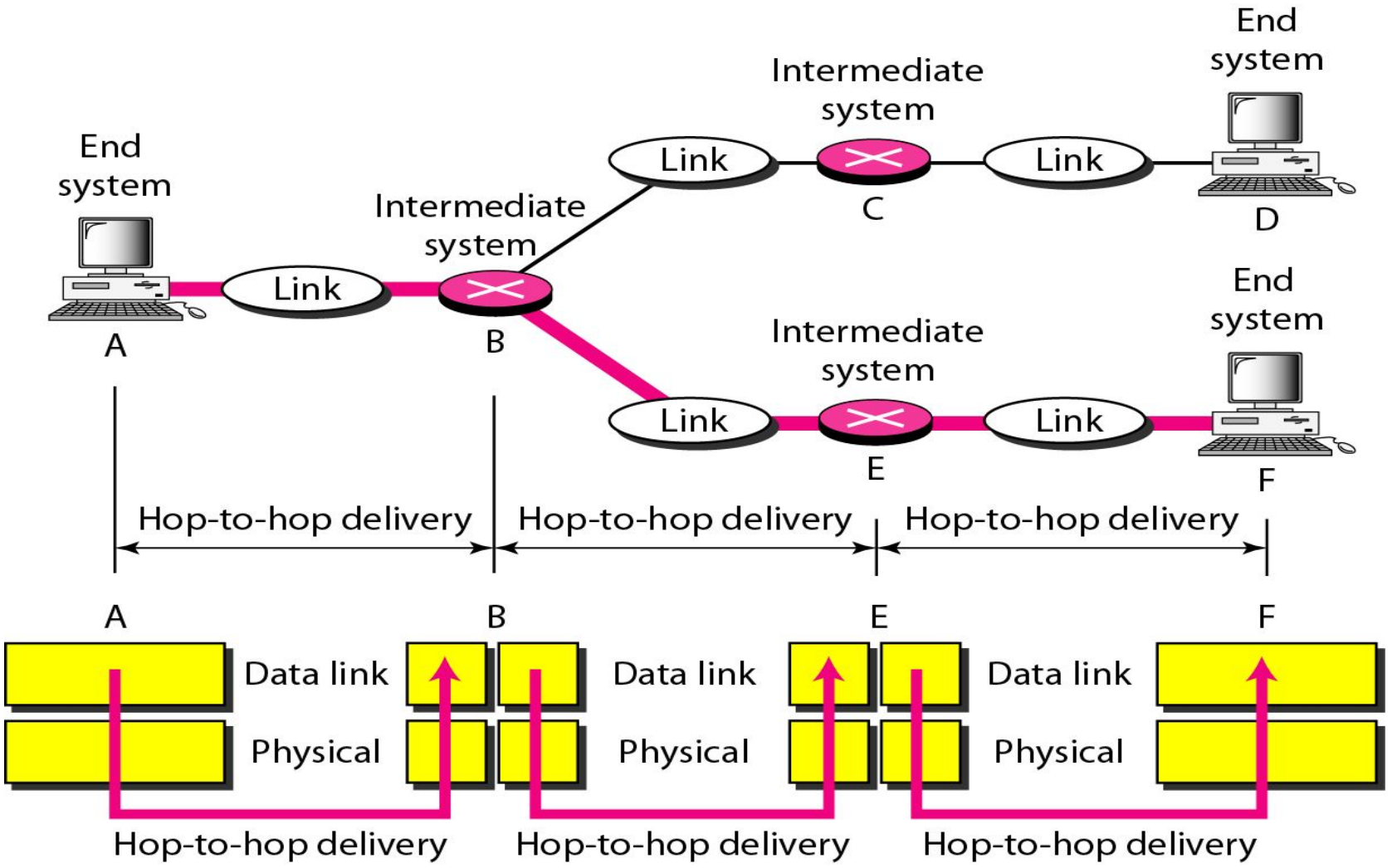


Data link layer

- Transforms the physical layer transmission facility to a reliable link
- Other responsibilities:
  - Framing – divides stream of bits
  - Physical Addressing – adds addresses **(MAC Address)**
  - Flow control – matches data rates
  - Error control – add redundancy
  - Access control – link control

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

Hop-to-hop delivery



Computer Network & Network Design

Module 1

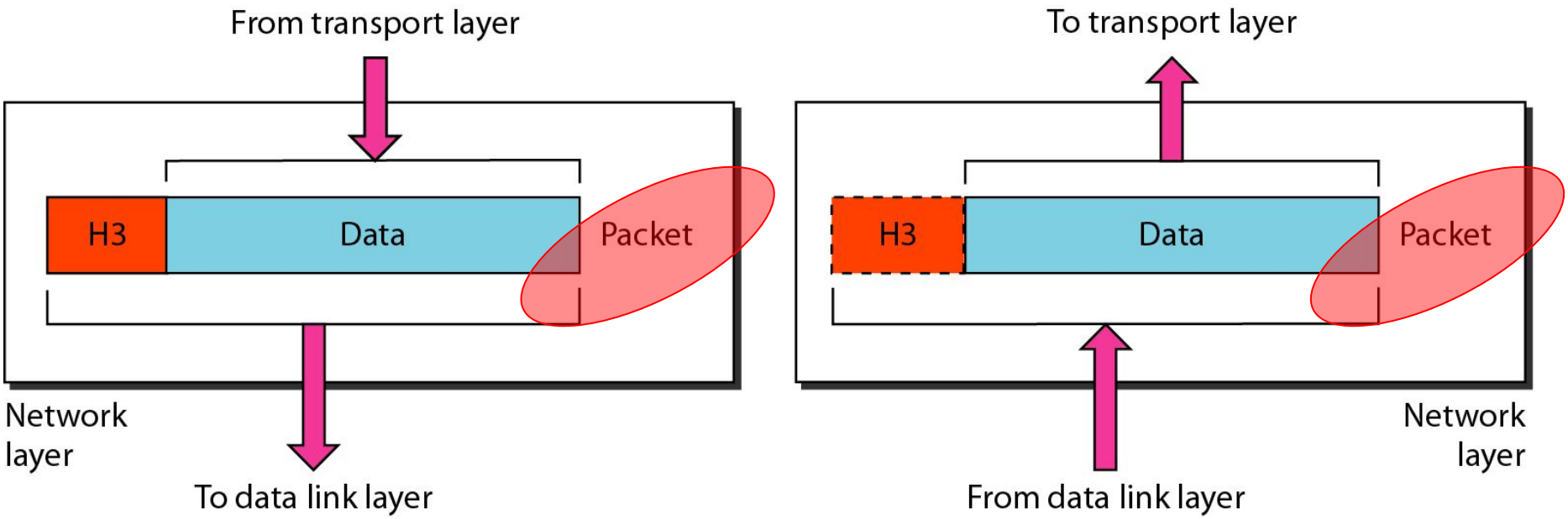
Introduction to Computer Networks

Lecture 6

Let's Revise

1. At physical layer, the data is commonly referred as _____ .
   a. Bit
   b. Byte
   c. Bit stream
   d. Word
2. A computer network is operating at a data rate of 200Mbps. Which layer decides this specification?
3. Which layer adds reliability in data transmission?
4. A hop-to-hop delivery is same as node-to-node delivery. True or False ?

Network layer



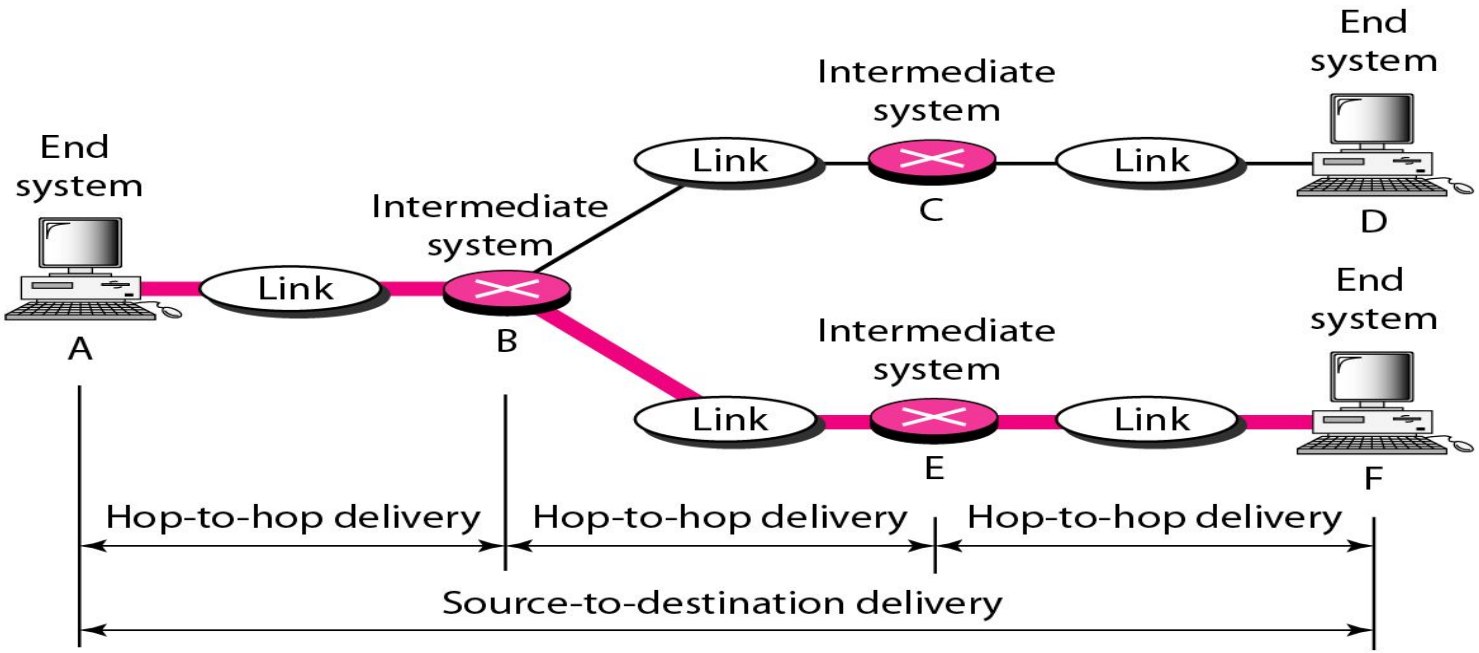
Network layer

- Responsible for the **source to destination** delivery of a packet across multiple networks.
- Other responsibilities:
  - Logical Addressing **(IP Address)**
  - Routing

