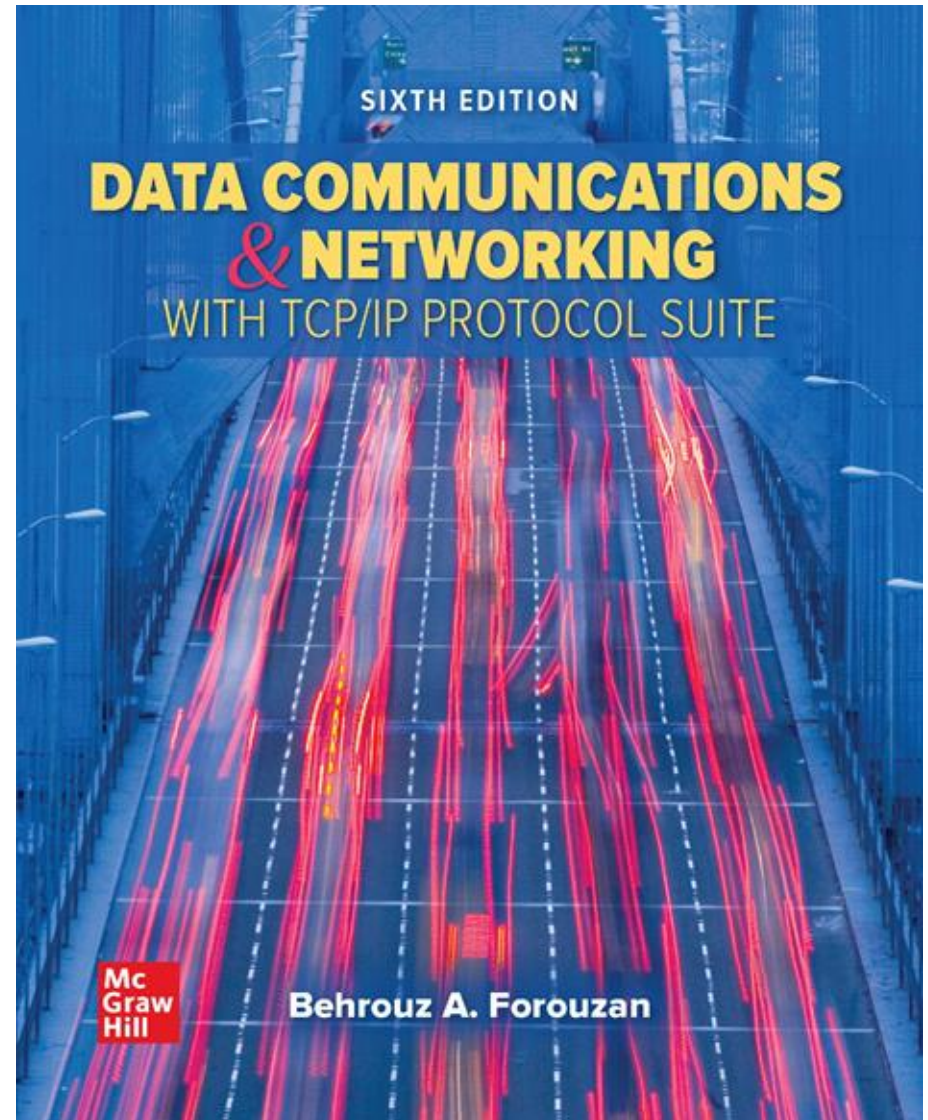


Chapter 01

Introduction

- Data Communications and Networking, With TCP/IP protocol suite Sixth Edition
- Behrouz A. Forouzan



Chapter 1-Part 2: Outline

- 1.4 PROTOCOL LAYERING
- 1.5 TCP/IP PROTOCOL SUITE
- 1.6 THE OSI MODEL

Protocol Layers and Service Models

- Computer network architecture is **complex**
 - Too many components
 - How to understand its architecture?
 - How to allow developers and users to deal with this complexity?
- **Solution** □
 - Computer networks functions are designed and implemented as **layers**
 - Layers are **logical groupings** of all the **processes or functions** required for effective **data exchange**
 - Layer **n-1** provides some service to the layer **n** through a **well-defined interface (boundary between each two layers)**
 - Each **interface** defines what **information, operations, and services** a layer must provide for the layer **above** it.
 - These layers are distributed across **all** nodes in the network

Layers, protocols, and interfaces.

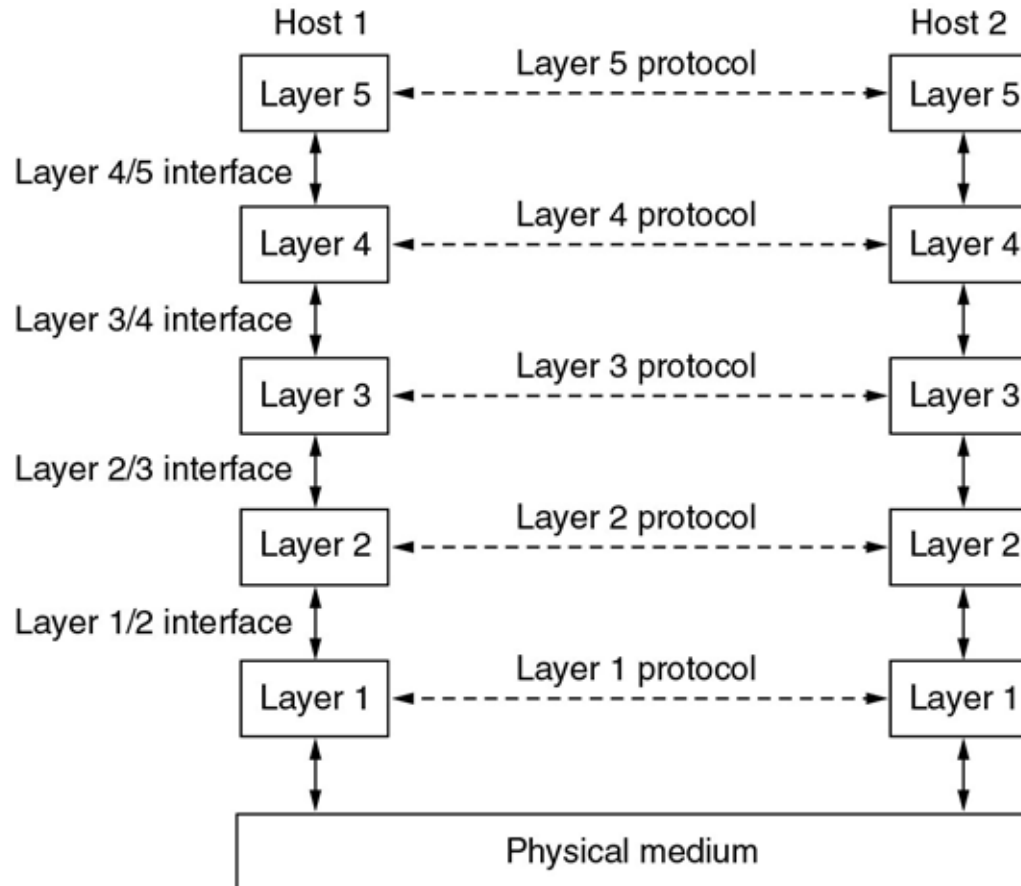
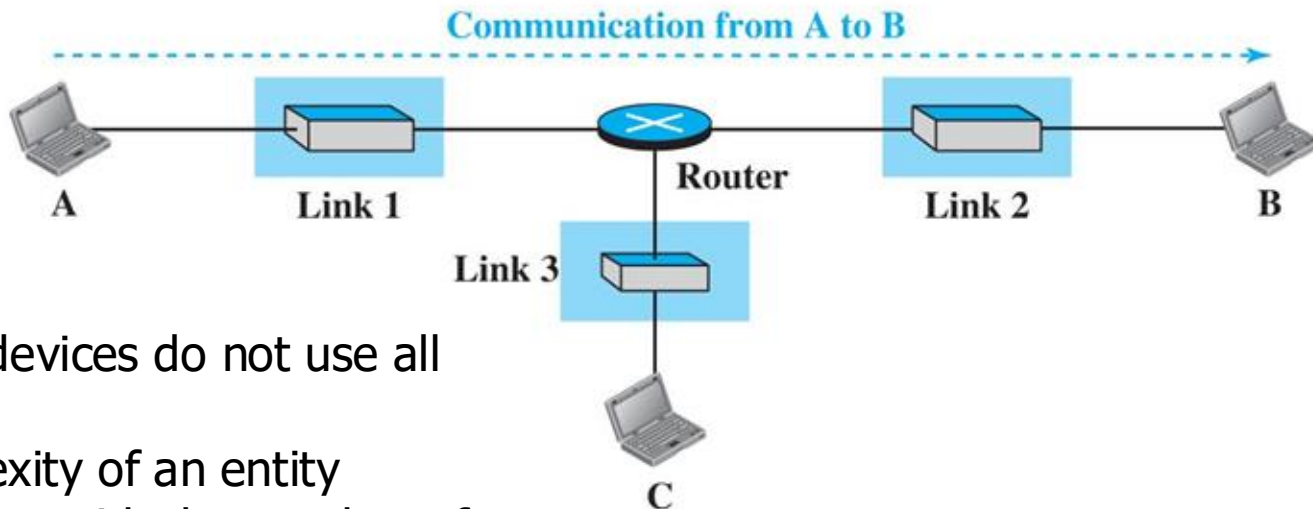
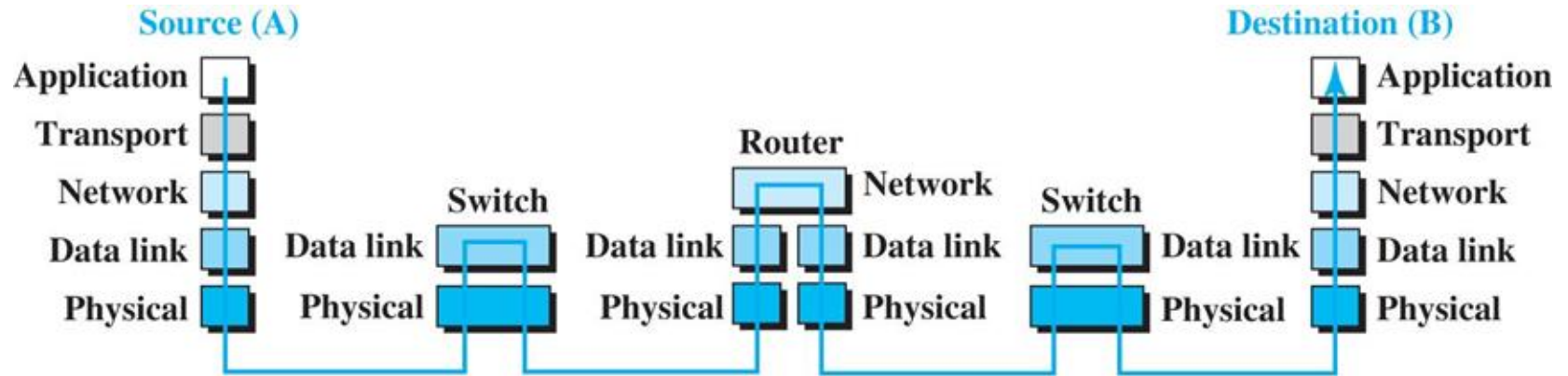


Figure 1.18 Communication through an internet



- Some devices do not use all layers.
- Complexity of an entity increases with the number of layers that it supports

Advantages of Layered Architecture

- Breaks the complicated communication process into layers of simpler processes which allows **easier hardware or software implementation**
- Each layer implements **distinct (different from other layers and unique)** set of protocols (functions), and
- Well-defined interface between layers n and $n-1$
- The advantage of the above two requirements:
 - The implementation of *each layer can be **done independently*** of the other layers.
 - This allows *different manufacturers to supply the **hardware and software*** needed to the different layers
 - encourages collaboration & Competition

Standard Protocol Models

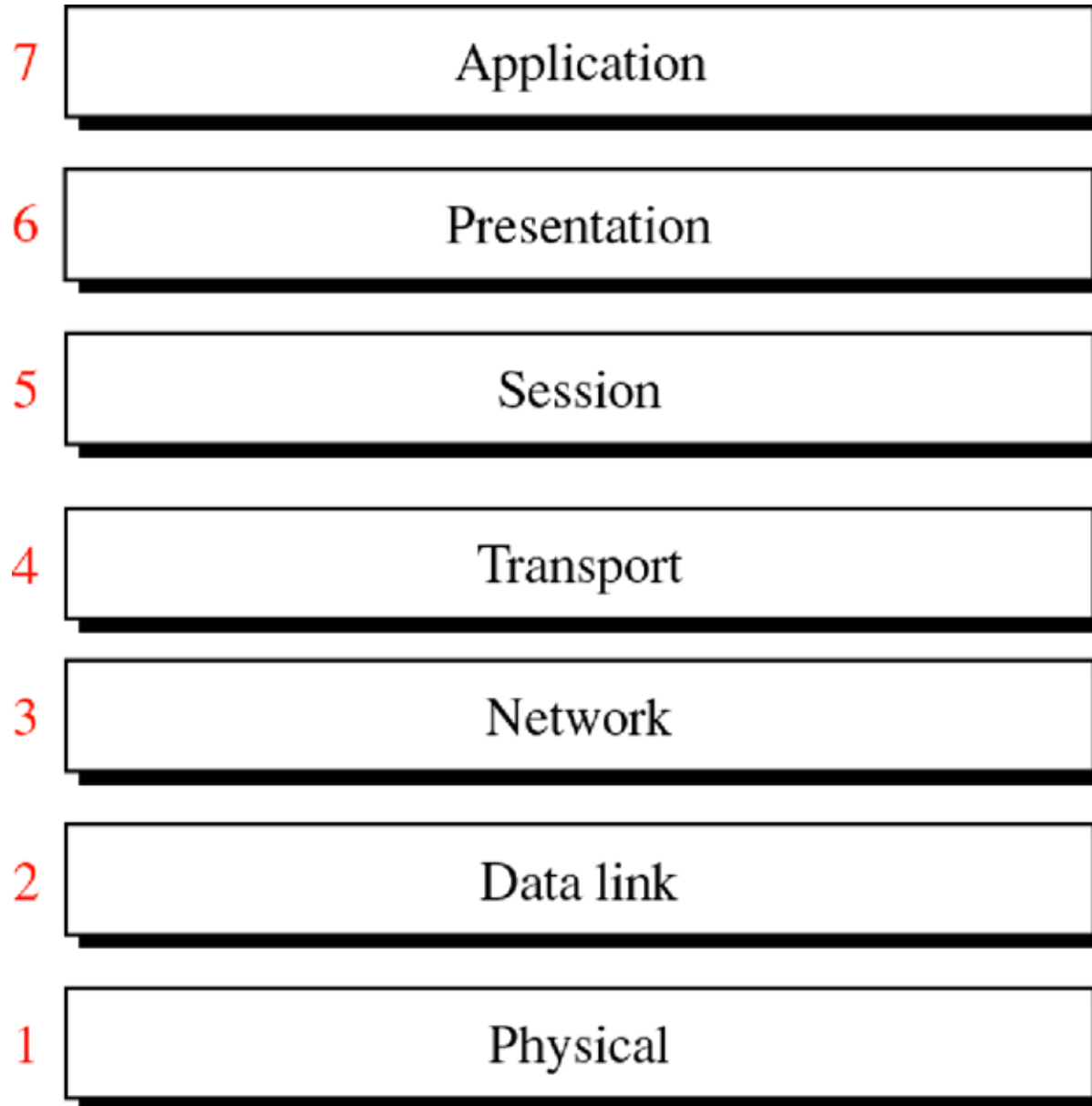
- The protocols of the various layers are called **protocol stack**
- **Two Standard Protocol models (stack) exist:**
 - Open System Interconnect (**OSI**)
 - Transmission Control Protocol/Internet Protocol (**TCP/IP**)

OSI Model



- Developed by ISO (the **International Organization for Standardization**) in 1970s
- Provides framework for standardization
- An open system is a set of protocols that allow any two different systems to communicate regardless of their underlying architecture.
- Describes how data and network information moves from an **application** in one computer to an **application** in another computer.
- Dominated before 1990

OSI Model



OSI Model

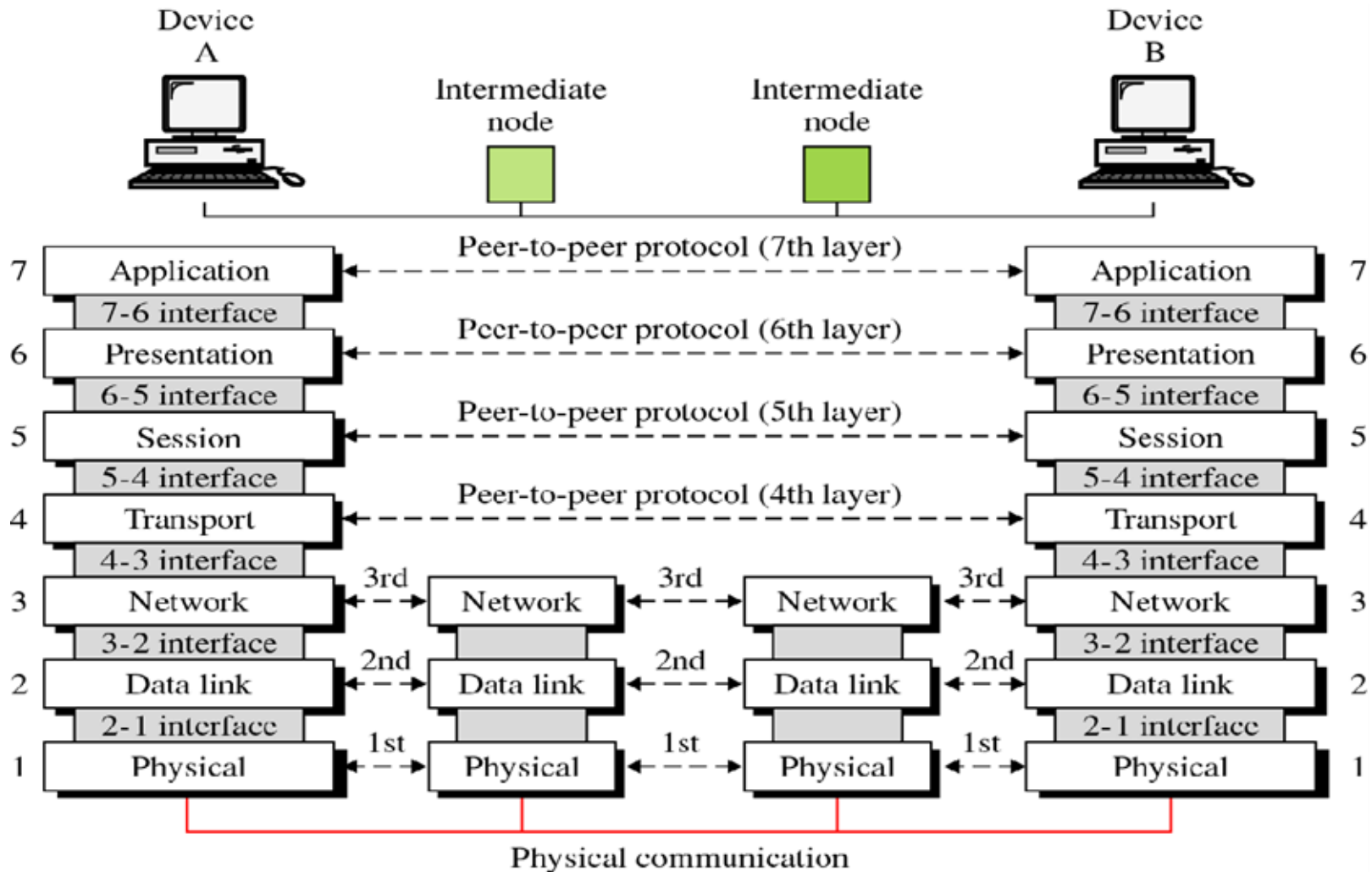
To remember the 7 layers is the sentence “All people seem to need data processing”

OSI Protocols Implementation

- A protocol layer can be implemented in software, in hardware, or in a combination of the two
- Application, Presentation, Session and Transport are implemented in software
- Network is a mixed implementation of *hardware and software*
- Physical and data link are implemented in *hardware* in the network interface card (NIC)

Peer-to-Peer Processes

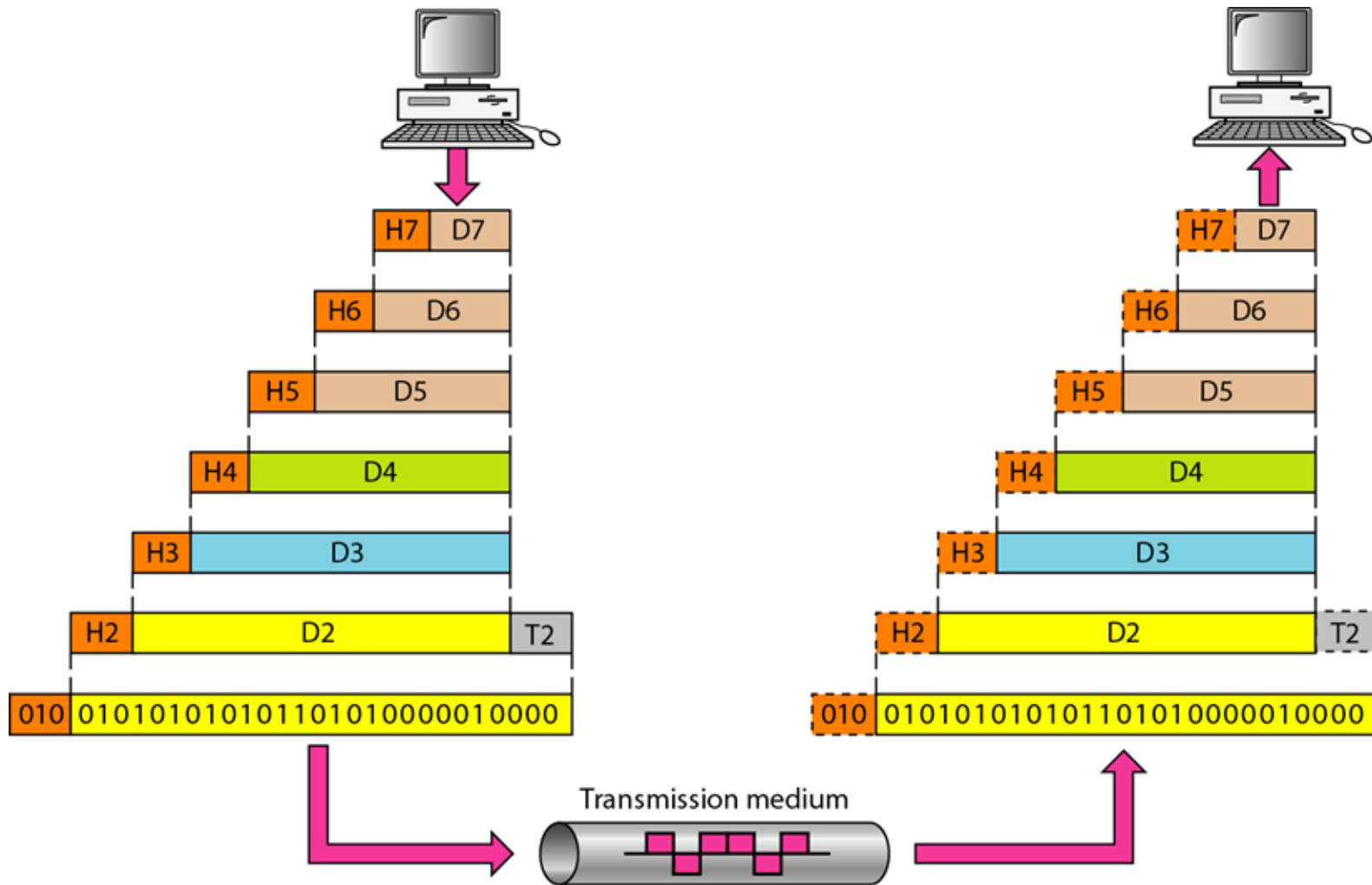
Peers are entities (processes, hardware devices) on two or more machines communicating at a **given layer**