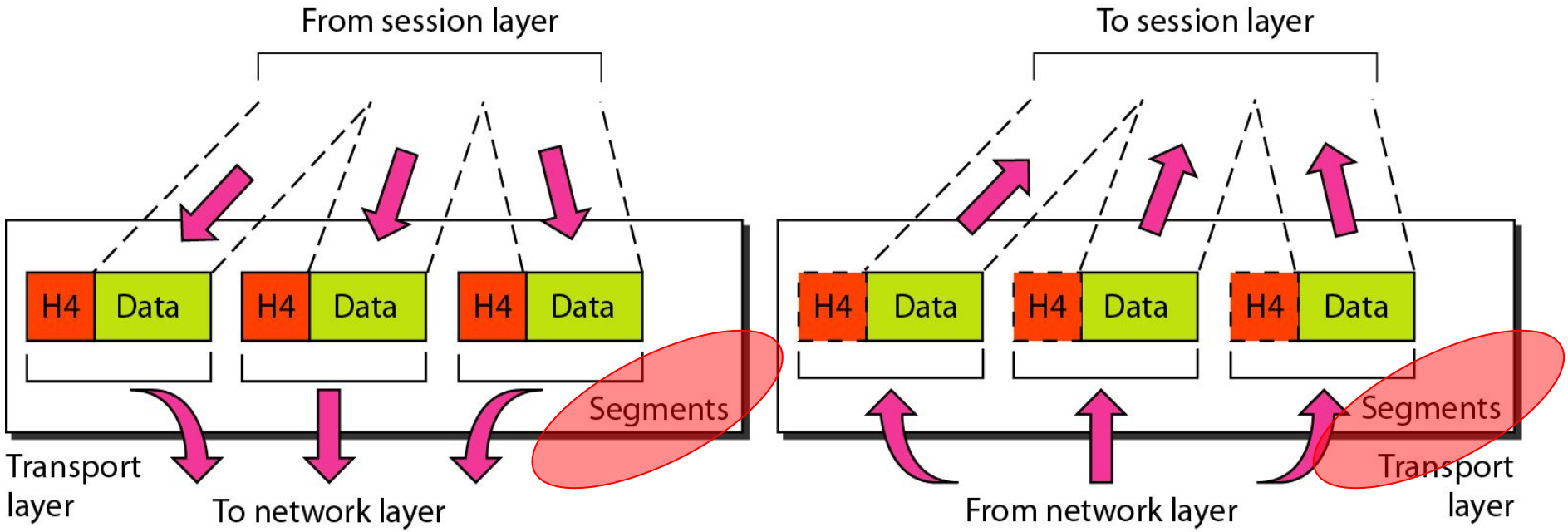
Note

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

Source-to-destination delivery



Transport layer

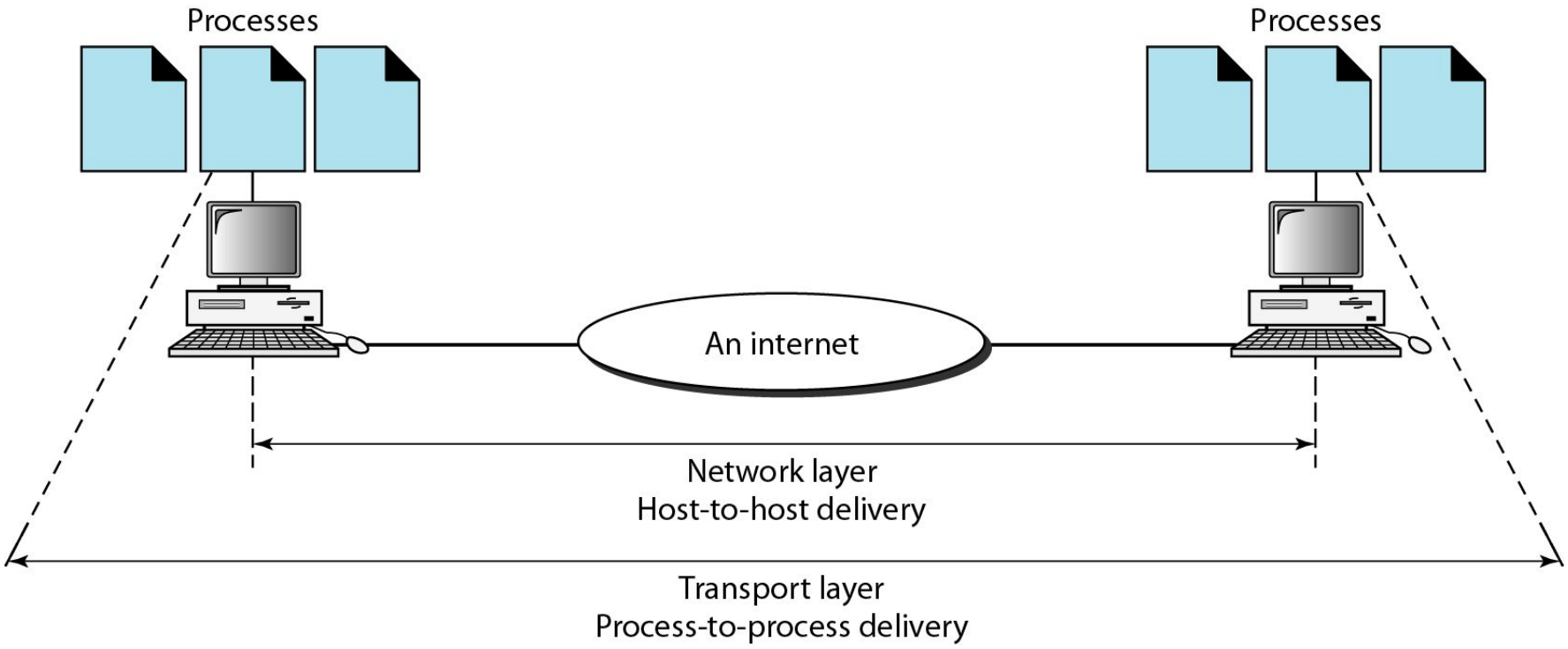


Transport layer

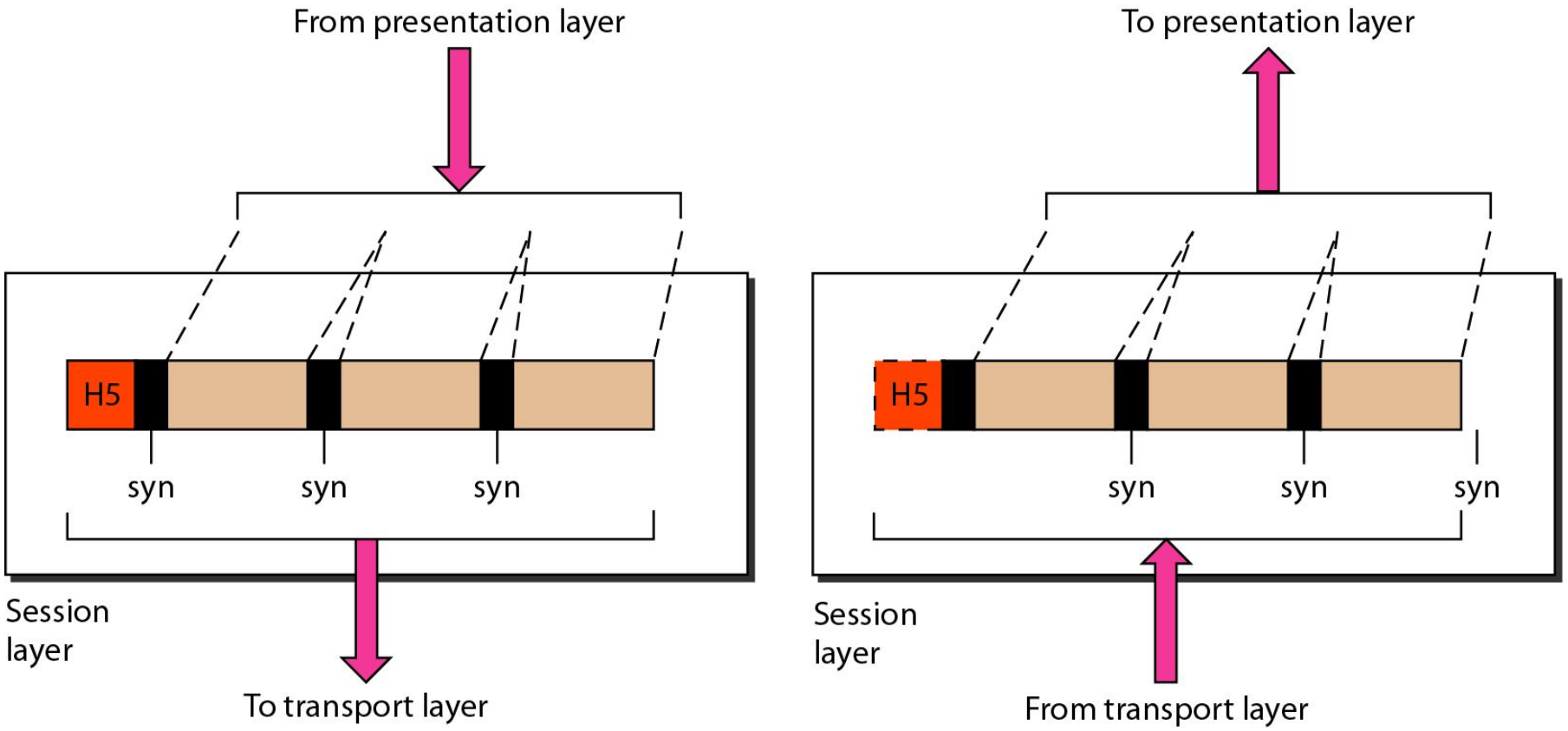
- Responsible for **process-to-process delivery** of the entire message
- Other responsibilities:
  - Service point (**port**) addressing
  - Segmentation and reassembly
  - Connection control – connectionless or connection oriented
  - Flow control
  - Error control

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

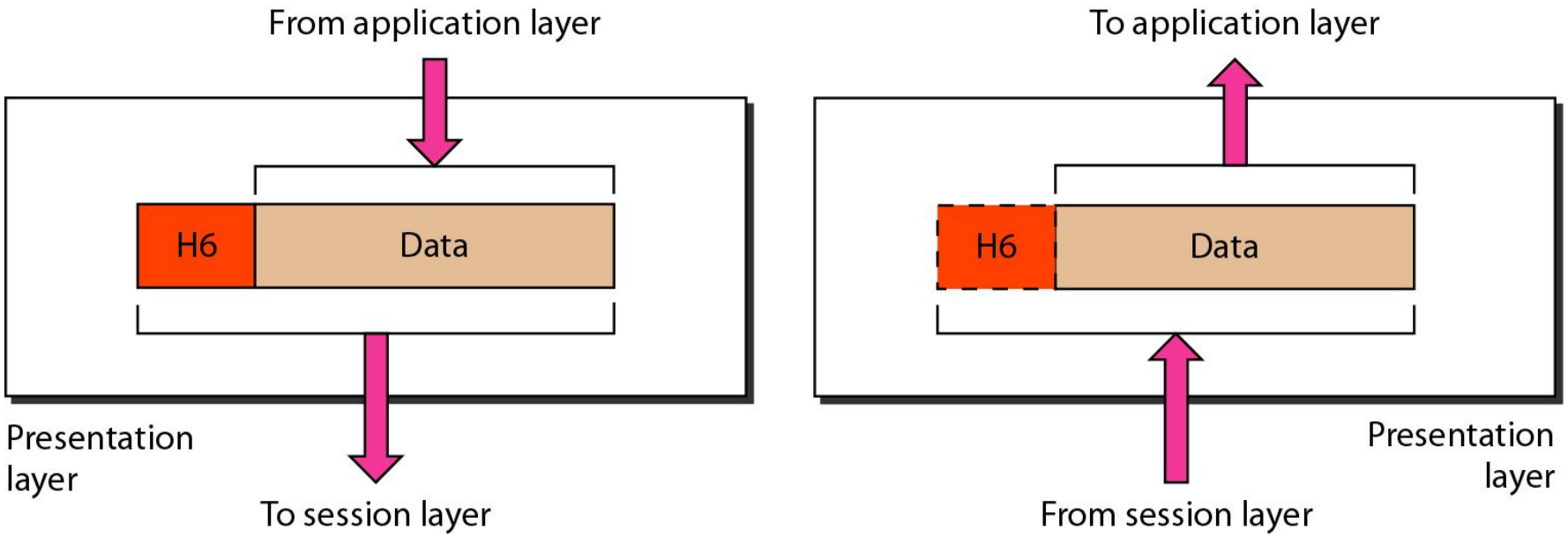


Session layer

- It is a network dialog controller.
- It establishes, maintains and synchronizes the interaction among communicating sessions.
- Responsibilities:
  - Dialog control – use half or full duplex mode for dialog
  - Synchronization – support check points or synchronization points

The session layer is responsible for dialog control and synchronization.

Presentation layer

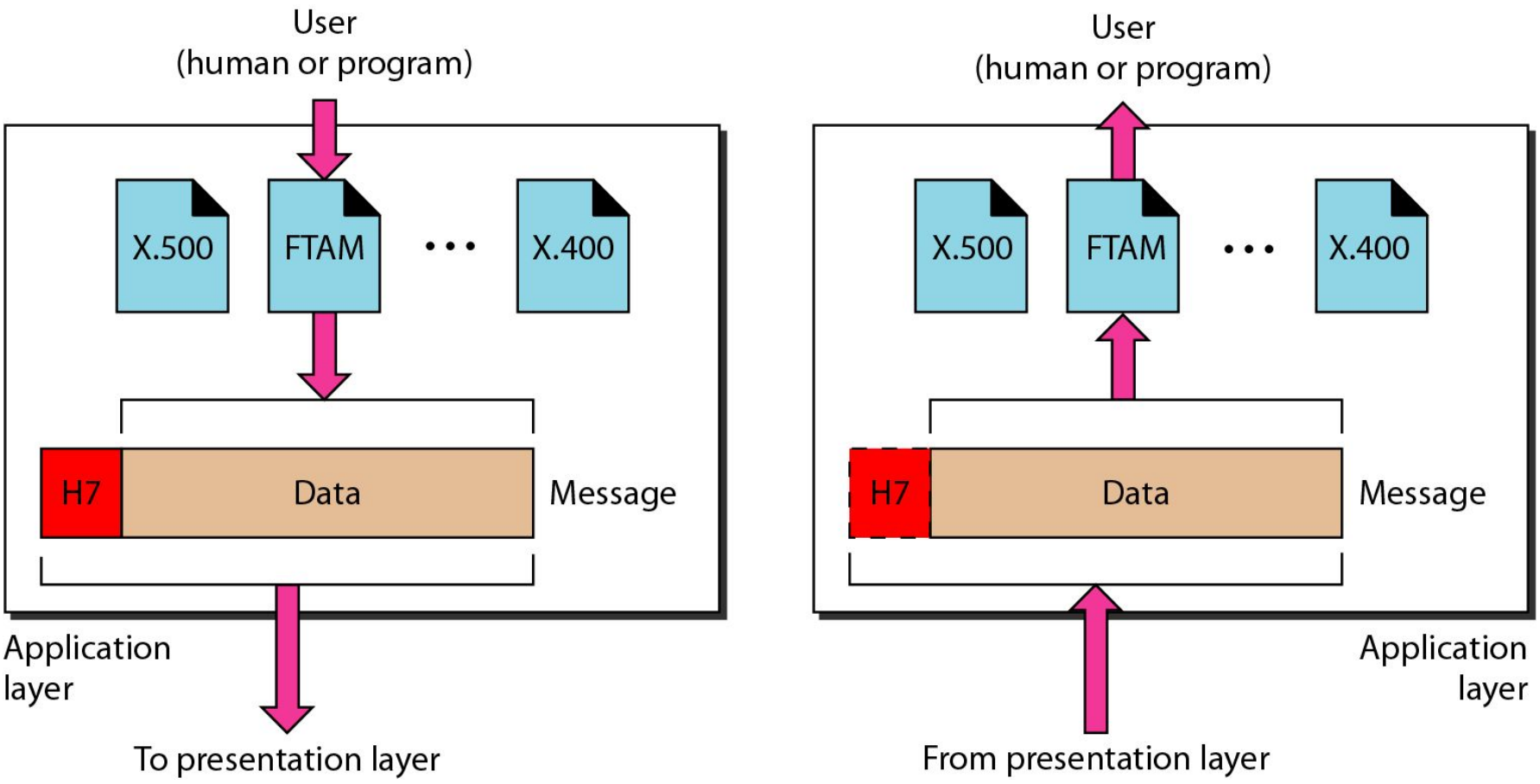


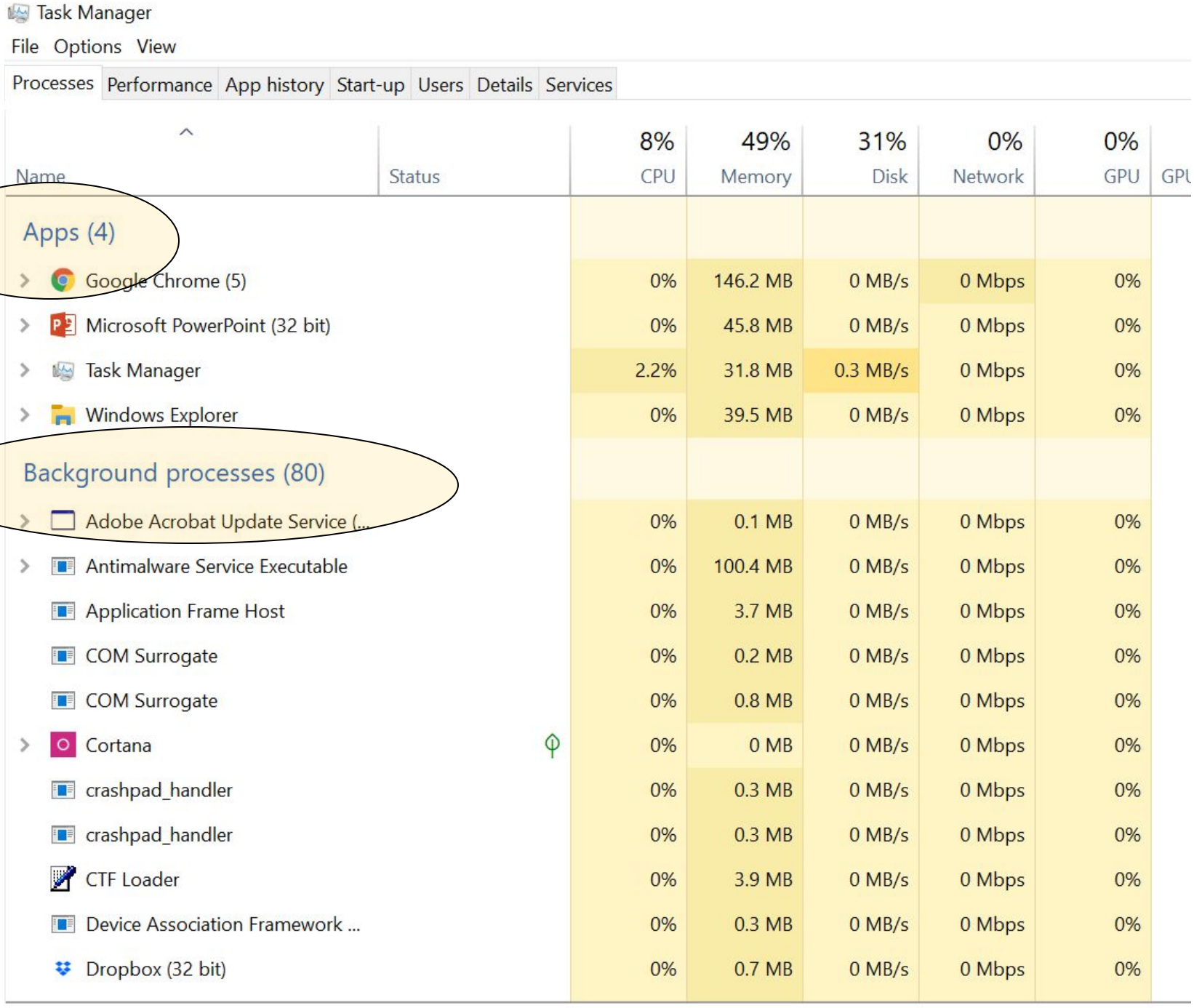
Presentation layer

- Concerns with syntax and semantics of the information exchanged
- Responsibilities:
  - **Translation** – ensures interoperability between different encodings (UTF, ASCII, ISCII)
  - **Encryption** – ensures privacy of data
  - **Compression** – ensures optimization of data rate

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

Application layer




Task Manager
File Options View
Processes Performance App history Start-up Users Details Services
Name Status 8% CPU 49% Memory 31% Disk 0% Network 0% GPU GPU
Apps (4)
Google Chrome (5) 0% 146.2 MB 0 MB/s 0 Mbps 0%
Microsoft PowerPoint (32 bit) 0% 45.8 MB 0 MB/s 0 Mbps 0%
Task Manager 2.2% 31.8 MB 0.3 MB/s 0 Mbps 0%
Windows Explorer 0% 39.5 MB 0 MB/s 0 Mbps 0%
Background processes (80)
Adobe Acrobat Update Service (... 0% 0.1 MB 0 MB/s 0 Mbps 0%
Antimalware Service Executable 0% 100.4 MB 0 MB/s 0 Mbps 0%
Application Frame Host 0% 3.7 MB 0 MB/s 0 Mbps 0%
COM Surrogate 0% 0.2 MB 0 MB/s 0 Mbps 0%
COM Surrogate 0% 0.8 MB 0 MB/s 0 Mbps 0%
Cortana 0% 0 MB 0 MB/s 0 Mbps 0%
crashpad_handler 0% 0.3 MB 0 MB/s 0 Mbps 0%
crashpad_handler 0% 0.3 MB 0 MB/s 0 Mbps 0%
CTF Loader 0% 3.9 MB 0 MB/s 0 Mbps 0%
Device Association Framework ... 0% 0.3 MB 0 MB/s 0 Mbps 0%
Dropbox (32 bit) 0% 0.7 MB 0 MB/s 0 Mbps 0%

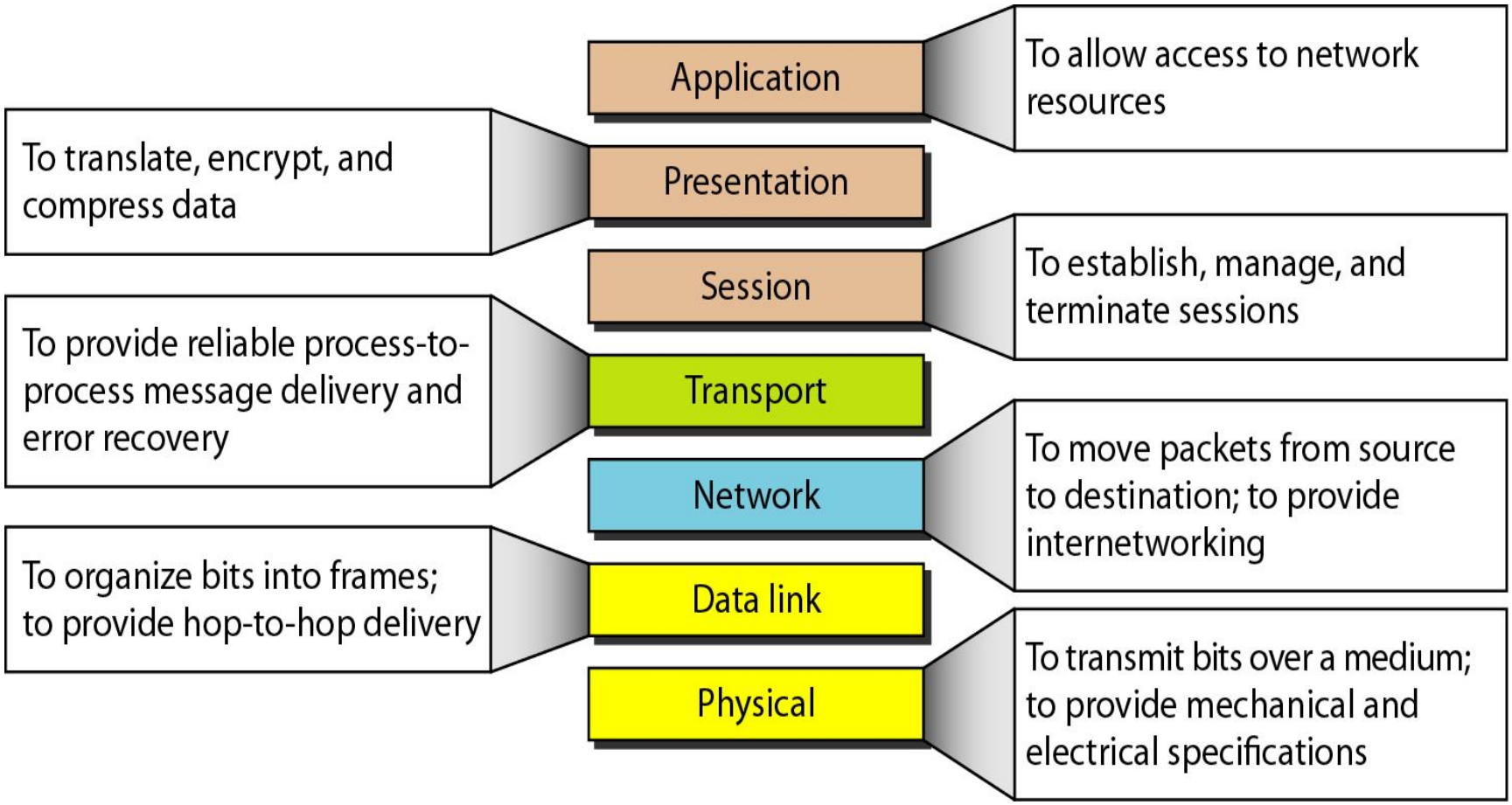
Application layer

- Enables user to access the processes.
- Provides interfaces and support for services.
- Responsibilities:
  - Network virtual terminal – a software version of physical terminal
  - File transfer, access and management
  - Mail services – e.g. e-mail
  - Dictionary services – e.g. search engines

Note

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

Summary of layers



Computer Network & Network Design

Module 1

Introduction to Computer Networks

Lecture 7

TCP/IP PROTOCOL SUITE

The layers in the TCP/IP protocol suite do not match with those in the OSI model.

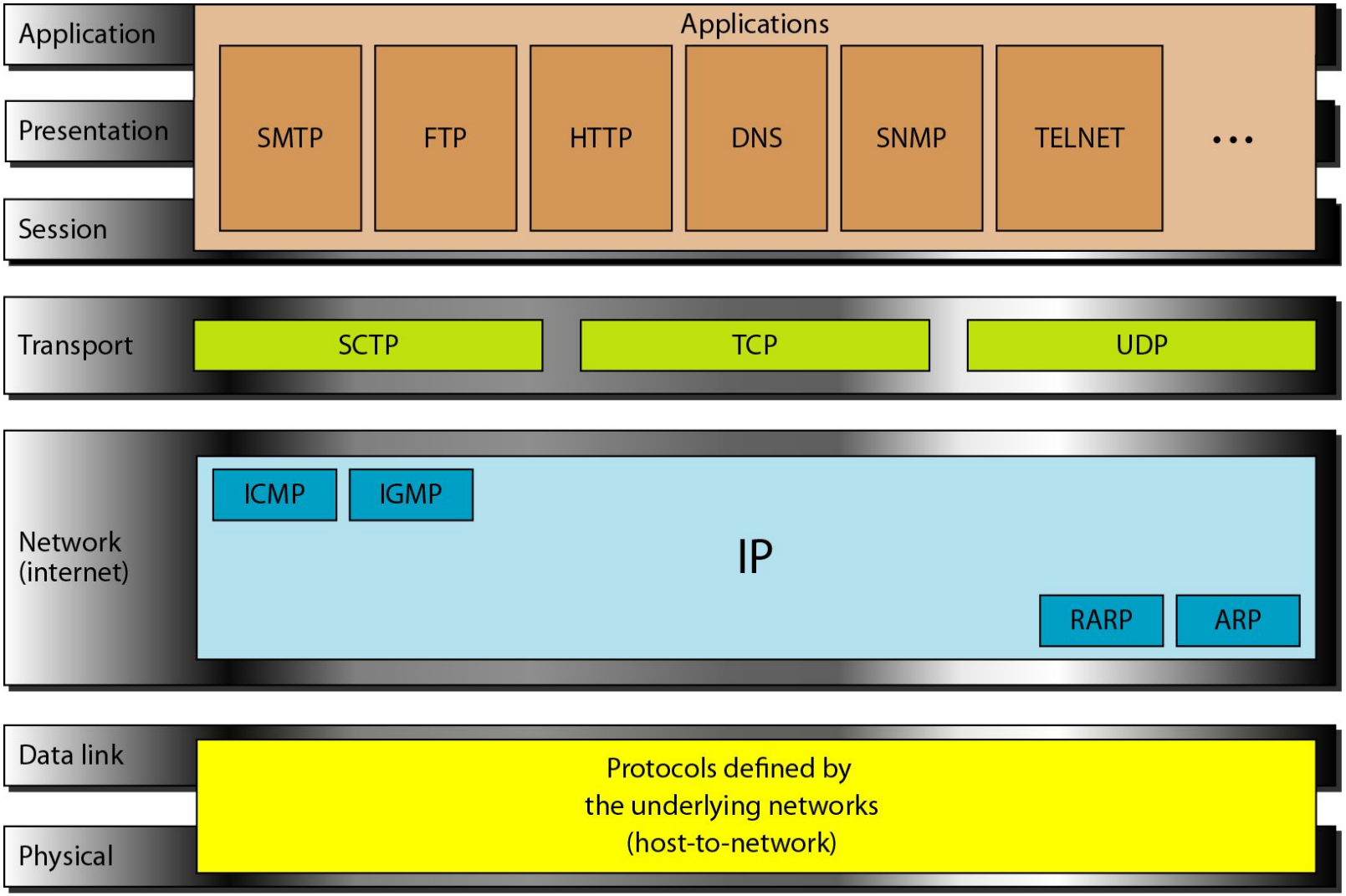
The original TCP/IP protocol suite was defined as having four layers: host-to-network, internet, transport, and application.

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.

Topics discussed in this section:

Physical and Data Link Layers (***host-to-network***)
Network Layer (***internet***)
Transport Layer
Application Layer

TCP/IP and OSI model



TCP/ IP Protocol

- Physical and Data link layers (host-to-network layer)
  - No specific protocol is defined
  - Supports all the standard and proprietary protocols
  - The network can be LAN or WAN
- Network layer (internetwork layer)
  - Support Internetworking Protocol (IP)
  - IP uses four supporting protocols : ARP, RARP, ICMP, IGMP
- Transport layer
  - Protocols are responsible for delivery of a message from process to process
  - Popular protocols are UDP, TCP and SCTP (stream control TP)
- Application layer
  - Equivalent to the combined session, presentation and application layers
  - Protocols used here are application dependent

Computer Network & Network Design

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Lecture 8

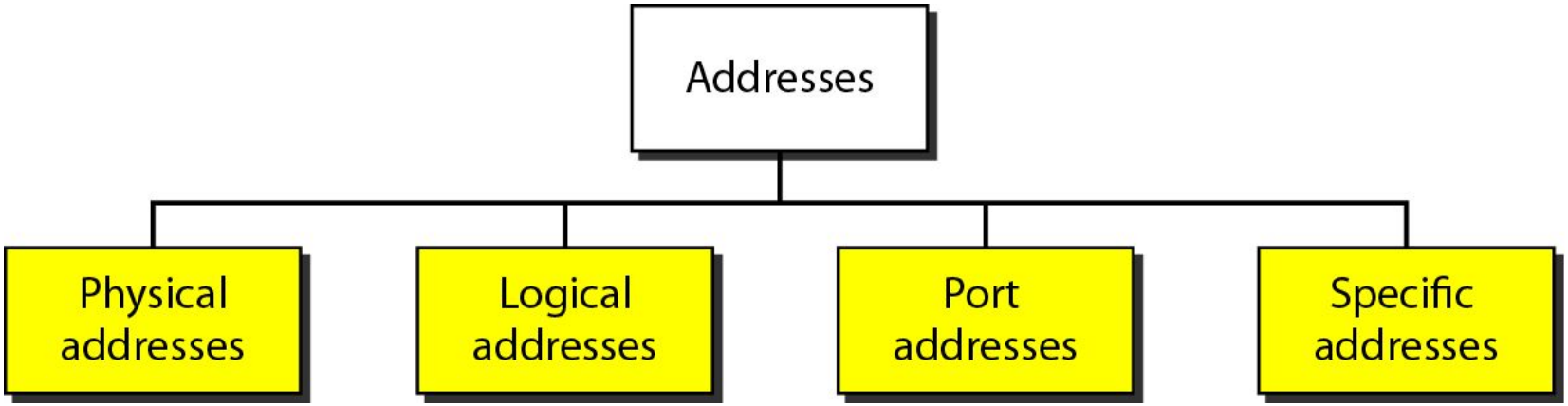
ADDRESSING

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

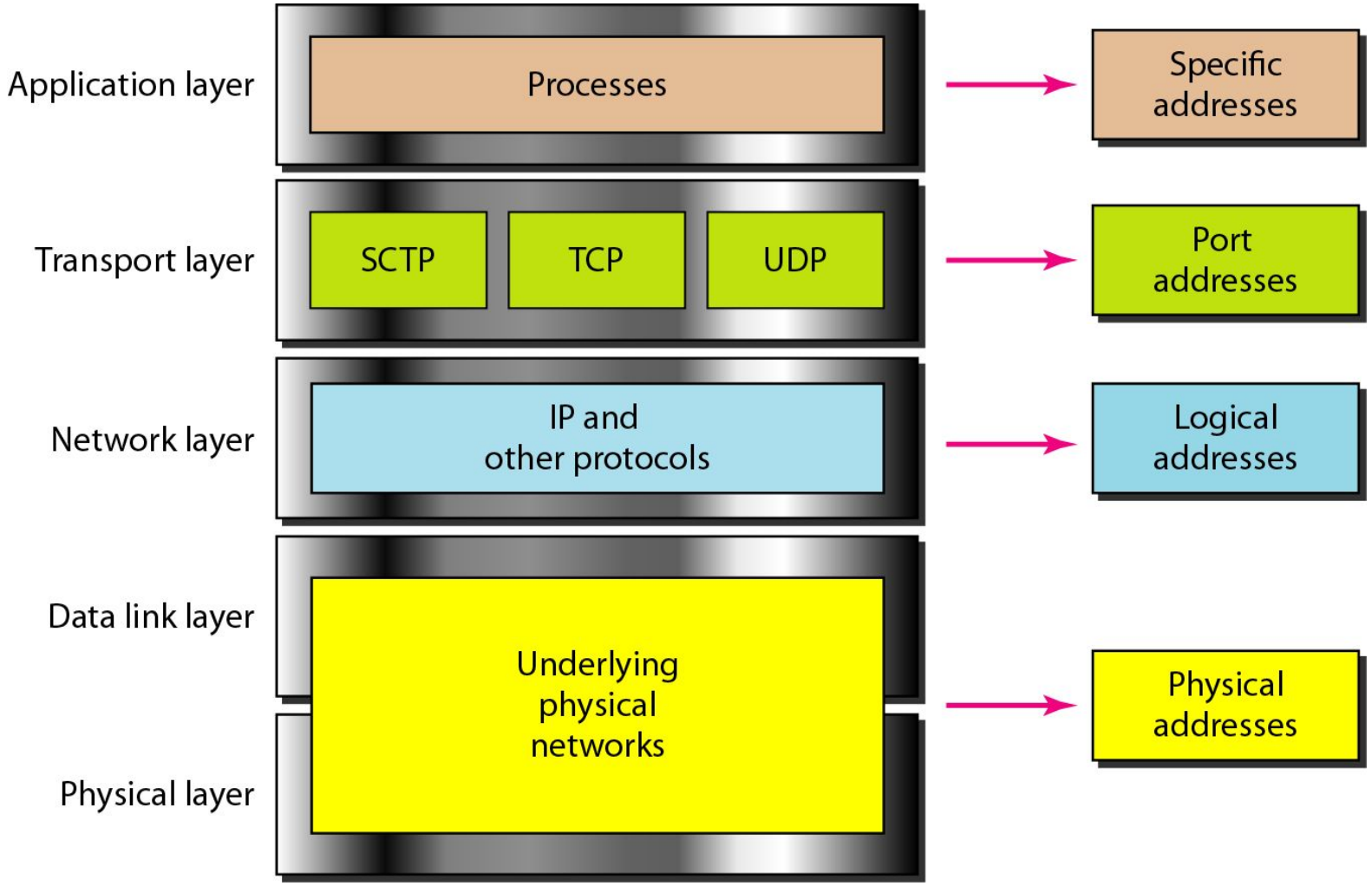
Topics discussed in this section:

Physical Addresses
Logical Addresses
Port Addresses
Specific Addresses

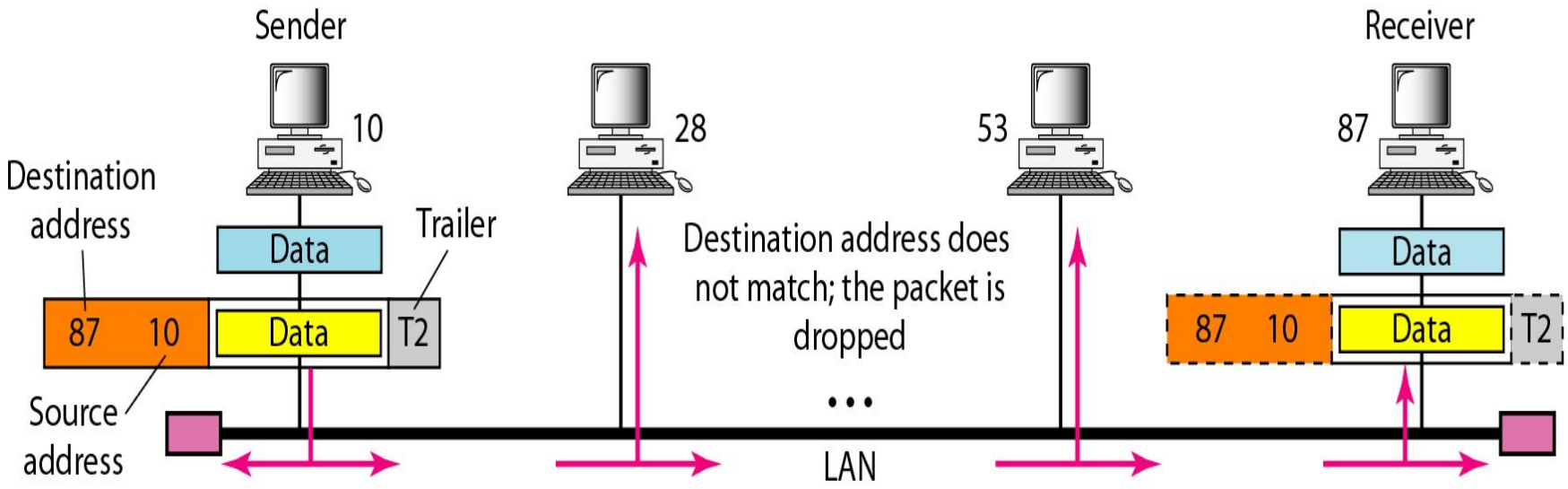
Addresses in TCP/IP



Relationship of layers and addresses in TCP/IP

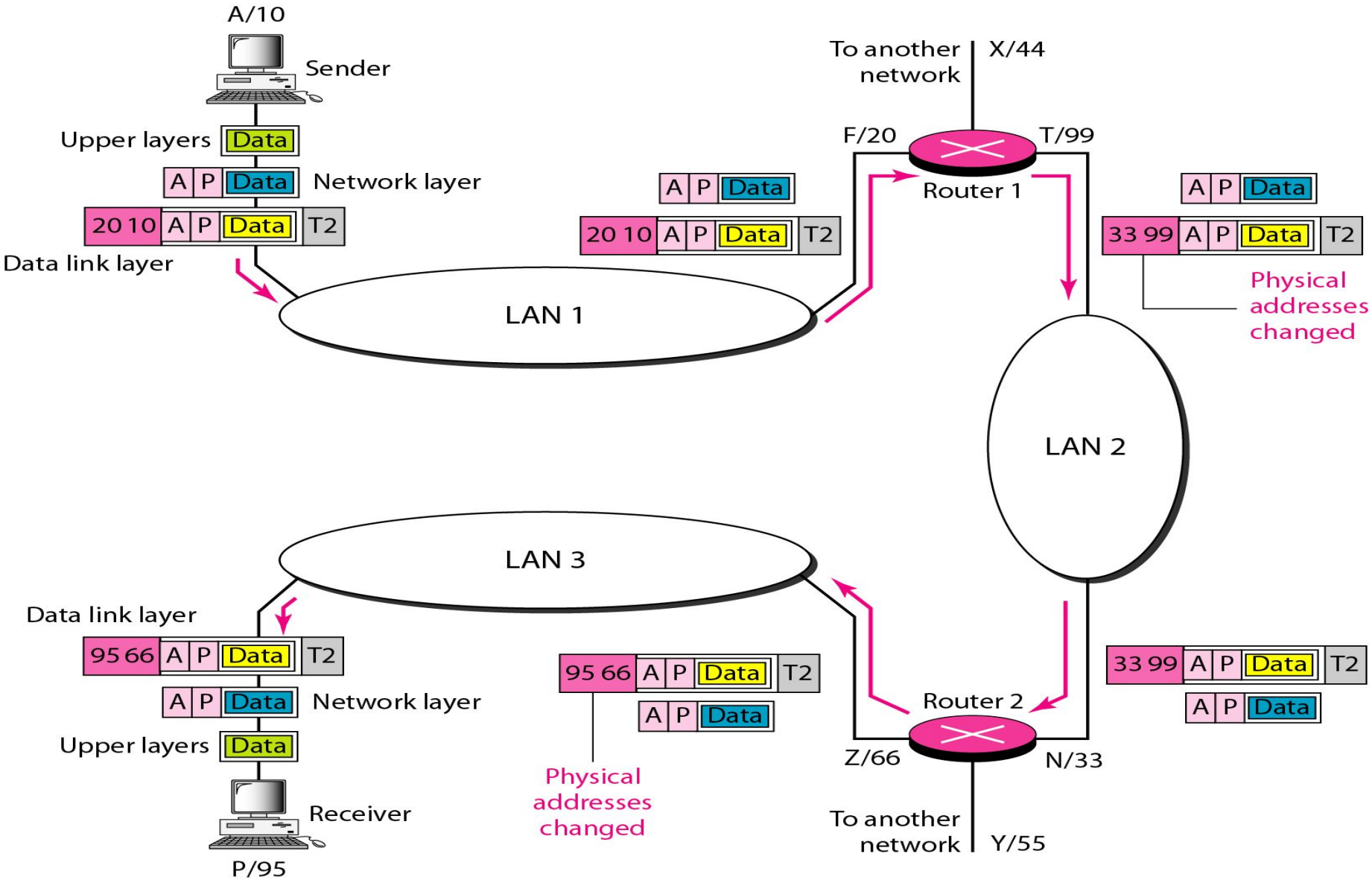


Use of Physical addresses (MAC addresses)



- Another use of physical address is to allows nodes to access the medium.
- Thus, another name “Medium Access Control” (MAC)

Use of Logical addresses (IP addresses)



Computer Network & Network Design

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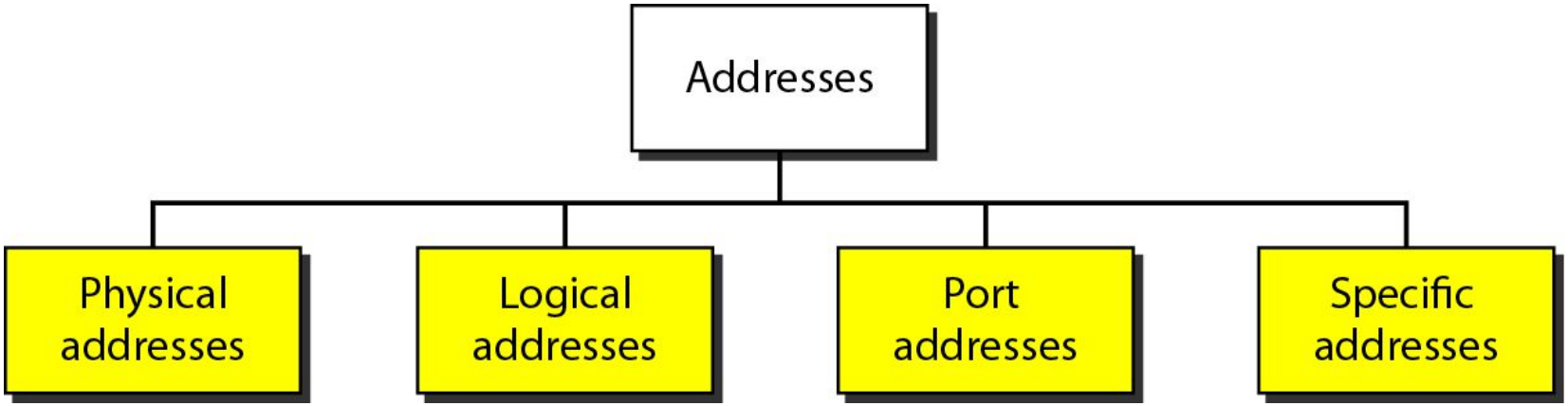
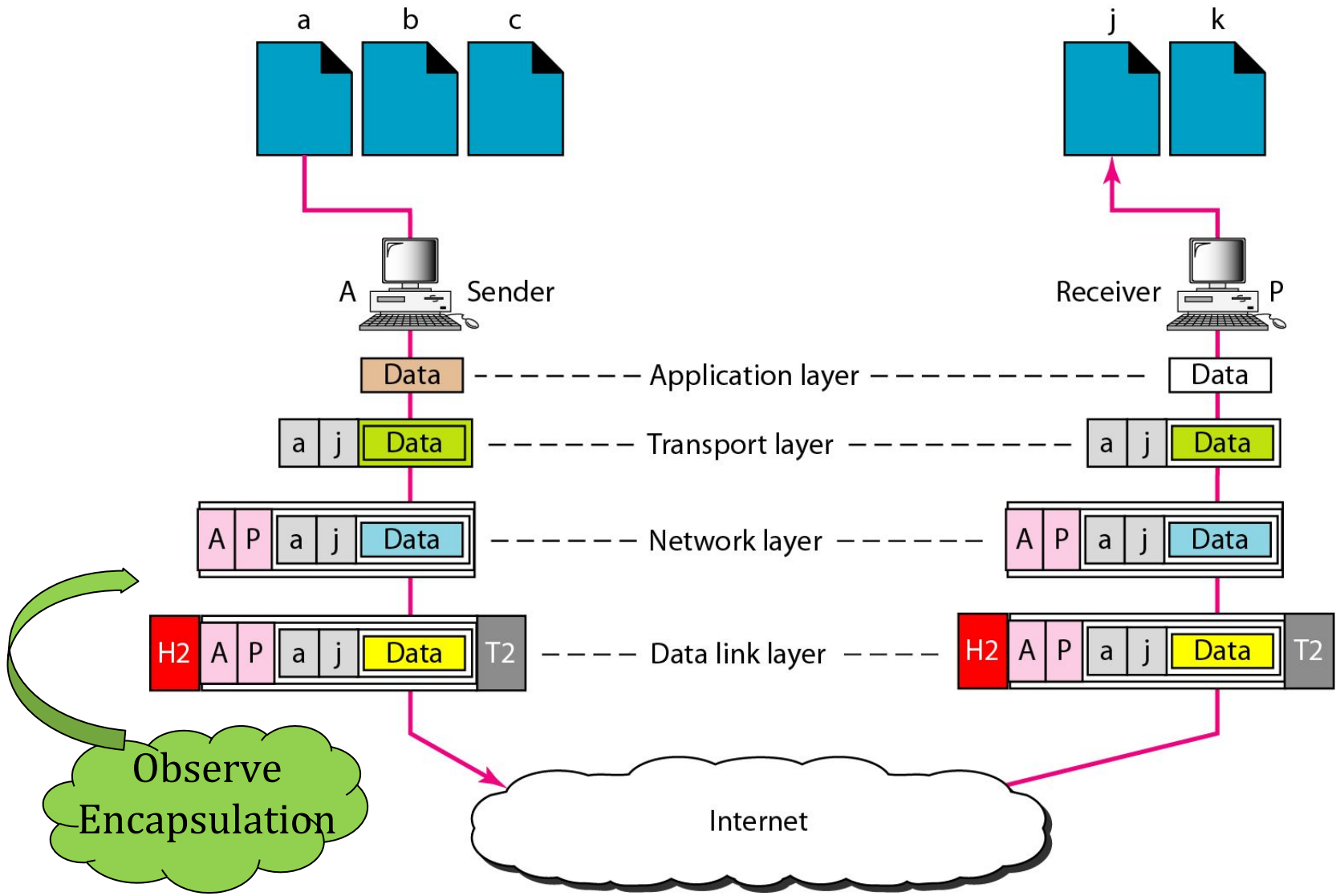
Lecture 9

Addresses in TCP/IP



Use of Port addresses (service point addresses)



Specific addresses

- Created by applications
- User friendly
- Example:
- e-mail address: minal@sfit.ac.in
- URL address: sfit.ac.in

Analogy

Physical Address: GPS coordinates:
(longitude/ latitude)