OSI model-Basic Operation

- **Peer-to-Peer communication:** Each layer on a **sending node** communicates (**logically**) with its peer layer on the **receiving node** using **formatted blocks of data** called **Protocol Data Units (PDU)**
- **PDU** = combination of **data (payload)** from the *next higher layer* and the **control information** of the *current layer* (Specific **requests** and **instructions**)
 - Control information are given in the **header** fields of the block except for the data link (has both header and trailer)
 - Control information is read and executed **ONLY** by the peer layer on the **receiving node**

Figure 2.4 *An exchange using the OSI model*



Data Encapsulation

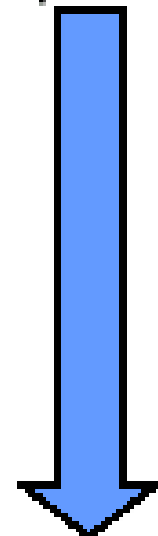
Data encapsulation refers to the fact that layer N-1 carries in its data part the PDU of layer N without any knowledge of its content and its different parts.



protocol data unit (PDU) = combination of data from the next higher and control information

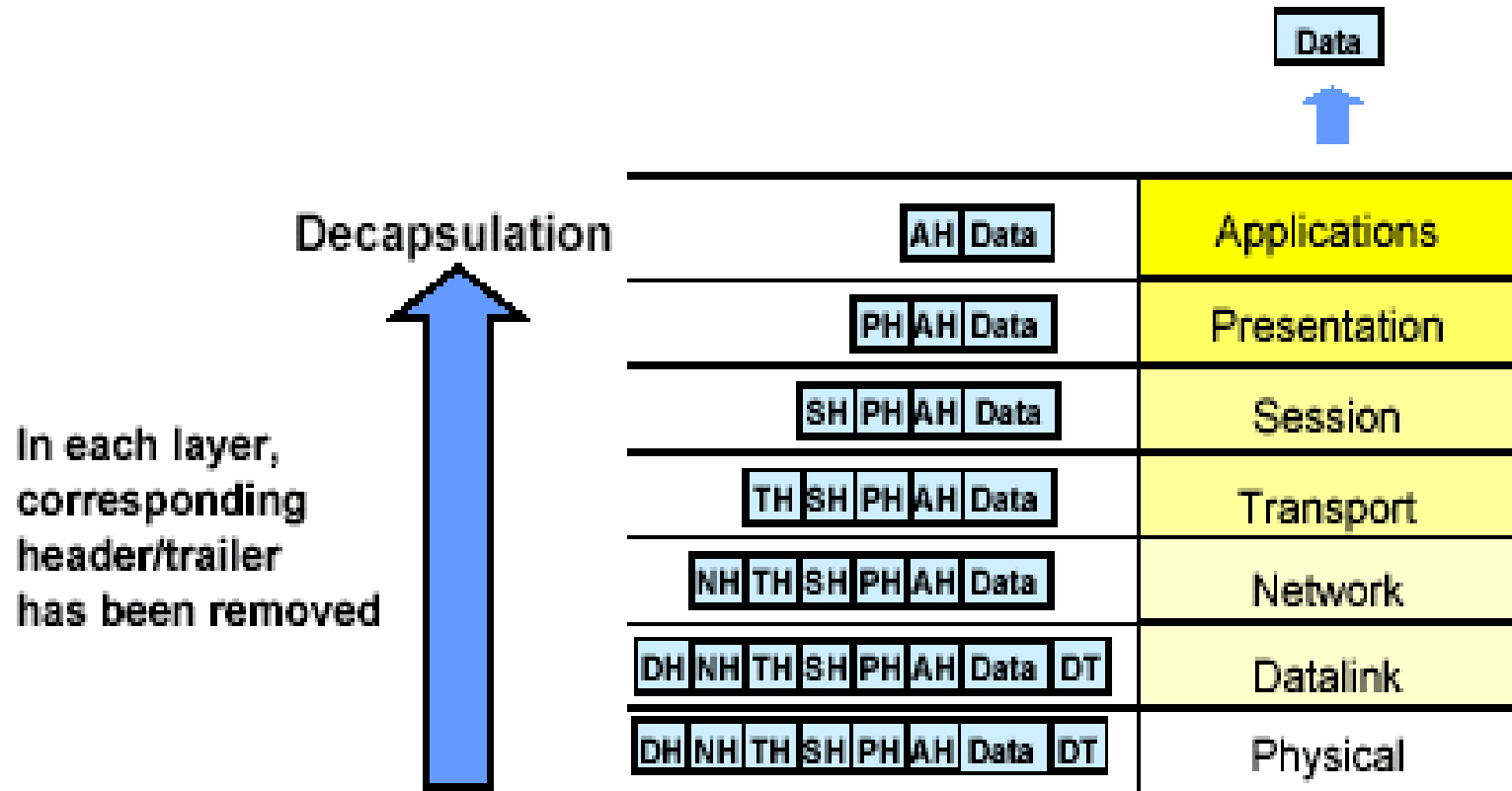
Applications	Application PDU	AH Data
Presentation	Presentation PDU	PH AH Data
Session	Session PDU	SH PH AH Data
Transport	Transport PDU	TH SH PH AH Data
Network	Network PDU	NH TH SH PH AH Data
Datalink	Datalink PDU	DH NH TH SH PH AH Data DT
Physical		DH NH TH SH PH AH Data DT

Encapsulation

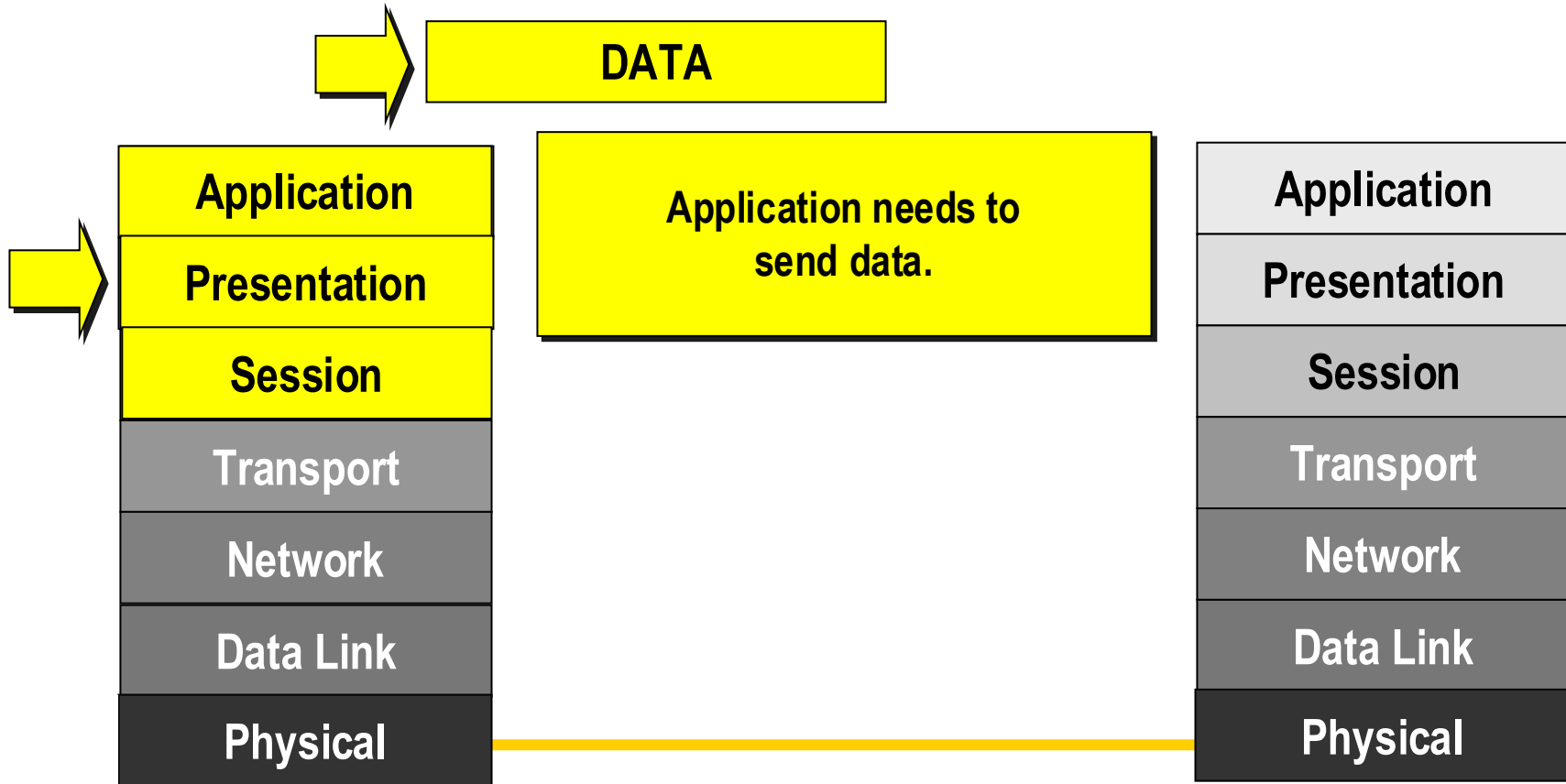


Additional of control information to data is referred to encapsulation

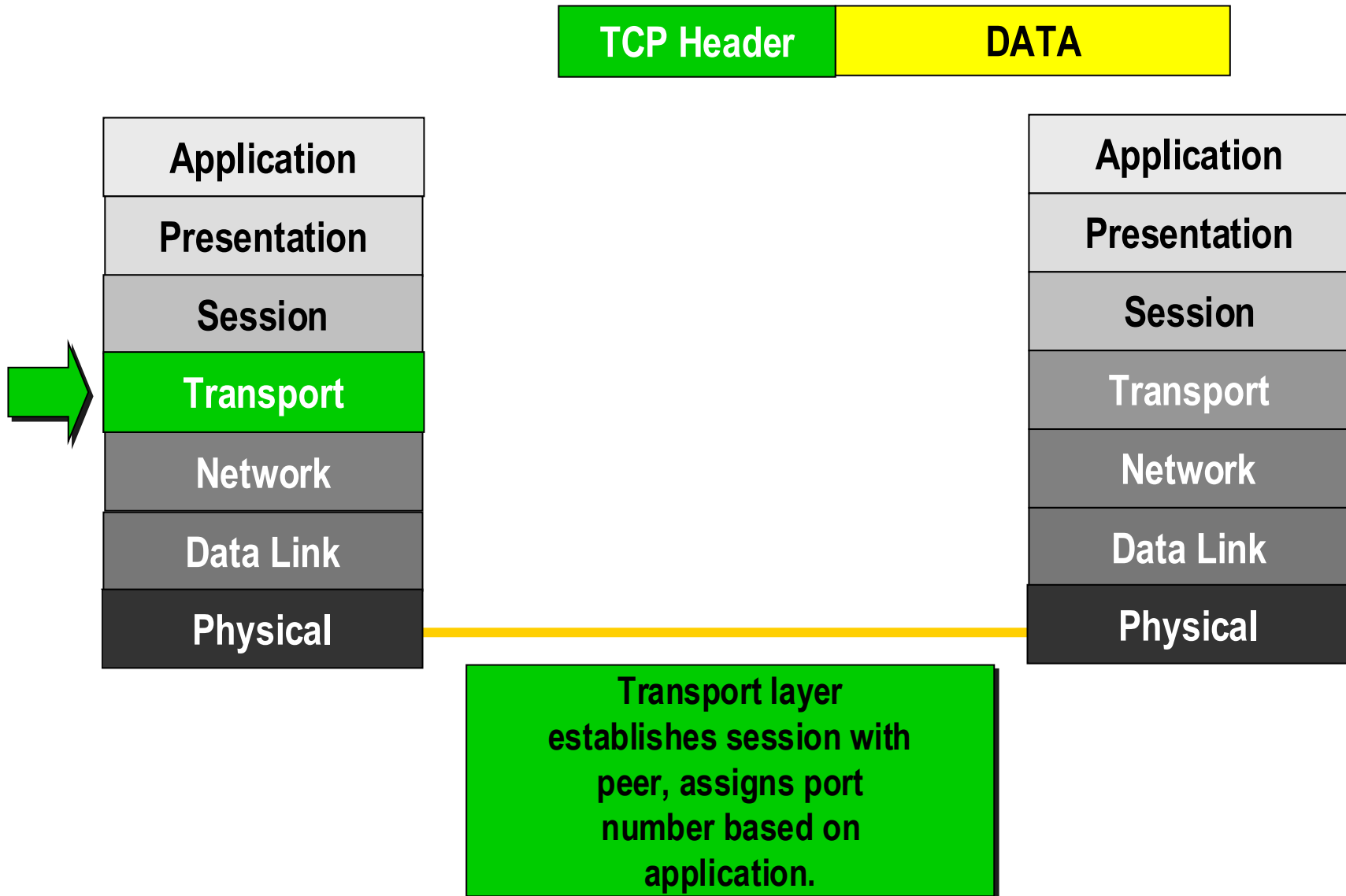
Decapsulation



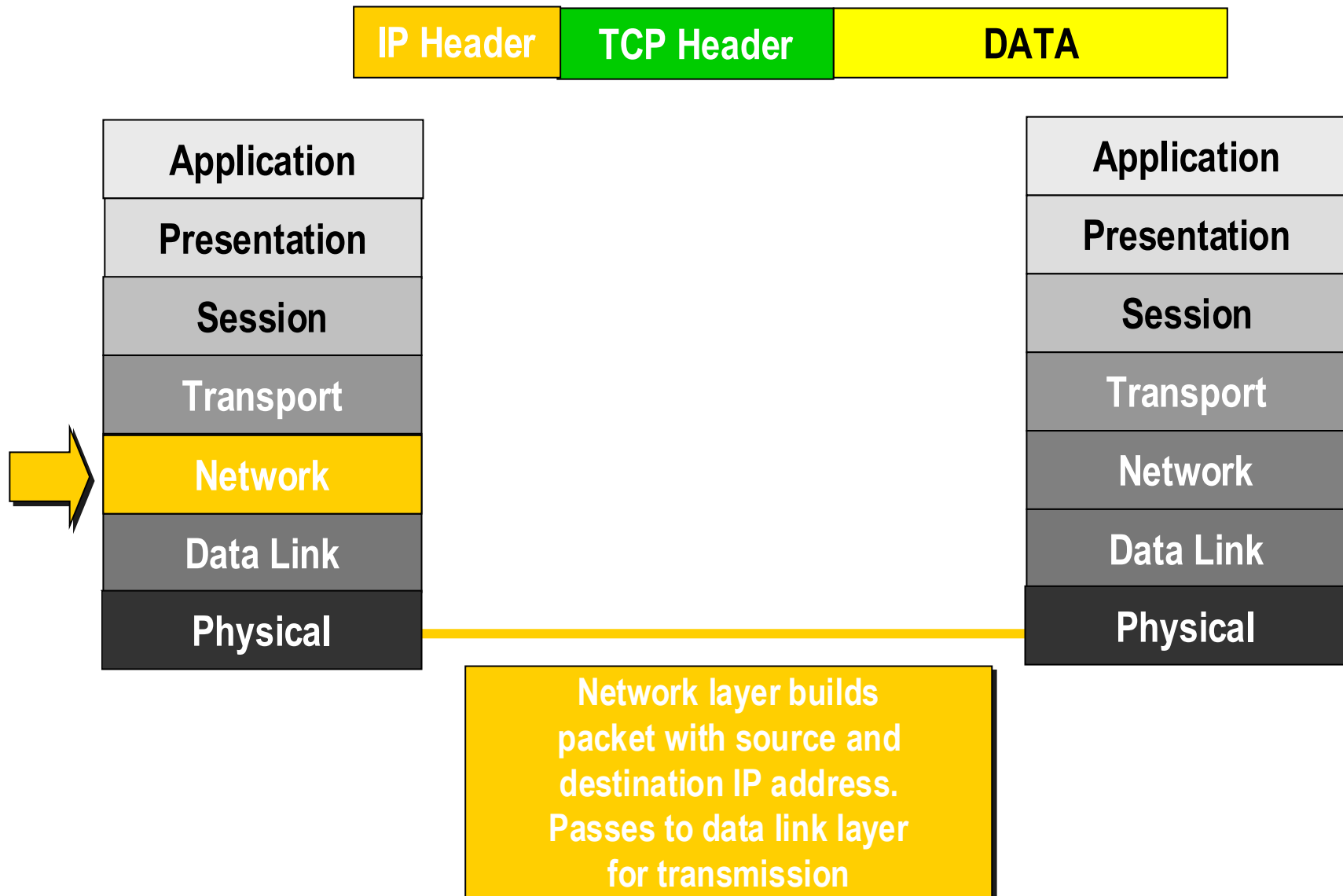
How Hosts Talk over a Network



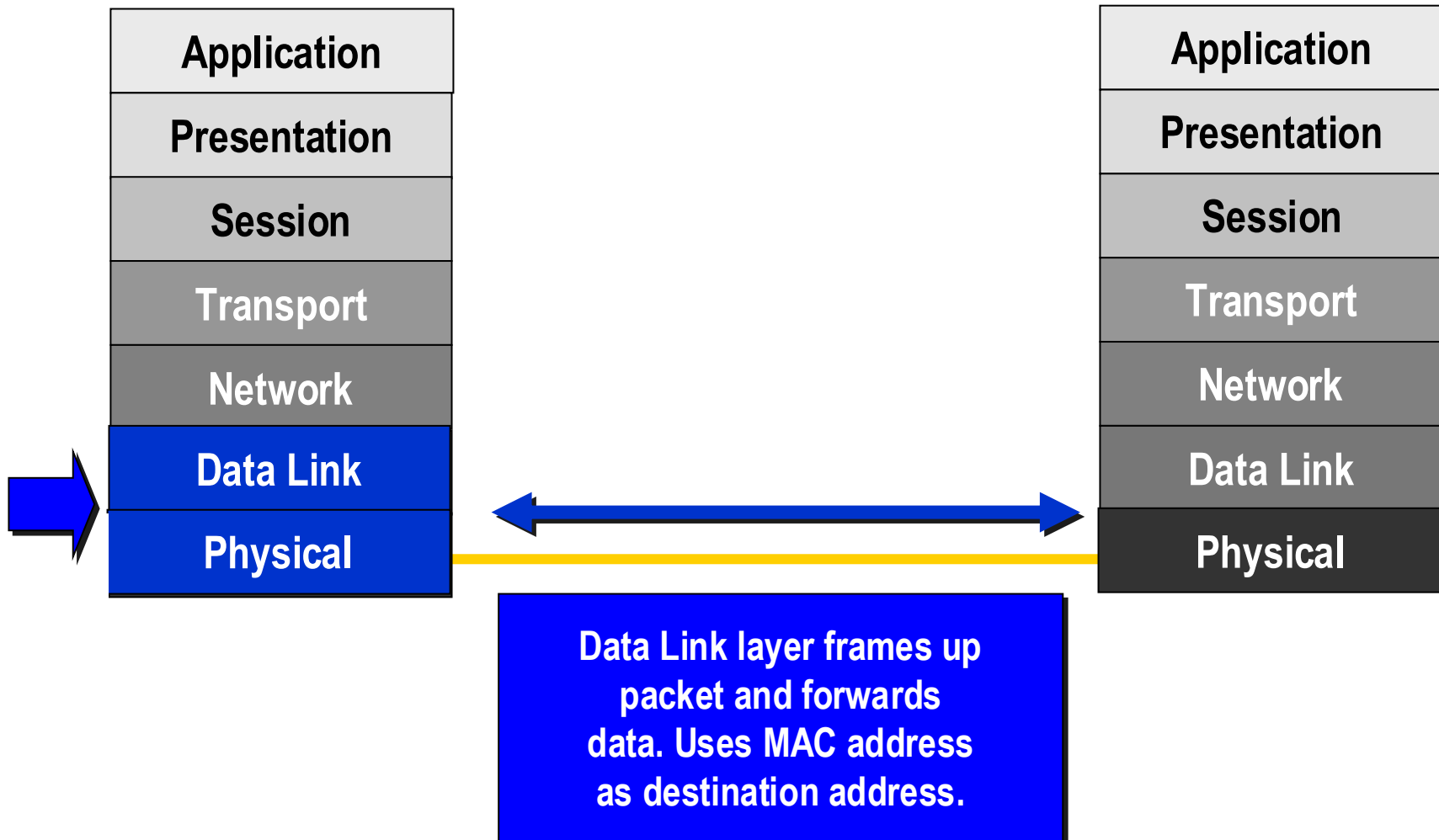
How Hosts Talk over a Network



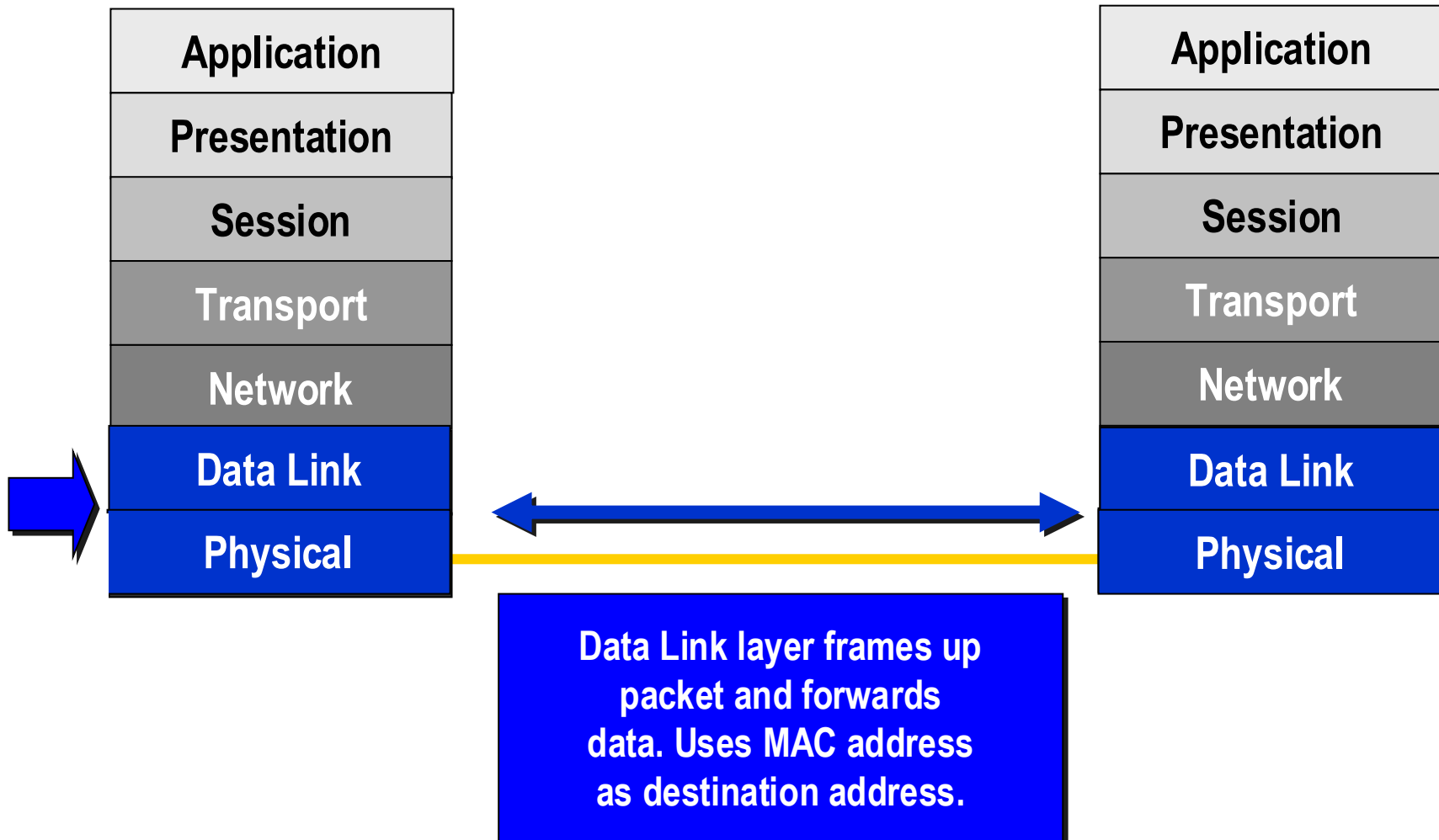
How Hosts Talk over a Network



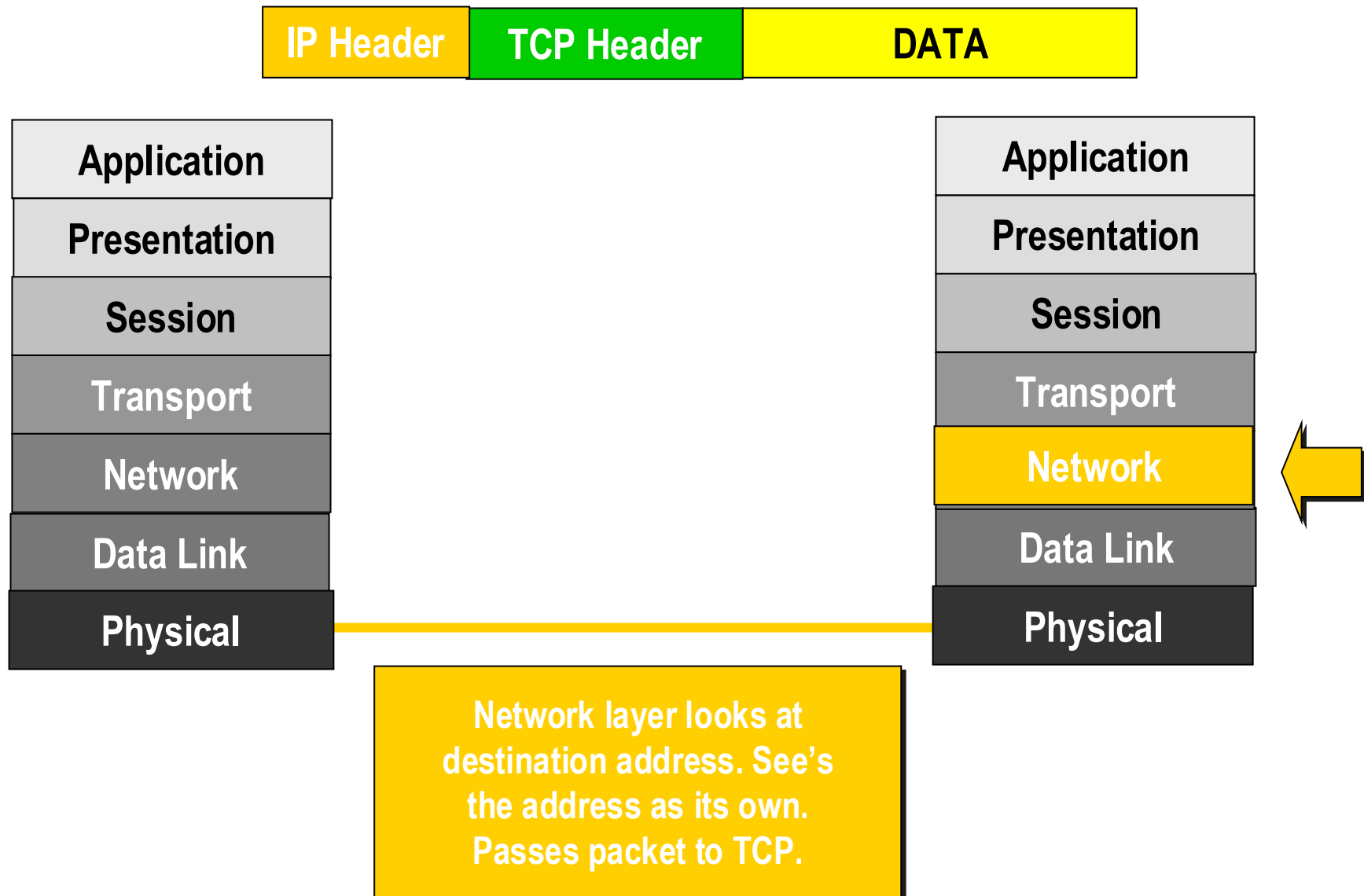
How Hosts Talk over a Network



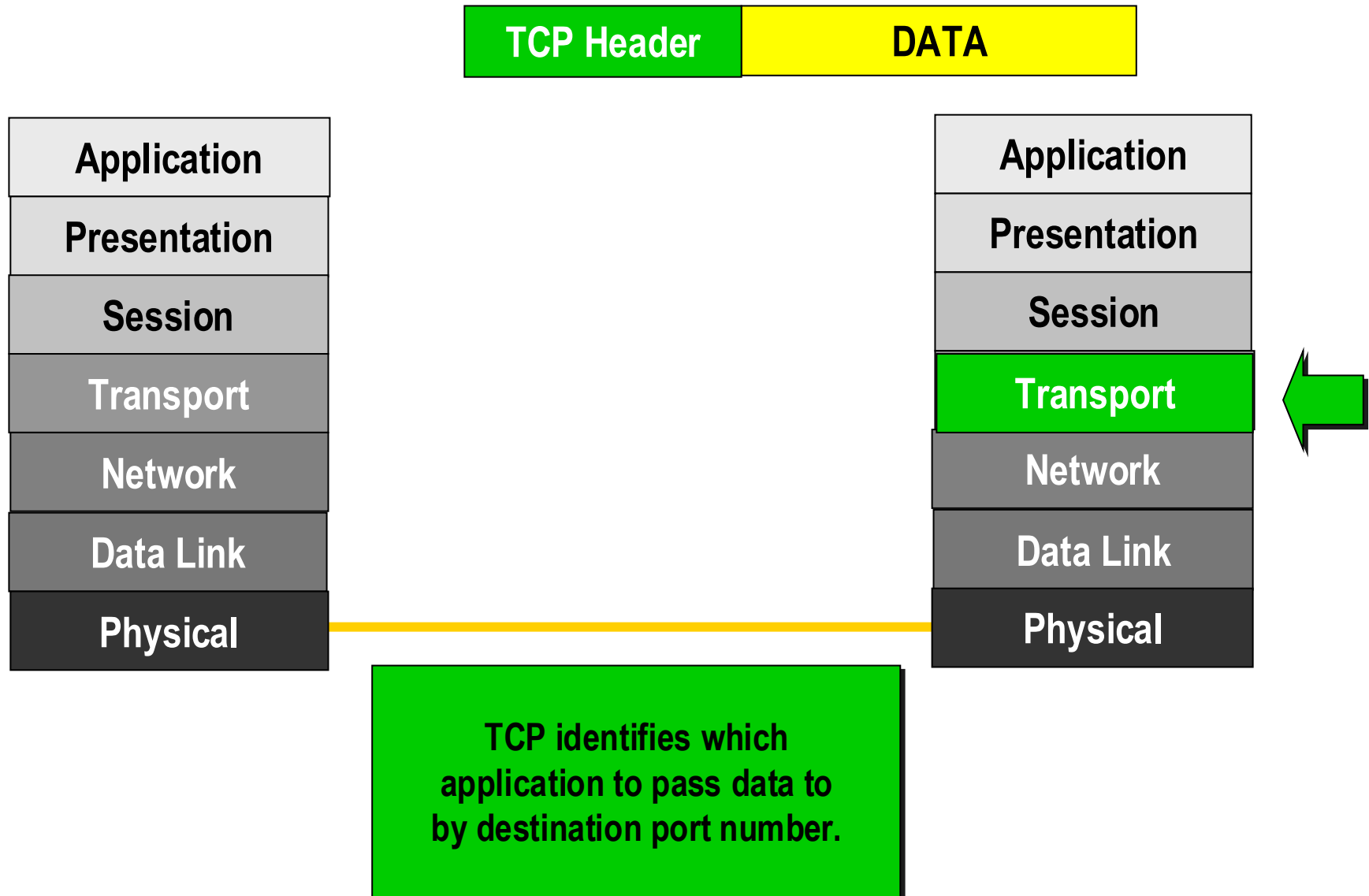
How Hosts Talk over a Network



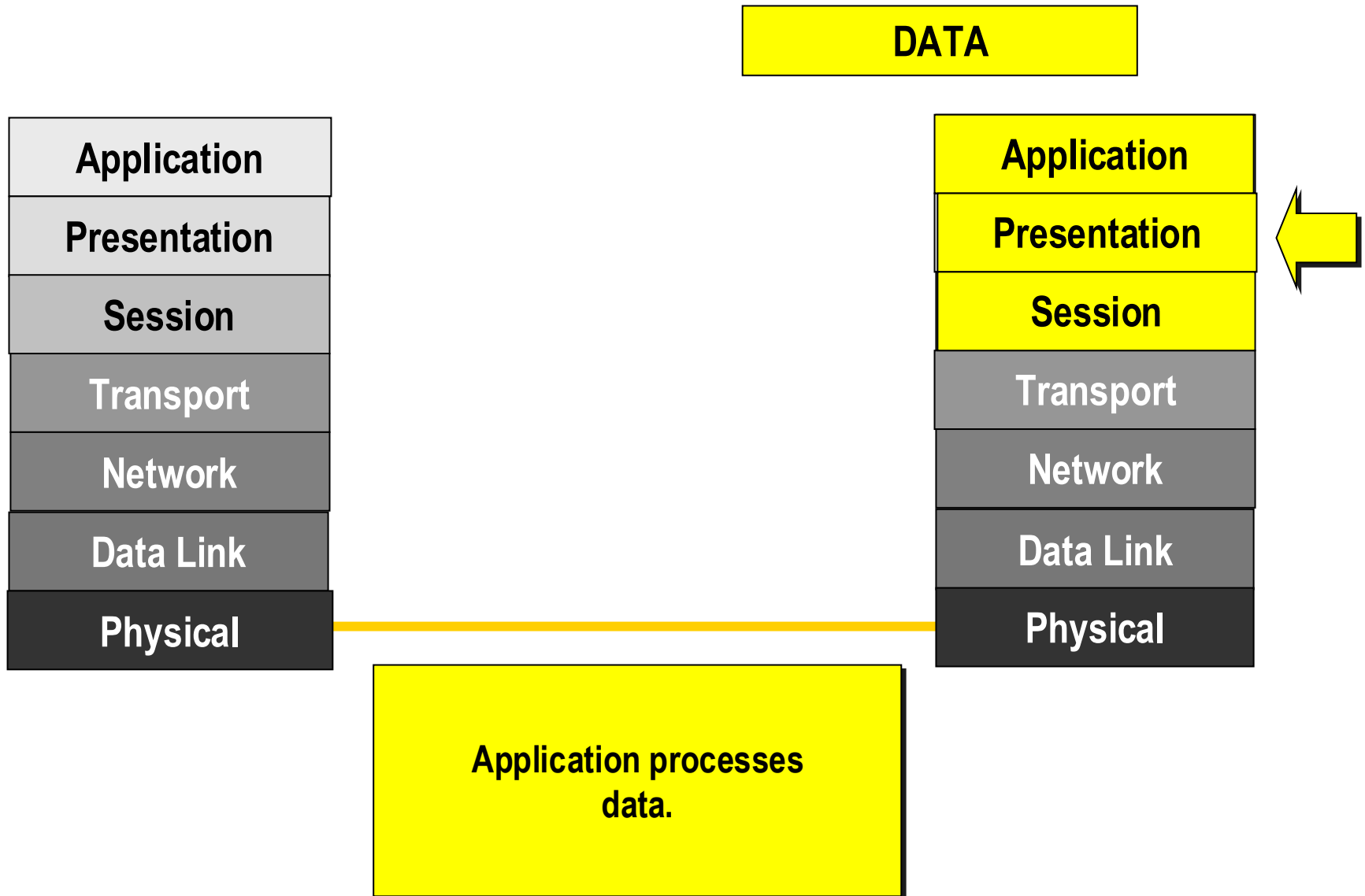
How Hosts Talk over a Network



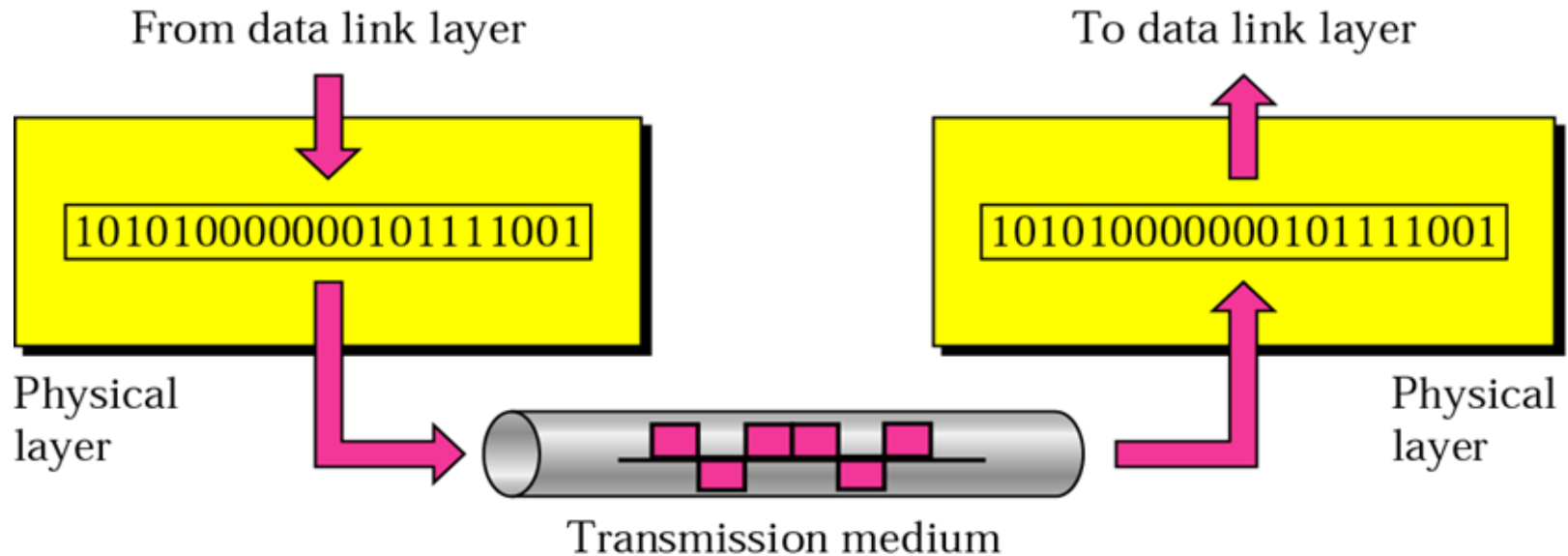
How Hosts Talk over a Network



How Hosts Talk over a Network



Physical Layer



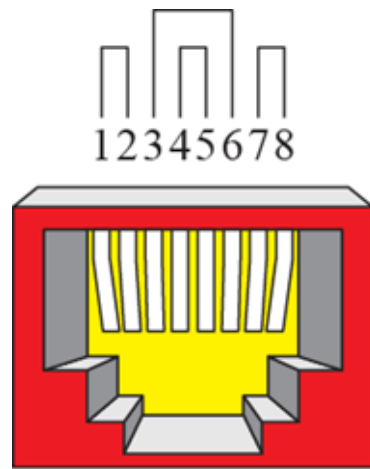
The physical layer is responsible for movements of individual bits from one hop (node) to the next.