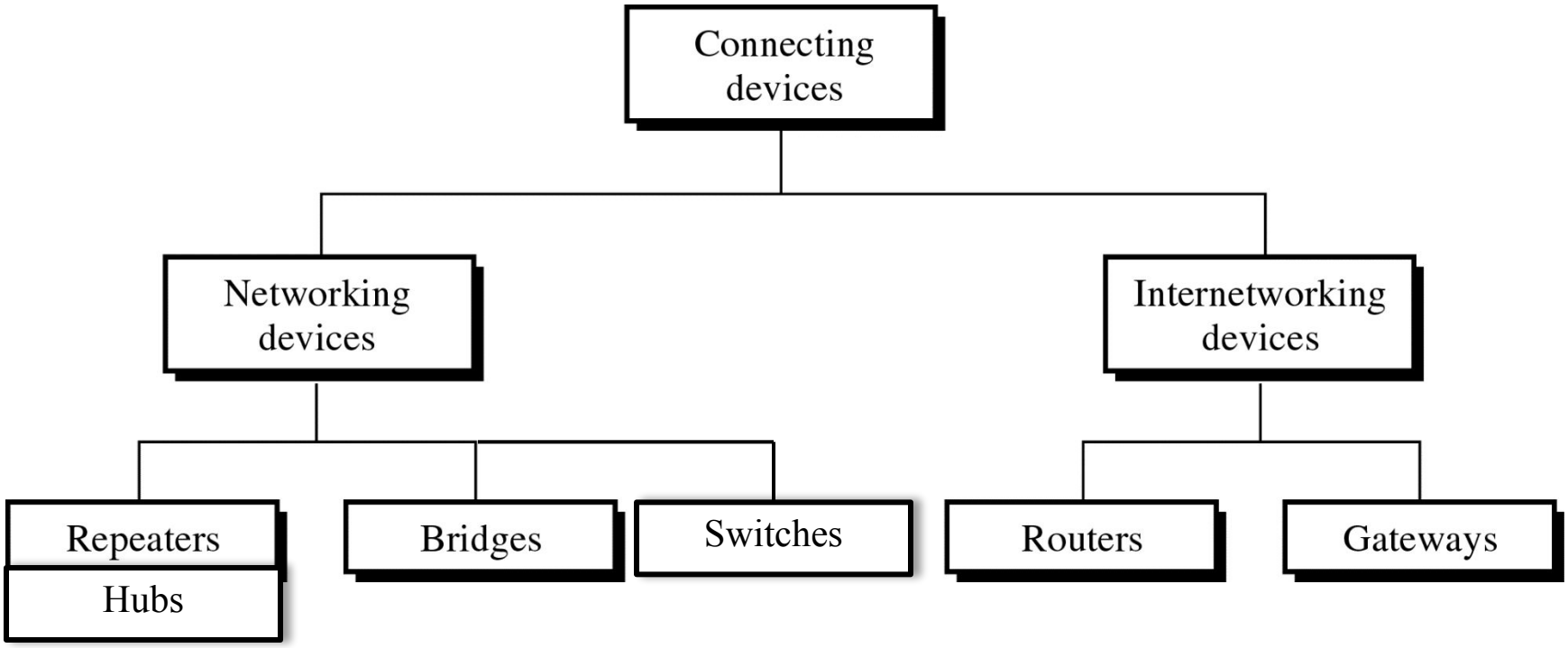
Logical Address: Name of the place, street

Port Address: Name of the person

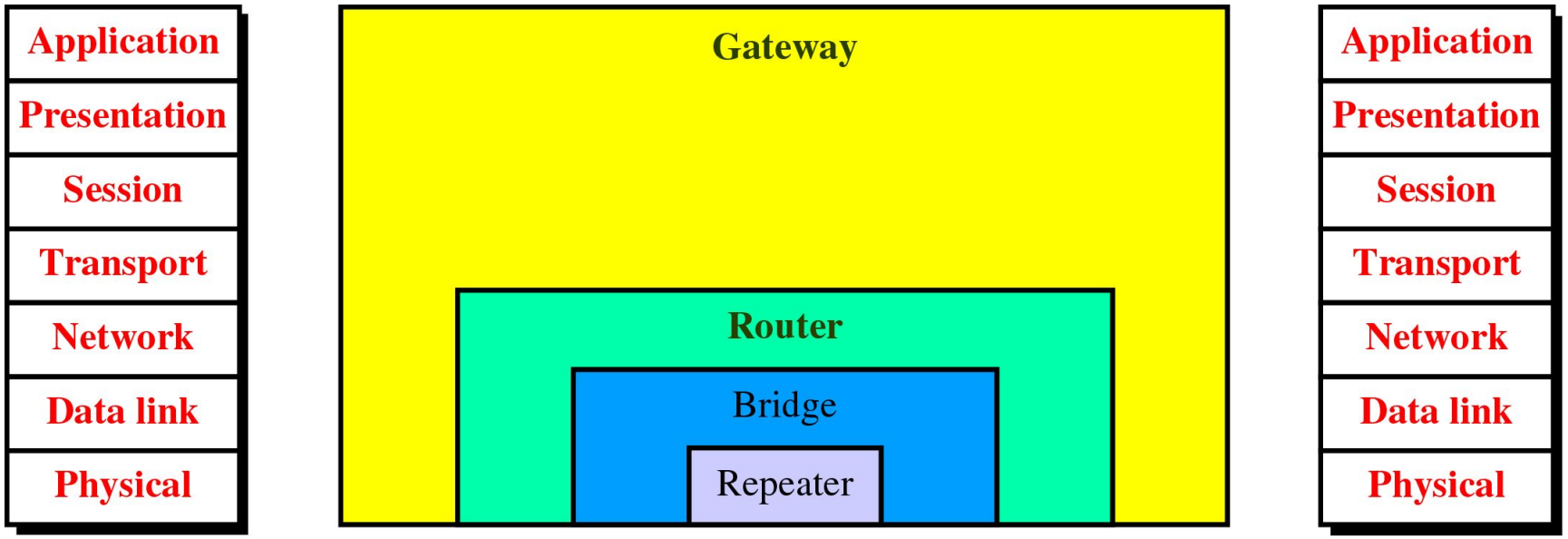
Let's revise

- List the layers of TCP-IP.
- Why is the physical address called MAC address?
- What is another name for port address?