Physical Layer

- Deals with **the actual communication media**
 - Defines the **physical characteristics** of **interfaces** and **transmission media**
 - the way devices are connected to each other and to the link (topology)
 - Shape, size and number of pins of connectors
 - What voltages and currents are used
 - The type of transmission media
 - Transmission mode (duplex type)
 - **Representation of bits** – encoding into Electrical or Optical signals
 - **Data Rate** = transmission rate = bandwidth (**number of bits sent per second**)
 - **Synchronization of bits** (sender and receiver clocks must be synchronized)
 - Devices that operates at this level: **Network card, repeater**

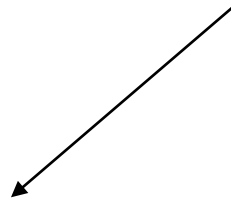


```
Computer → NIC → Cable → Repeater → Hub → Computer
          |               |
        signals       regenerates
```

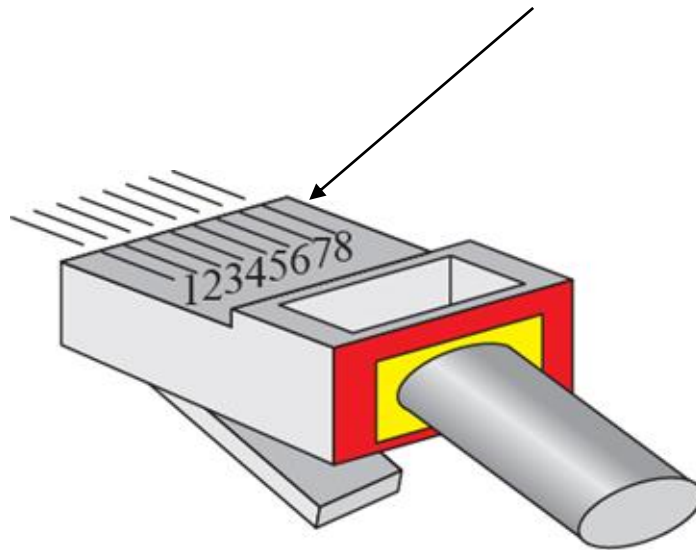


RJ-45 Female

**In NIC or networking
device**



Connected to the Cable



RJ-45 Male

Data Link Layer

- Data Link layer PDU is called frame
- Transfers *frames* across direct connections Node-to-Node (hop-to-hop) delivery
- **Framing**: dividing the stream of bits into units called frames
- **Physical Addressing**: sender and receiver physical addresses (Local address – hardware address – NIC address – LAN address)
- **Physical address = MAC address = hardware/NIC address**
- MAC tells us WHICH DEVICE should receive this frame on the current link.

A ——— Router ——— B
Change

Frame: Destination MAC = Router

Note

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

Data Link Layer

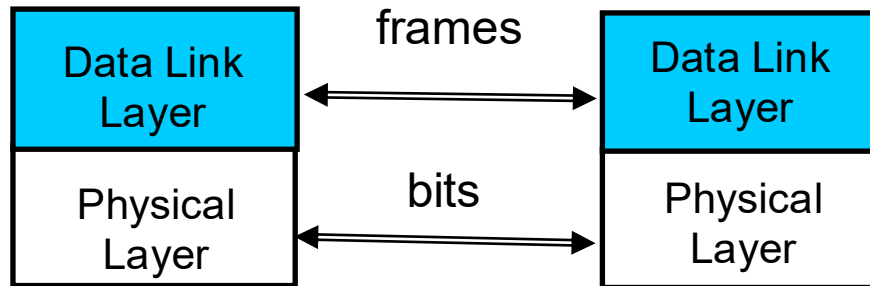
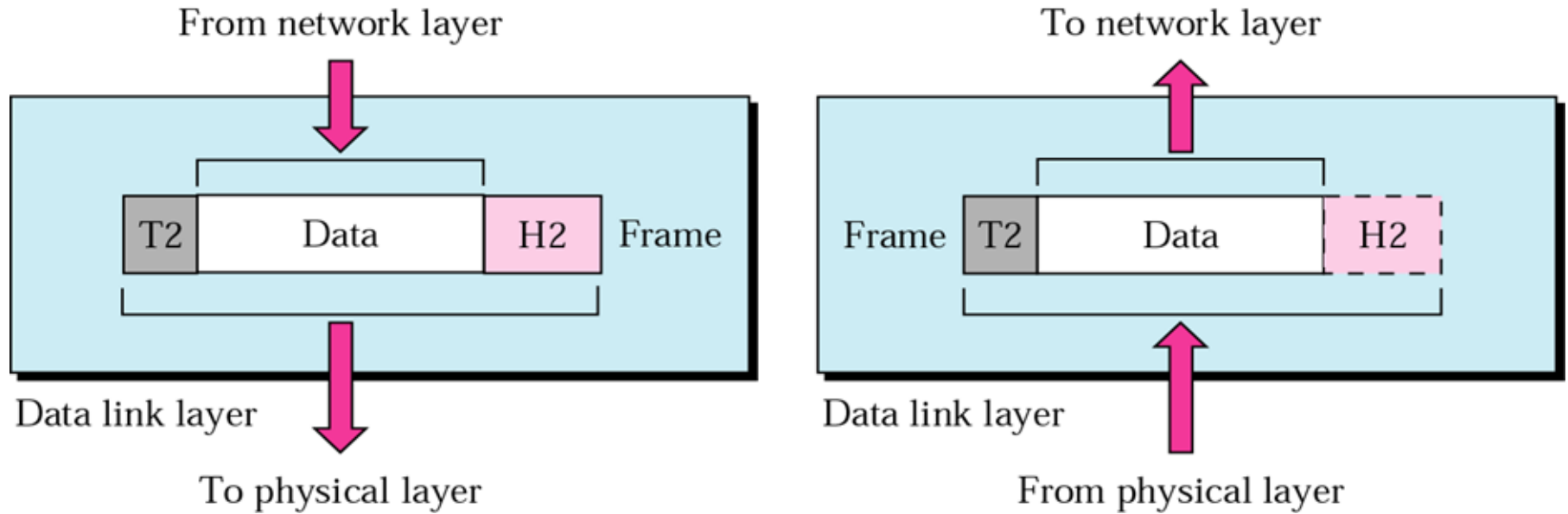


Figure 2.7 *Node-to-node delivery*

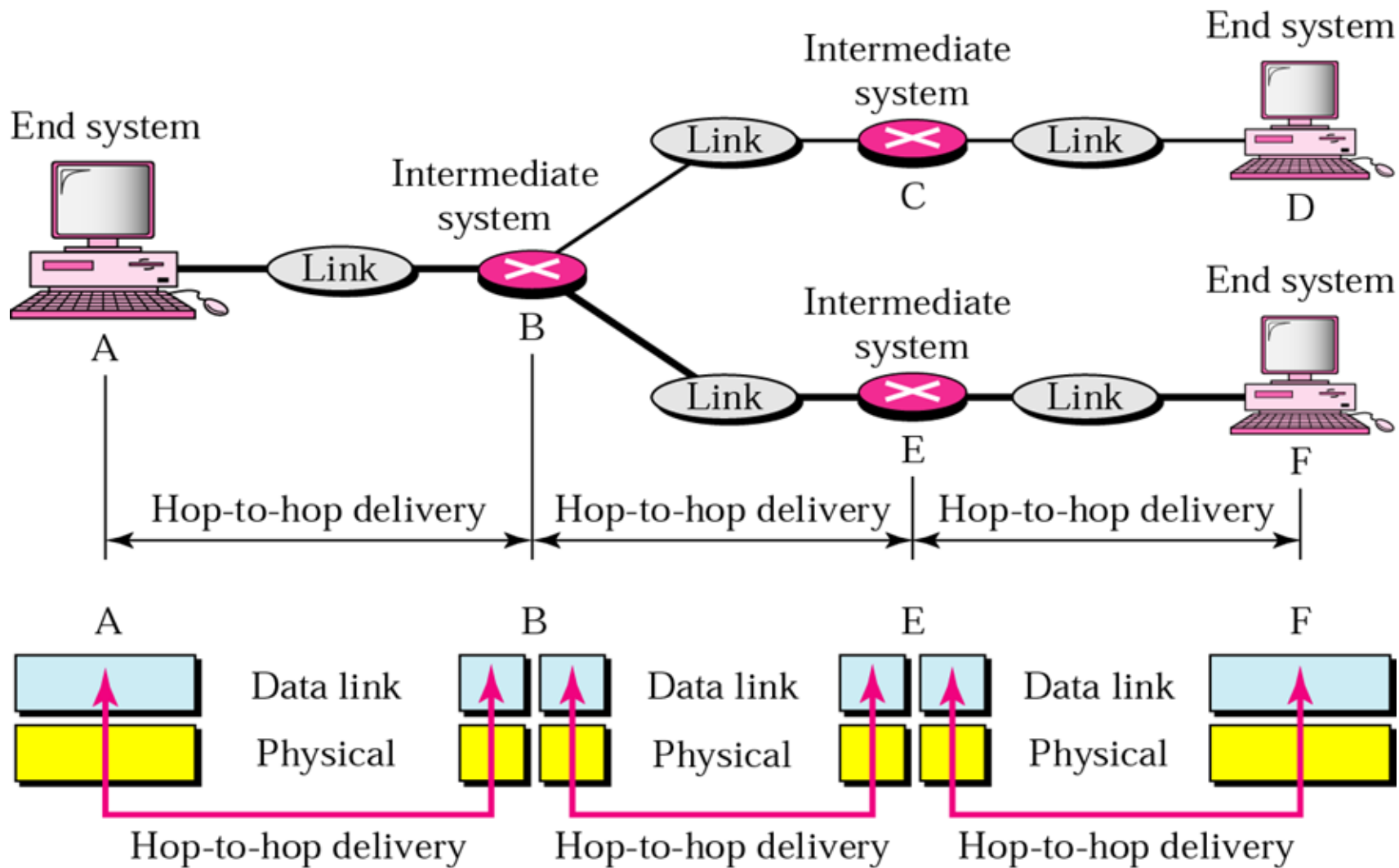
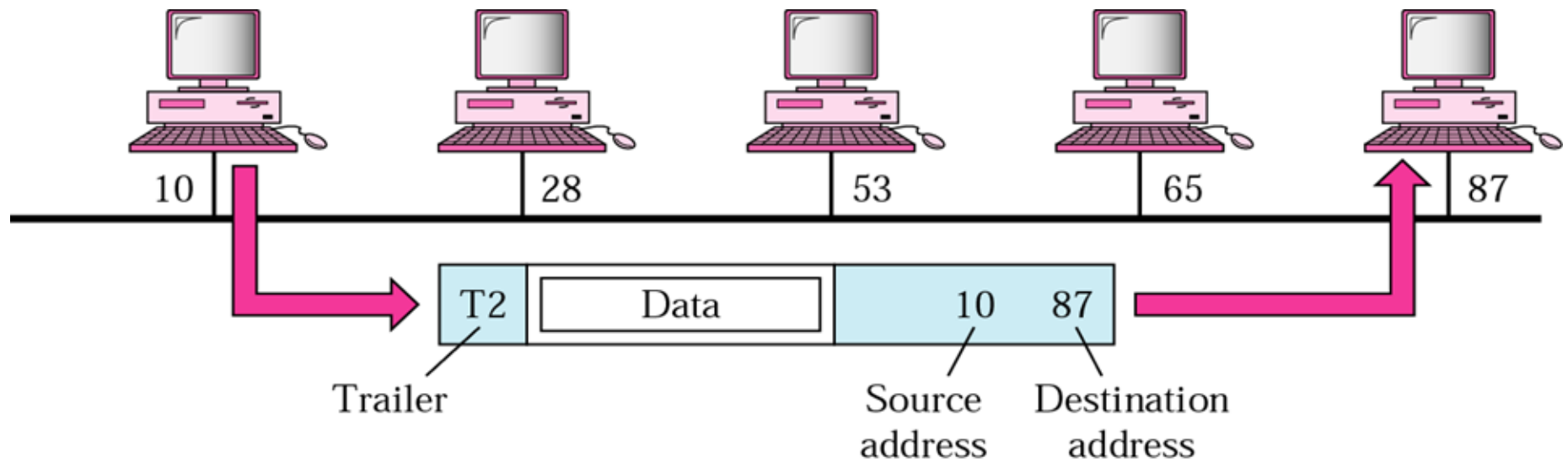


Figure 2.8 *Example 1*



Network Layer

- Network Layer PDU is called Packet or Datagram
- **Source-to-destination (host-to-host)** delivery of a **PACKET** possible across MULTIPLE networks.
- Logical addressing (Network address)
 - A unique global address that distinguishes each host connected to the Internet
 - In the Internet it is called IP address
- Routing
 - Network connecting devices (routers) route or switch the packets to their final destination through the best path.
- IP address = end-to-end destination
MAC address = next-hop destination

Note

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

Network Layer

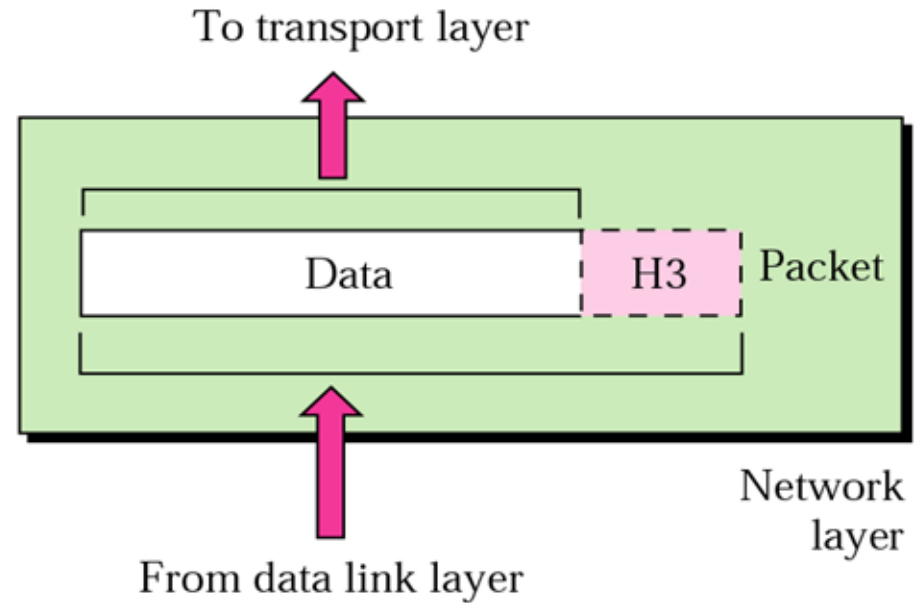
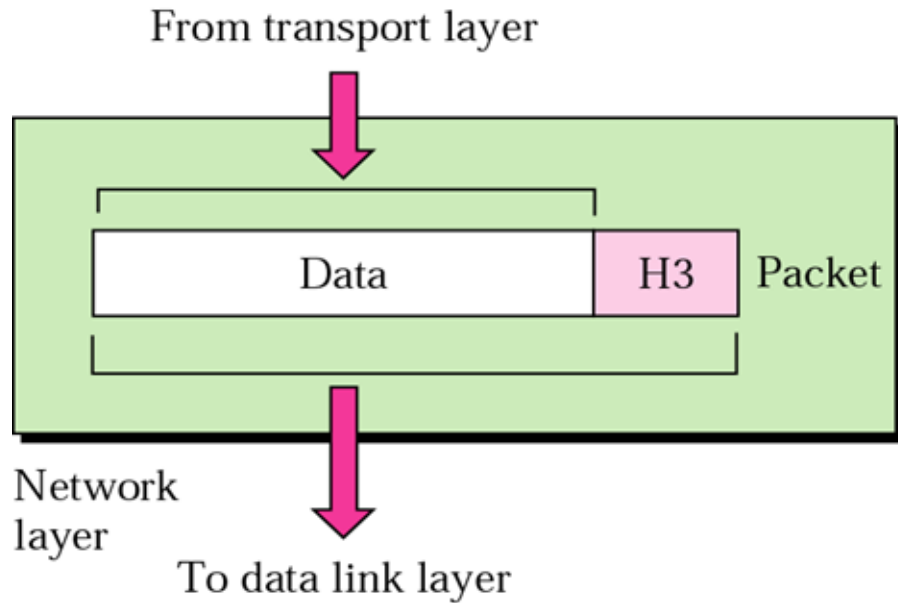


Figure 2.10 *Source-to-destination delivery*

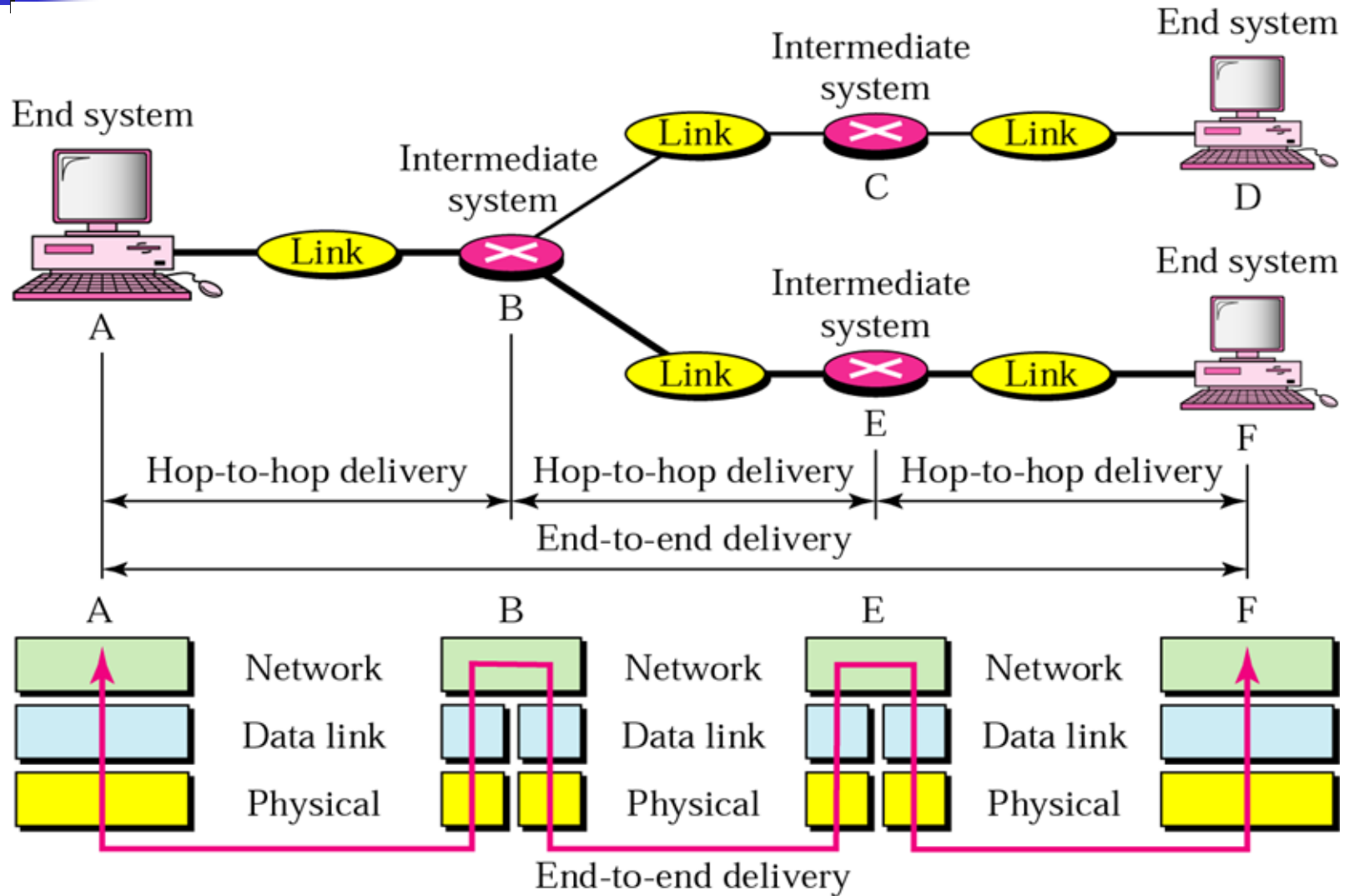
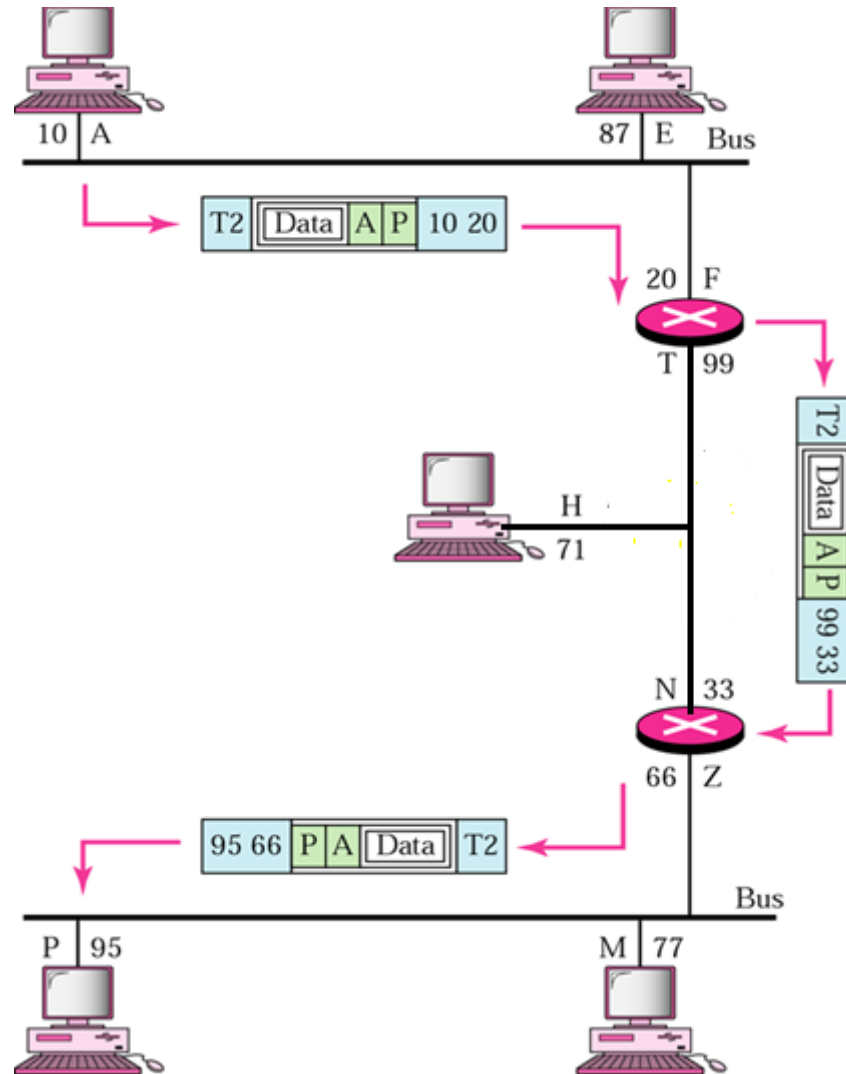