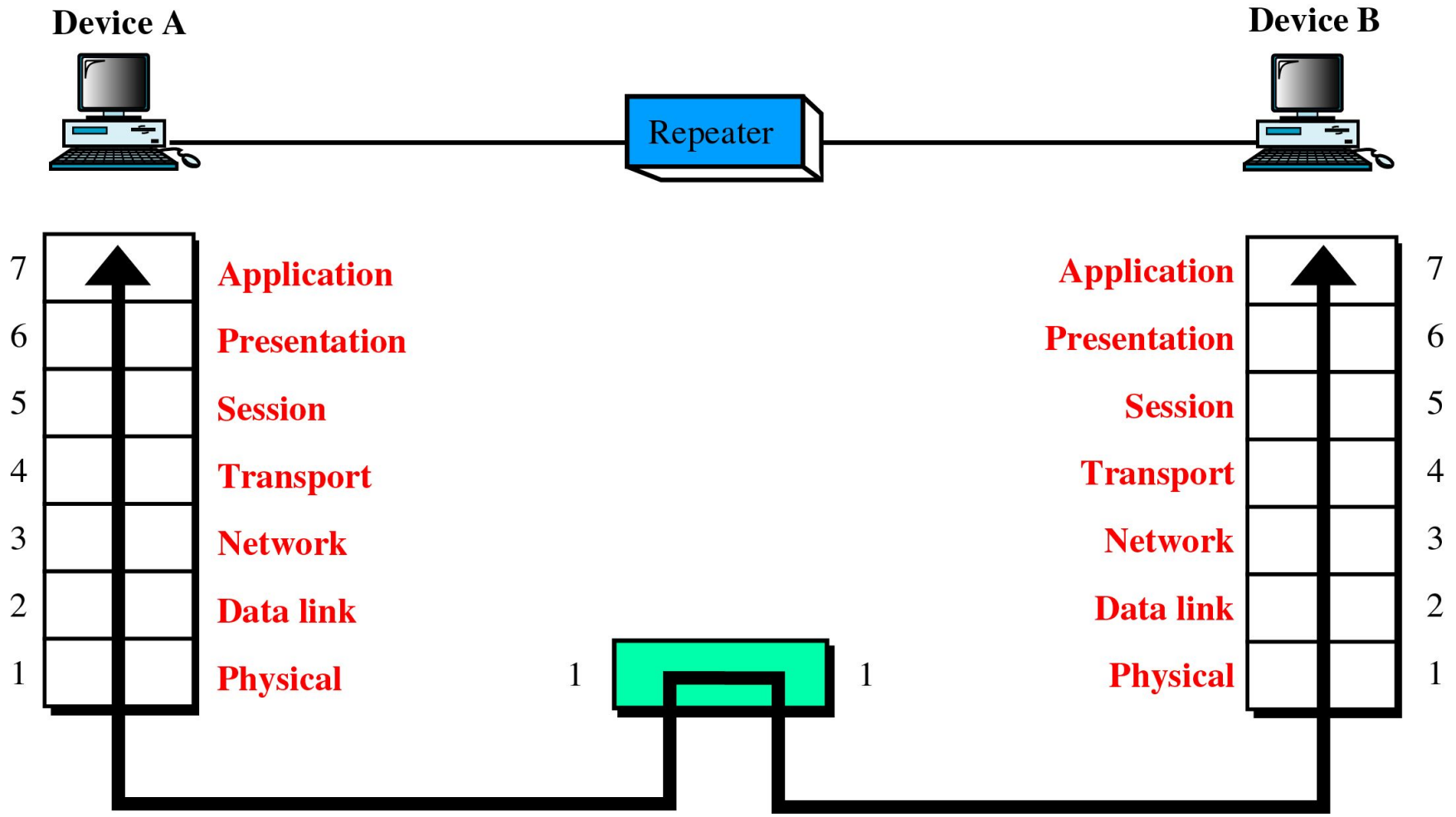
Network Devices



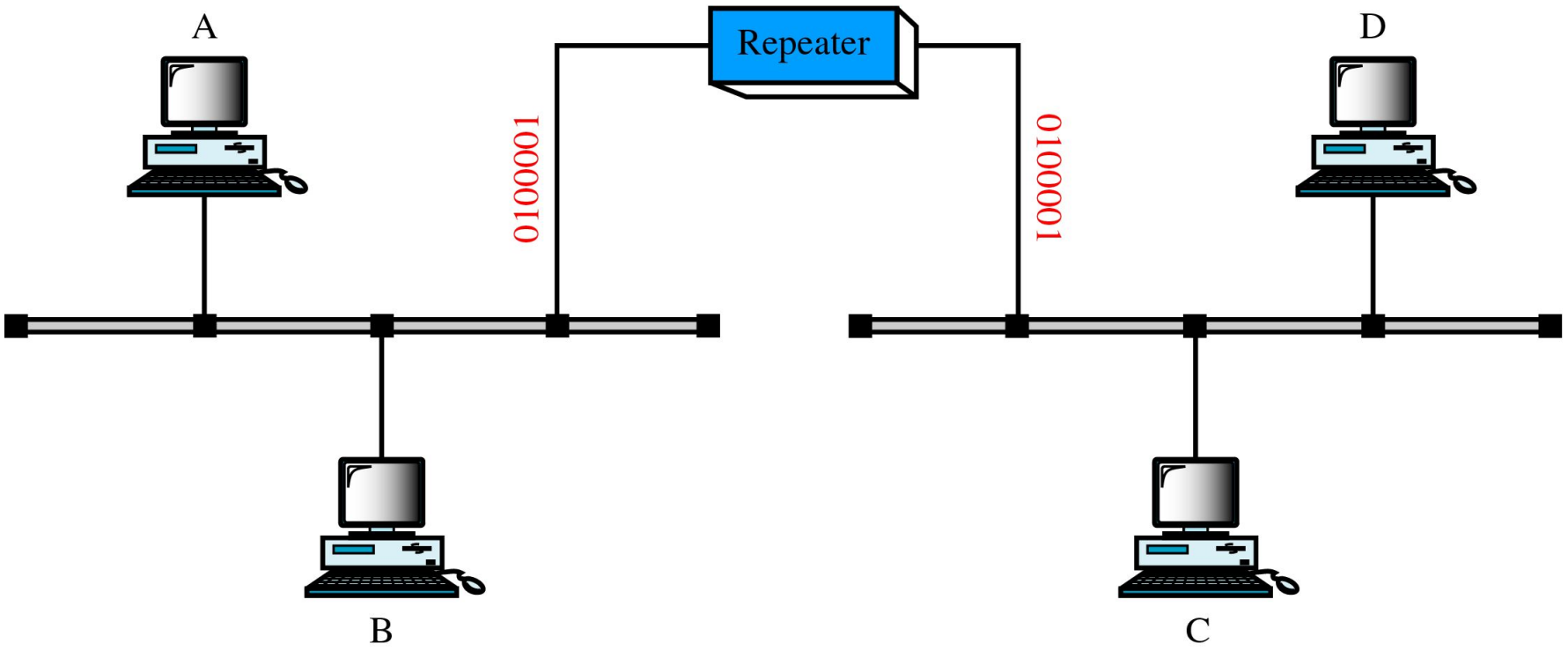
Network Devices and the OSI Model



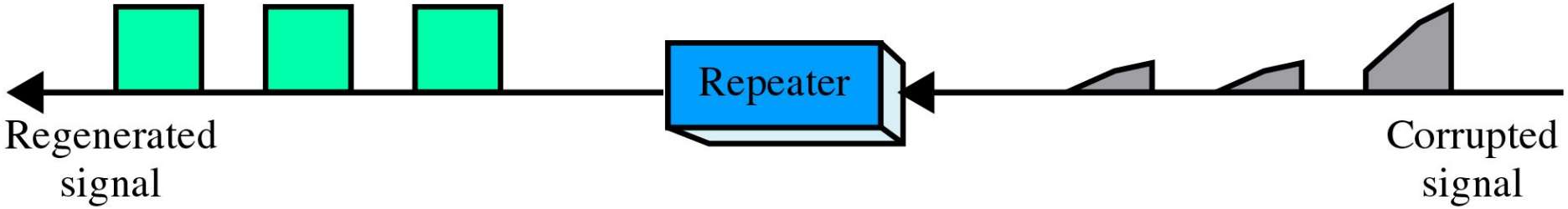
A Repeater in the OSI Model



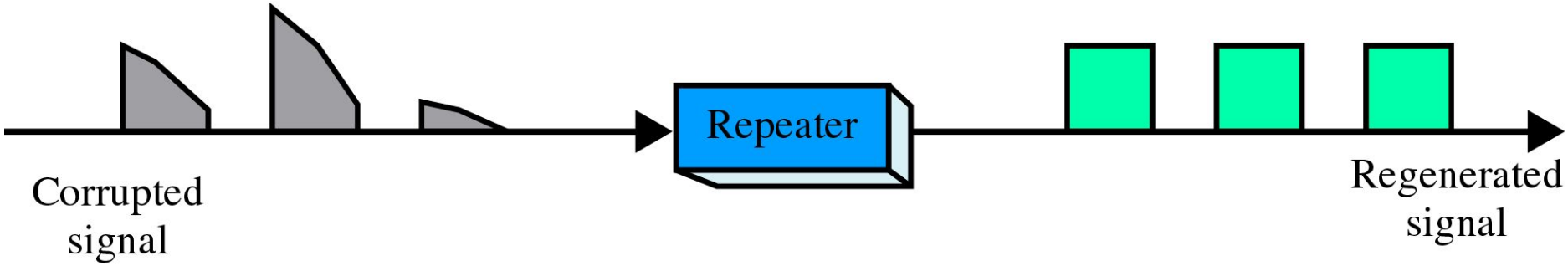
A Repeater



Function of a Repeater



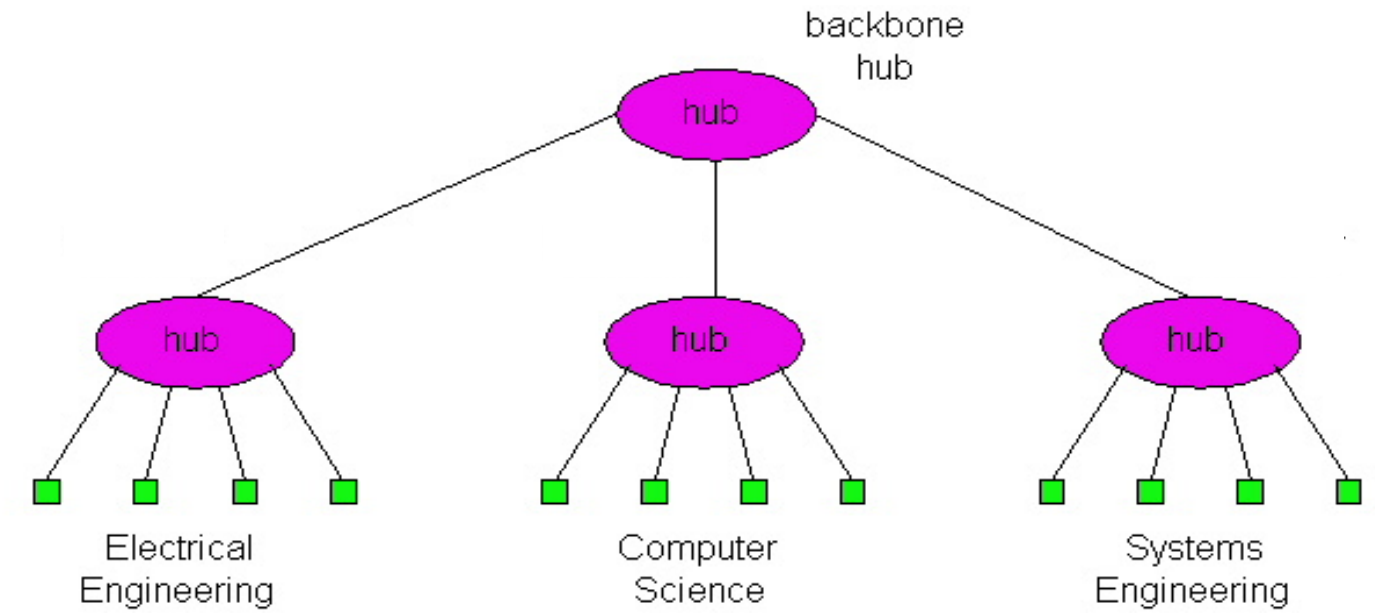
(a) Right-to-left transmission.



(b) Left-to-right transmission.

Repeaters / Hubs

- Physical Layer devices
- Essentially repeaters operating at bit levels: repeat received bits on one interface to all other interfaces
- Hubs can be arranged in a hierarchy (multi-tier design), with backbone hub at its top



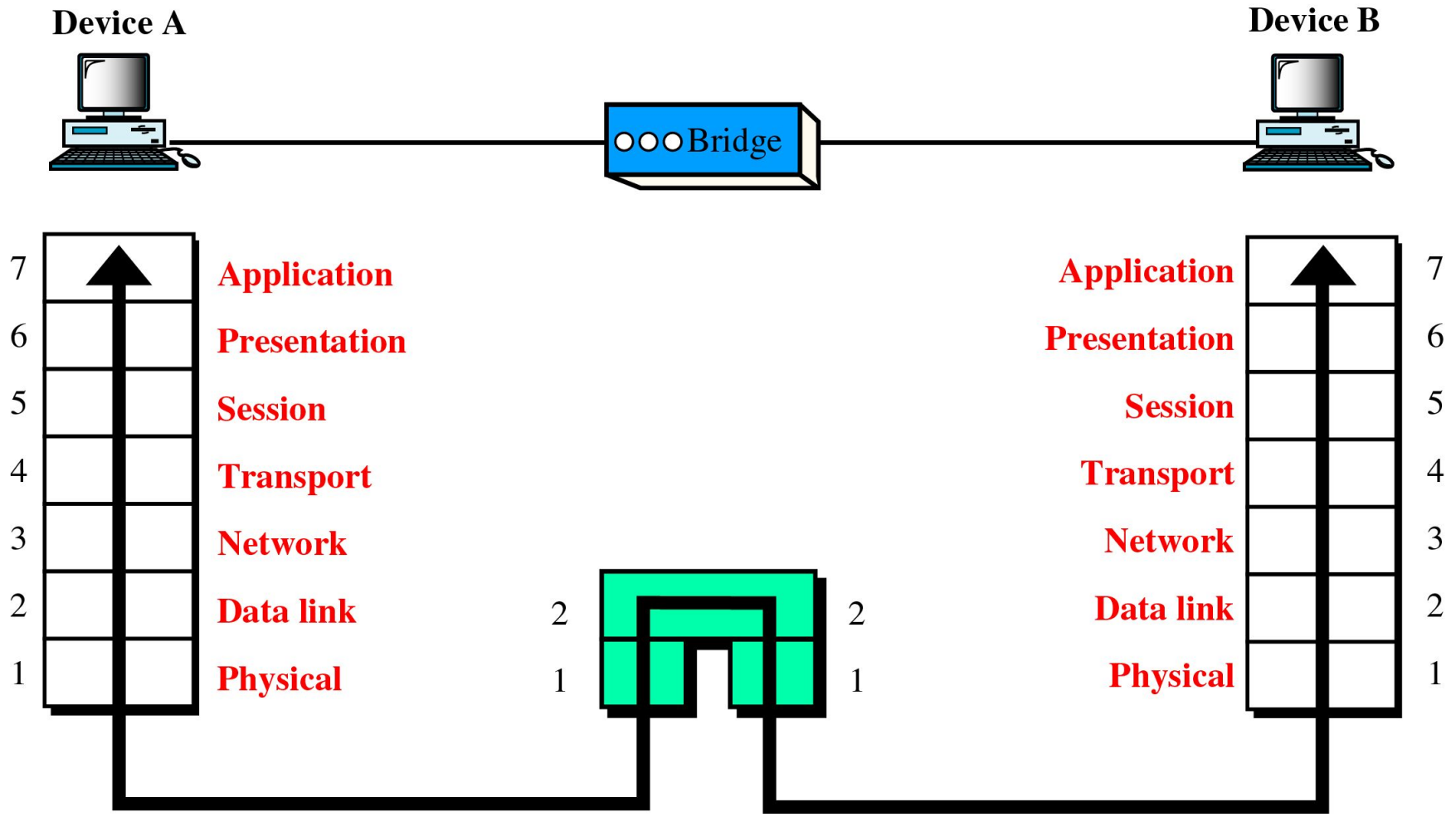
Computer Network & Network Design

Module 1

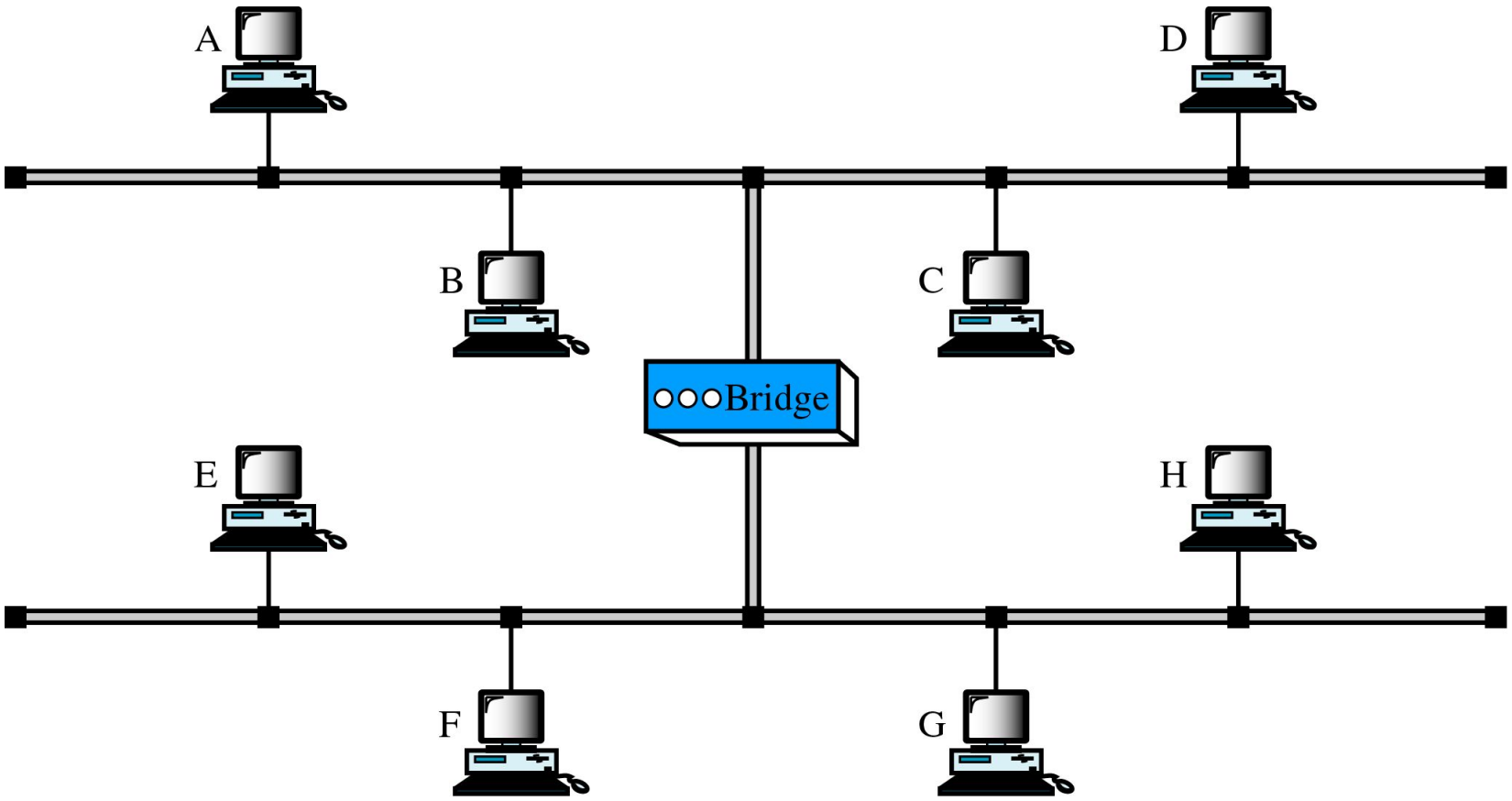
Introduction to Computer Networks

Lecture 10

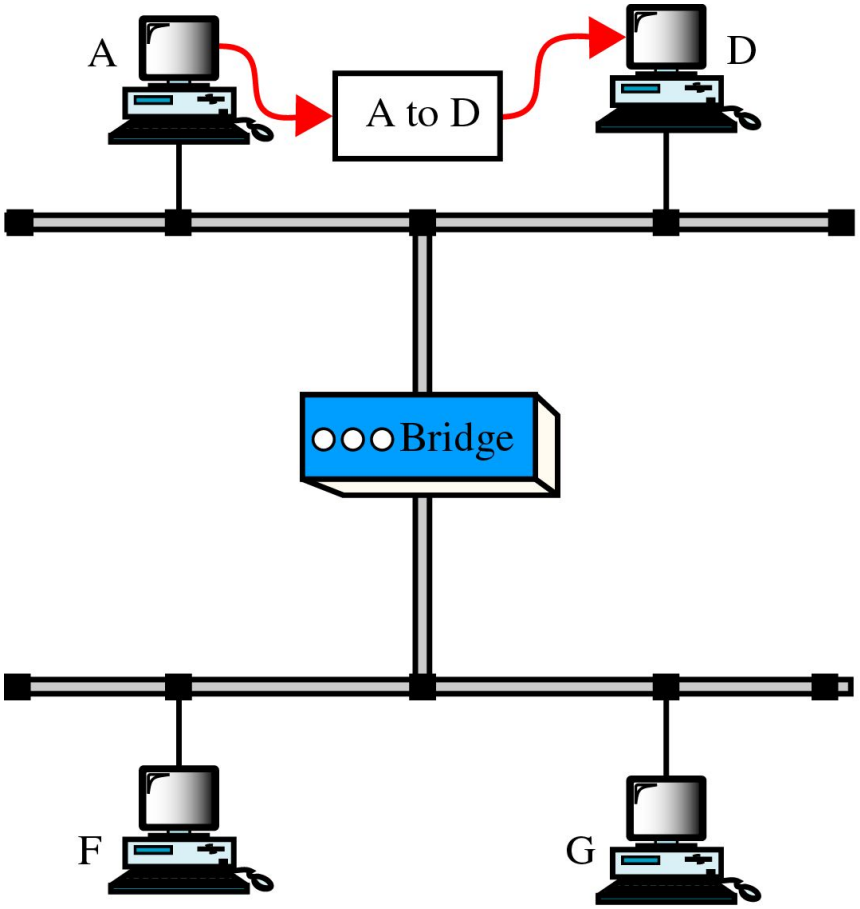
A Bridge in the OSI Model



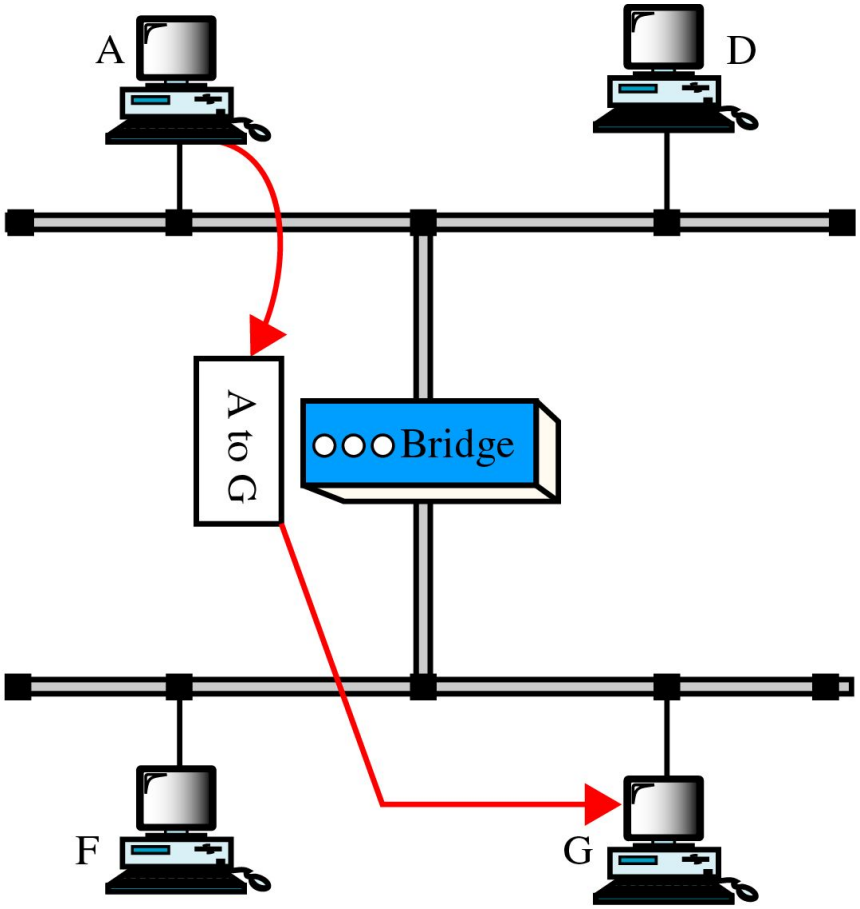
A Bridge



Function of a Bridge



a. A packet from A to D



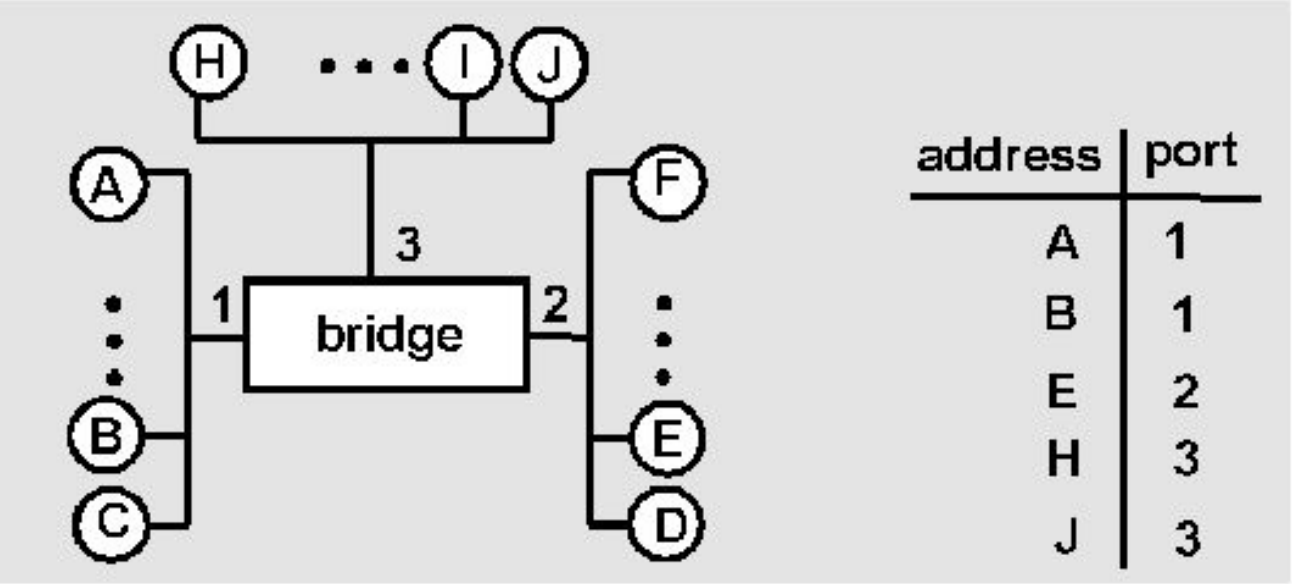
b. A packet from A to G

Bridges

- Link Layer devices
- Operate on frames, examining frame header and selectively forwarding frame based on its destination
- When frame is to be forwarded on segment, bridge use MAC protocol (CDMA/CD) to access segment and transmit
- Bridge isolates collisions: higher throughput
- Allow expansion: no limit on no. of nodes nor geographical coverage
- Can connect different types of Ethernet since it is a store and forward device

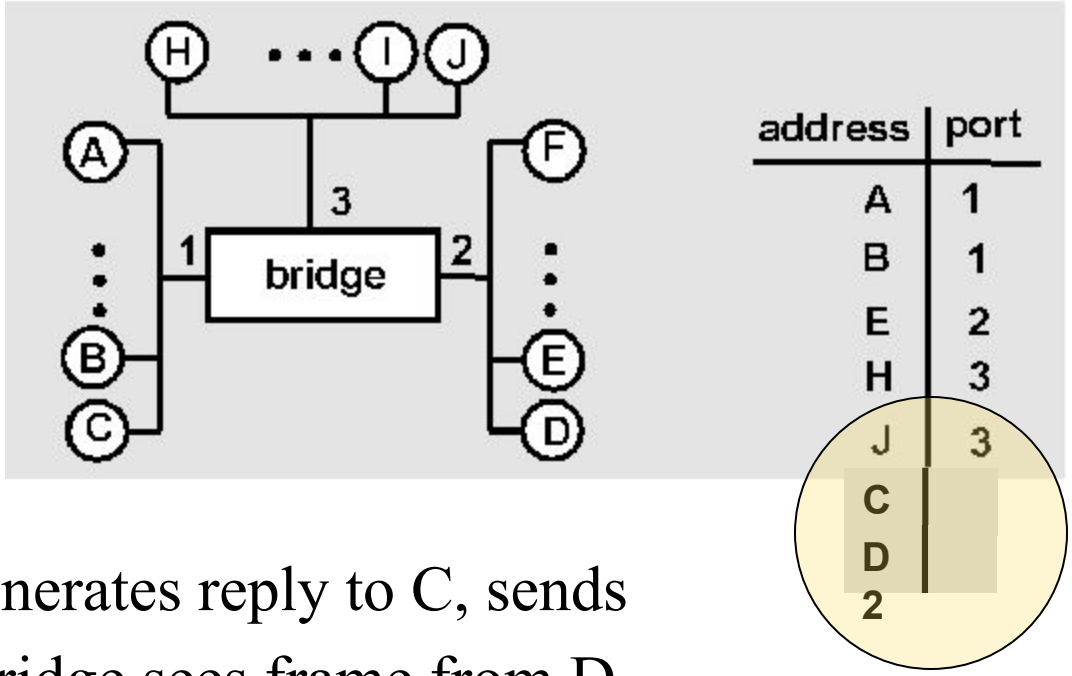
Bridge Learning: example

- Suppose C sends frame to D and D replies back with frame to C



- C sends frame, bridge has no info about D, so floods to both LANs
  - bridge notes that C is on port 1
  - frame received by D

Bridge Learning: example

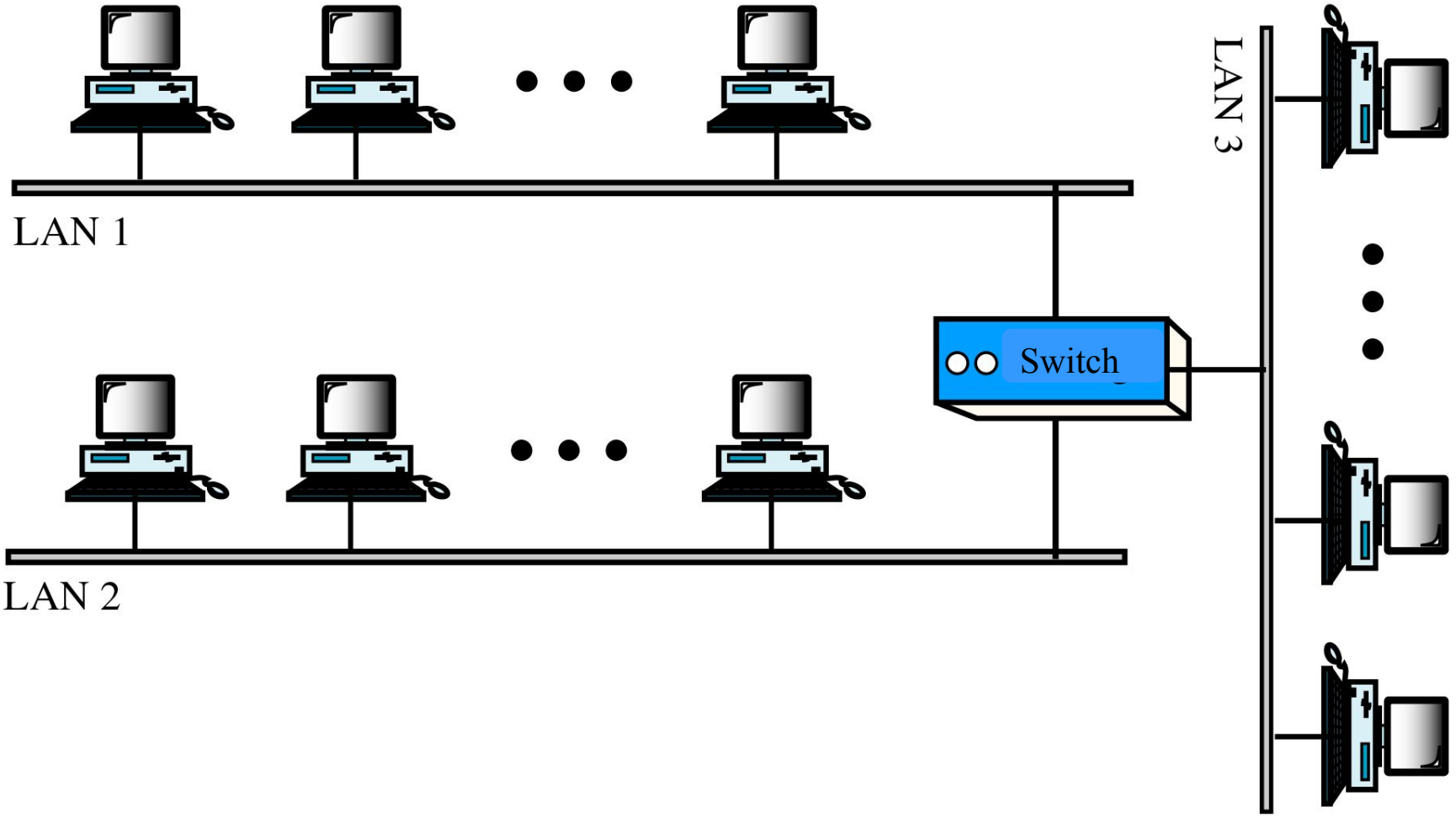


- D generates reply to C, sends
  - bridge sees frame from D
  - bridge notes that D is on interface 2
  - bridge knows C on interface 1, so *selectively* forwards frame out via interface 1

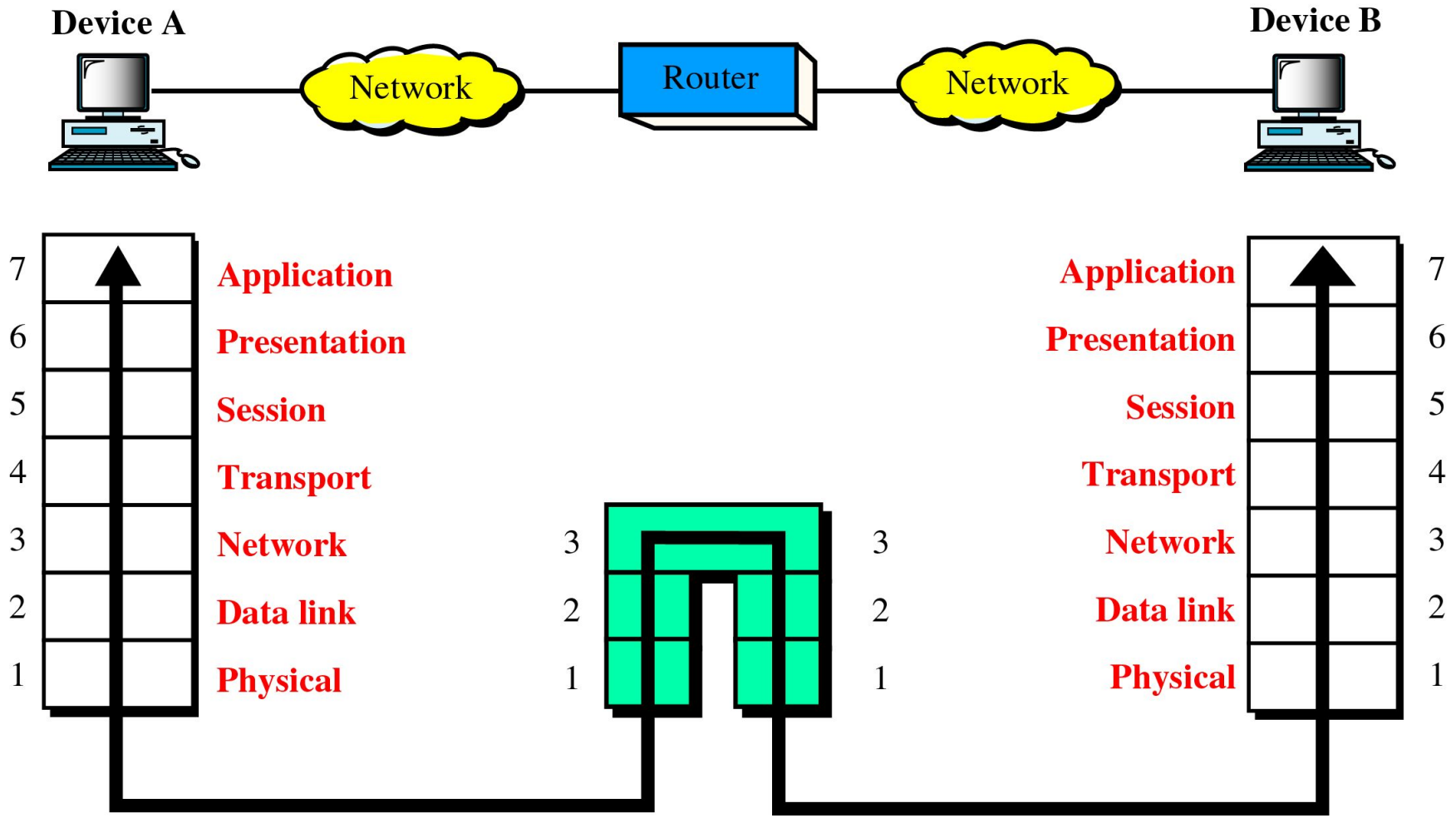
Switches

- Link Layer devices
- a multiport bridge with a buffer and a design that can boost its efficiency (large number of ports implies less traffic) and performance.
- Can perform error checking before forwarding data that makes it very efficient
- Switch divides collision domain of hosts, but broadcast domain remains same.

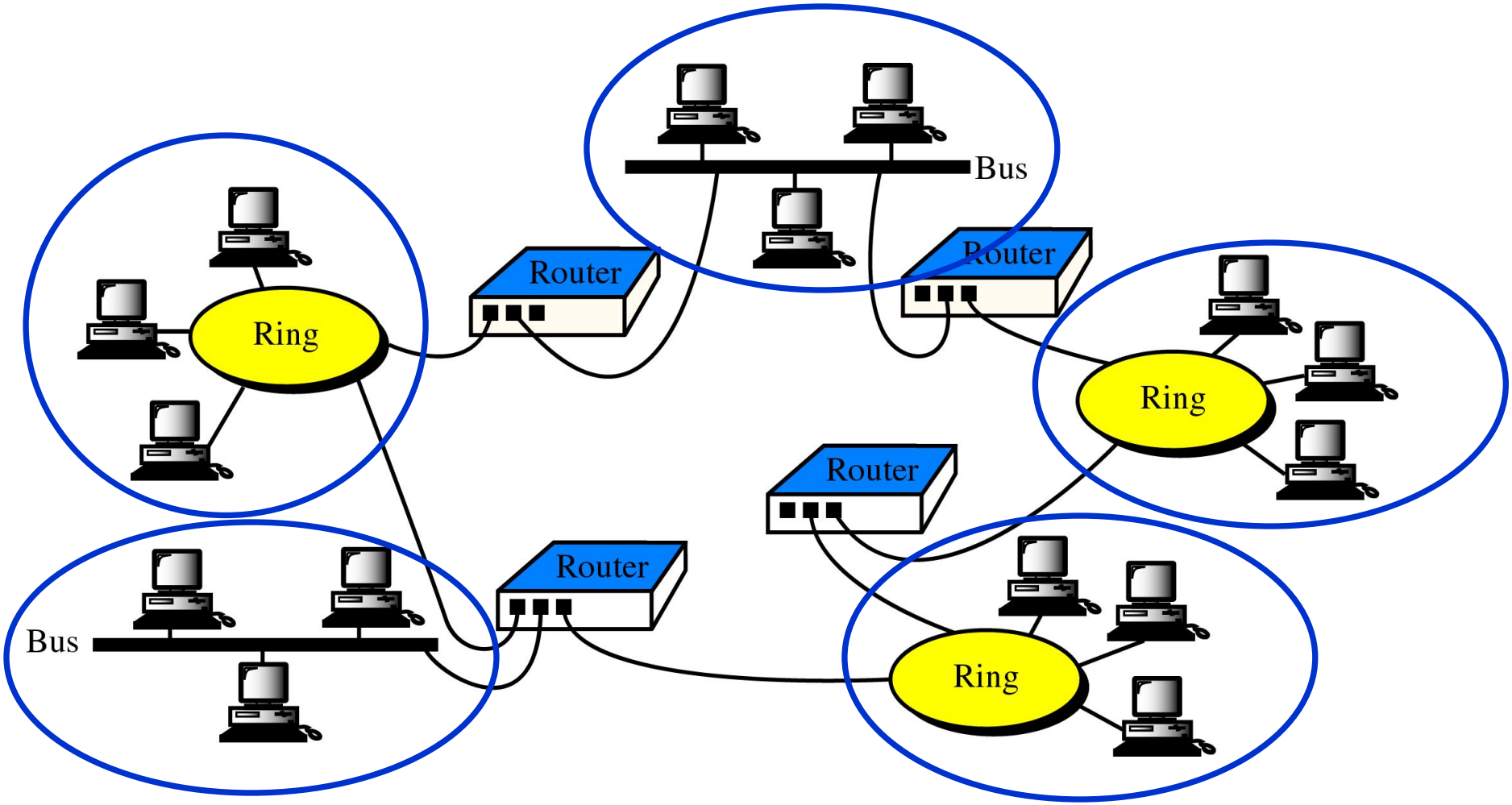
A Switched Network



A Router in the OSI Model



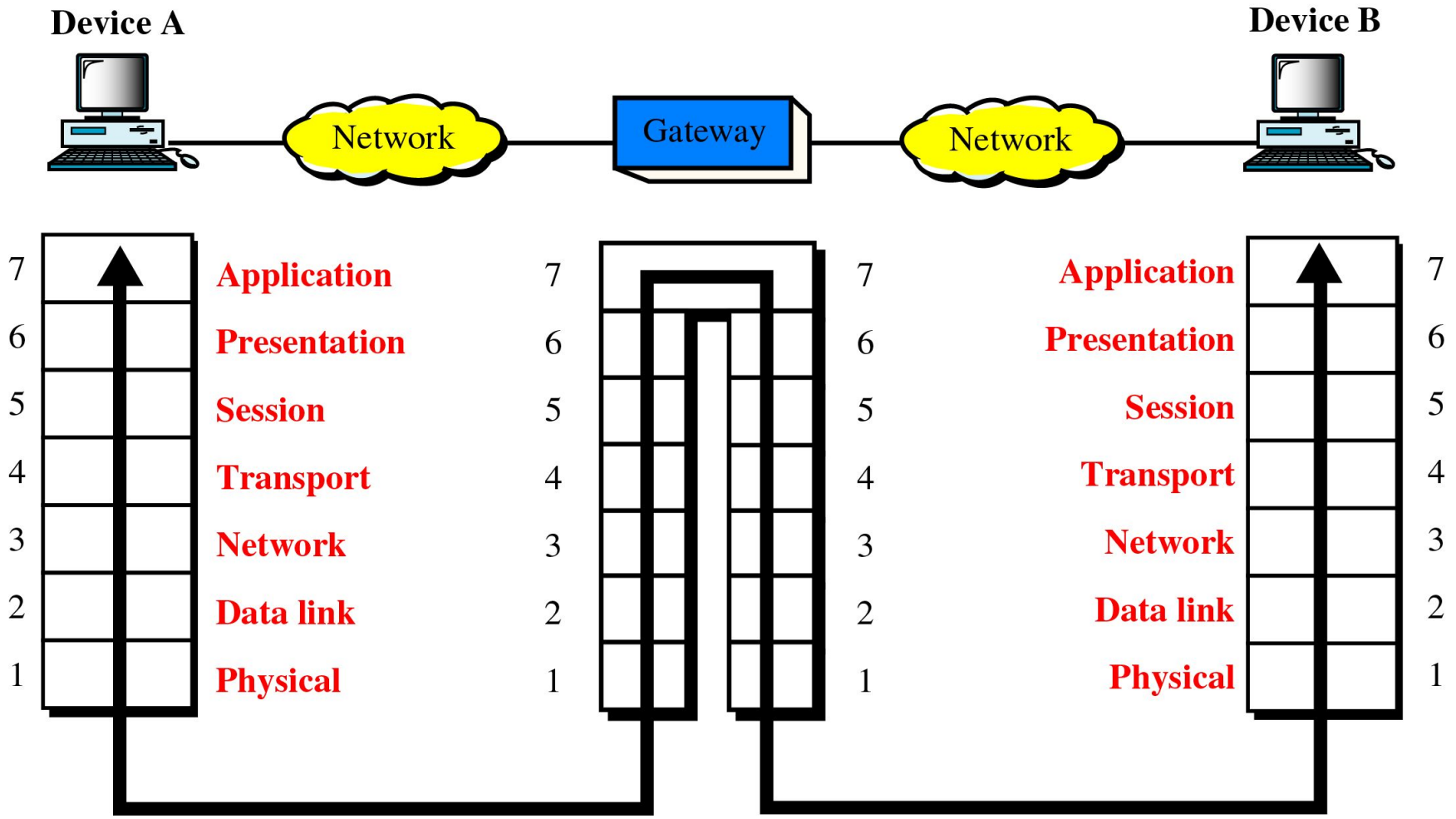
Routers in an Internet



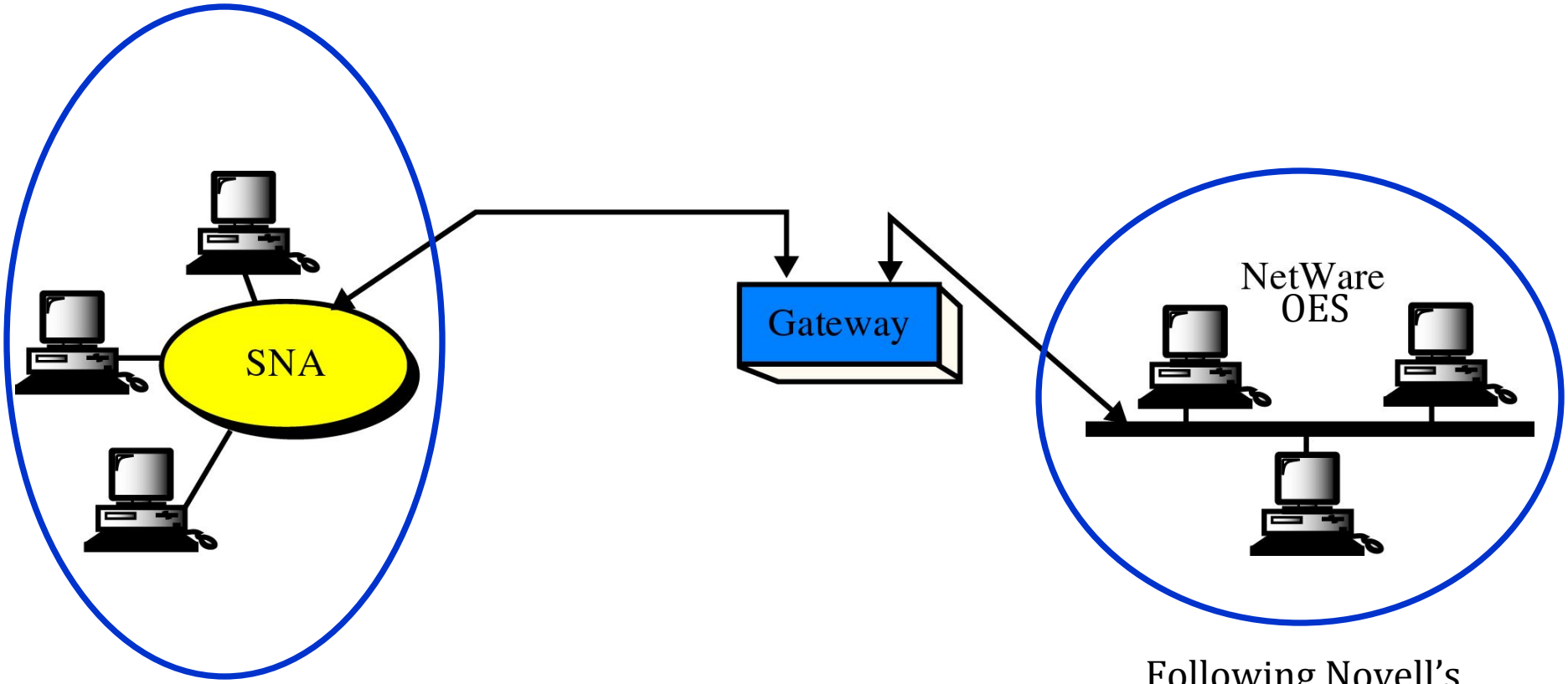
Routers

- Network Layer Device
- Determines routes for each packet using network layer addresses (e.g. IP)
- Can connect any type of network together
- Is capable of determining preferred paths where multiple paths exist

A Gateway in the OSI Model



A Gateway



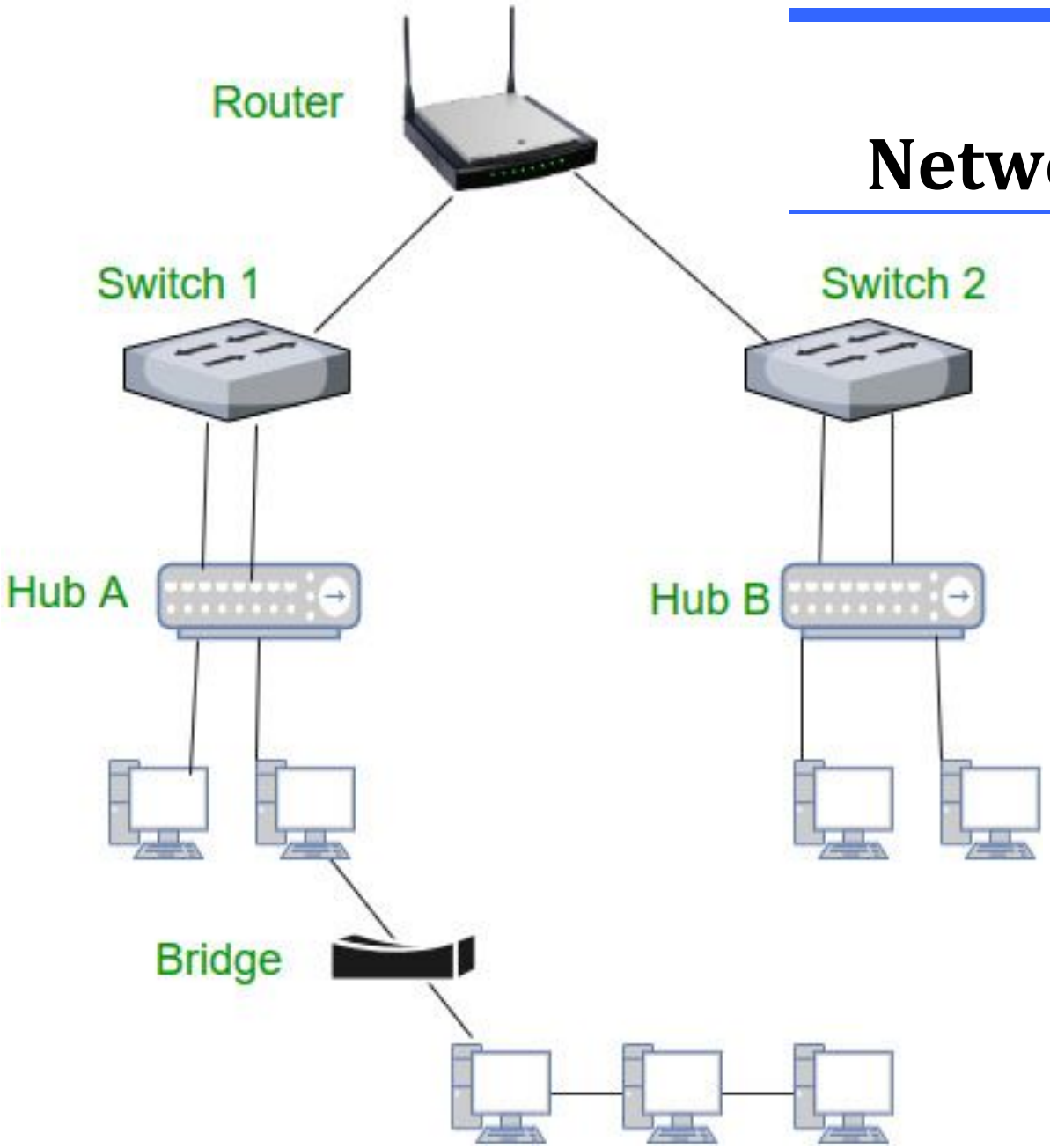
Following IBM's System Network Architecture

Following Novell's Open Enterprise Server architecture

Gateways

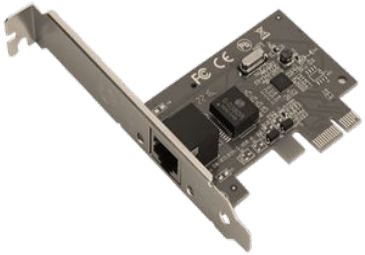
- A gateway, is a passage to connect two networks together.
- connects different networking models/architectures
- works as the messenger agents that take data from one system, interpret it, and transfer it to another system.
- Gateways are also called protocol converters
- Can operate at any layer.
- More complex than switch or router.

Connection of Networking devices



Networking Devices

Modem



NIC

Repeater

Hub

Switch

Router

Bridge

Gateway