Figure 2.11 *Example 2*



Transport Layer

- The transport layer is responsible for **Process-to-Process** delivery of the ENTIRE MESSAGE
- The network layer handles end-to-end (source-to-destination) delivery of INDIVIDUAL PACKETS; no relationship between packets, each one is considered **independently** but the transport layer ensures **whole message** arrives intact and in order
- Transport PDU is called **SEGMENT**
- Process addressing
 - Port address

Note

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

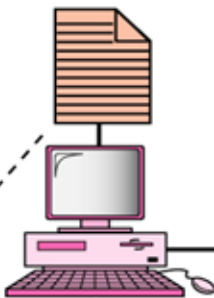
Figure 2.12 Reliable process-to-process delivery of a message

TCP Segment

```
Source Port:      52000
Destination Port: 443
Sequence Number:  1001
Acknowledgment:   ...
Other TCP information

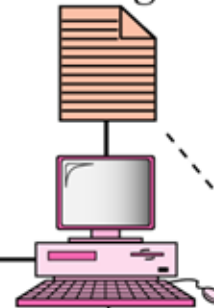
Data: "GET /index.html"
```

Message



An internetwork

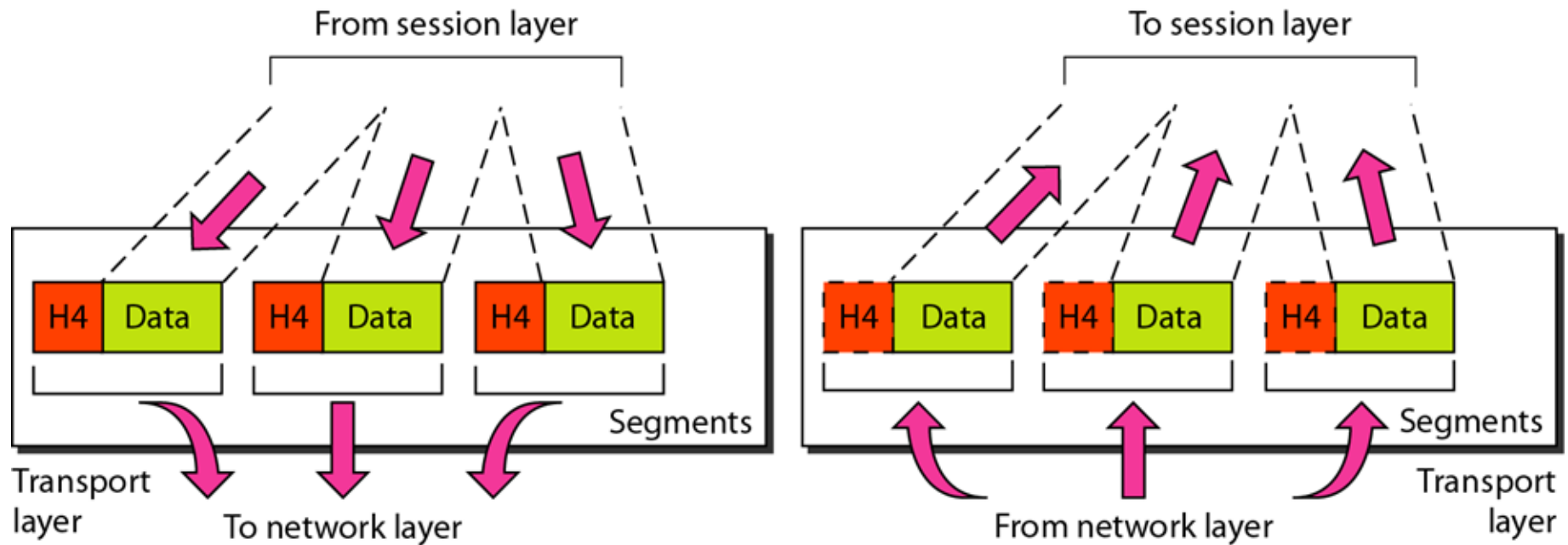
Message



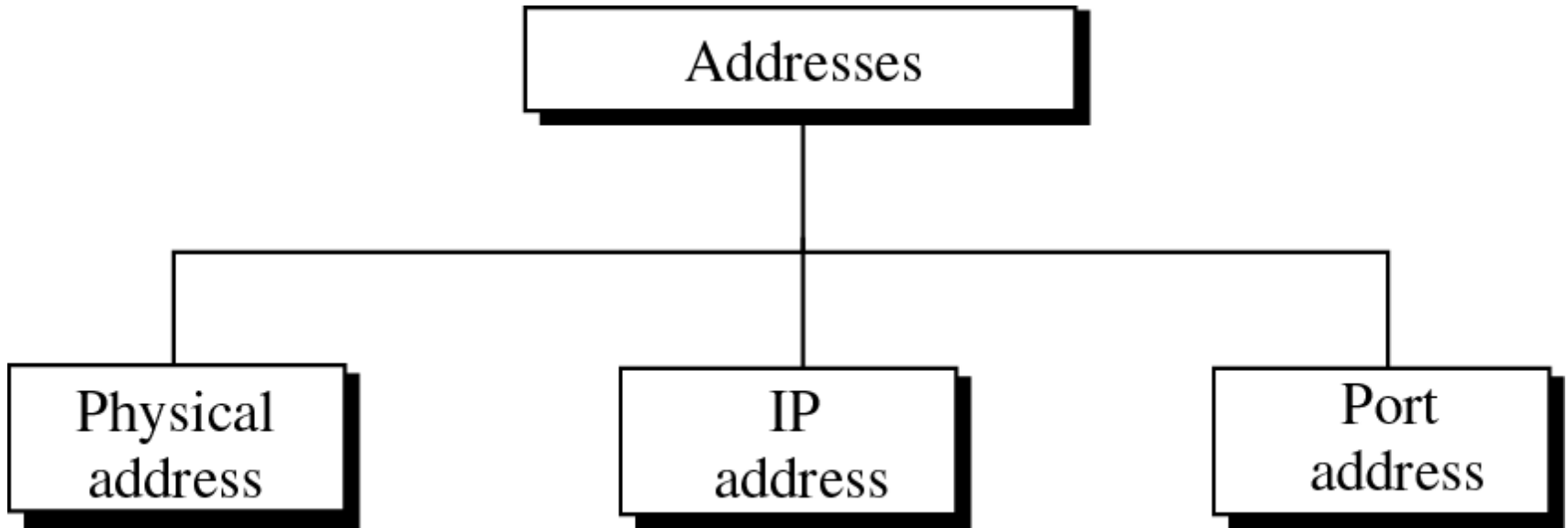
Network Layer
Host-to-host delivery

Transport Layer
Process-to-process reliable delivery

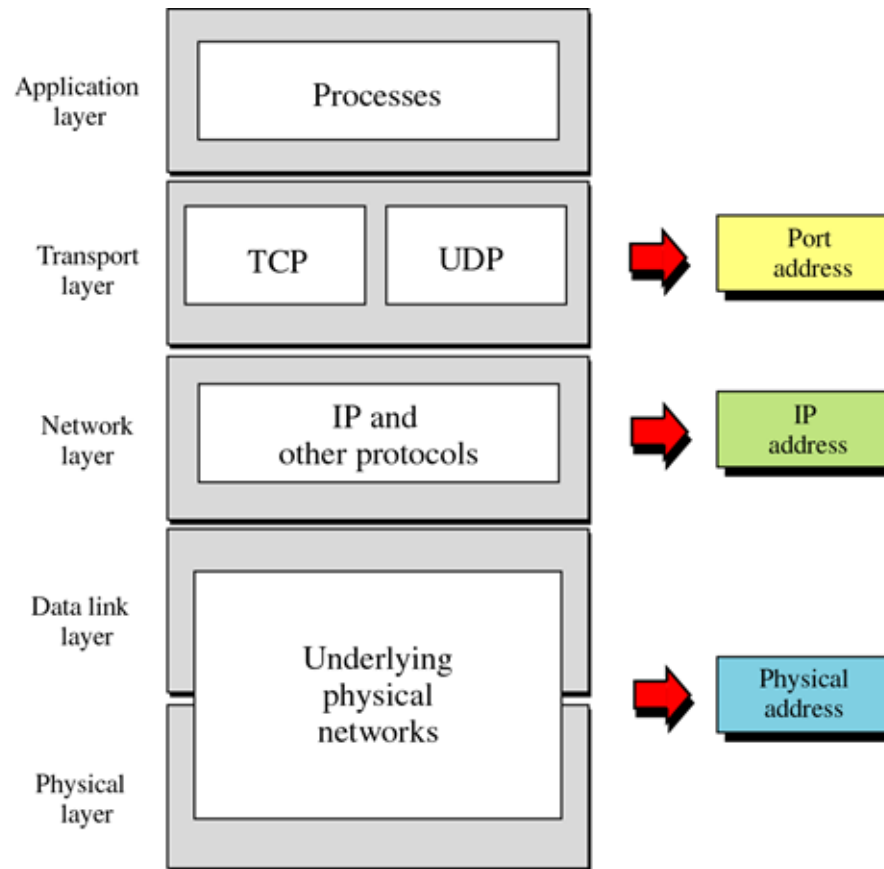
Figure 2.12 *Transport layer*



Addressing



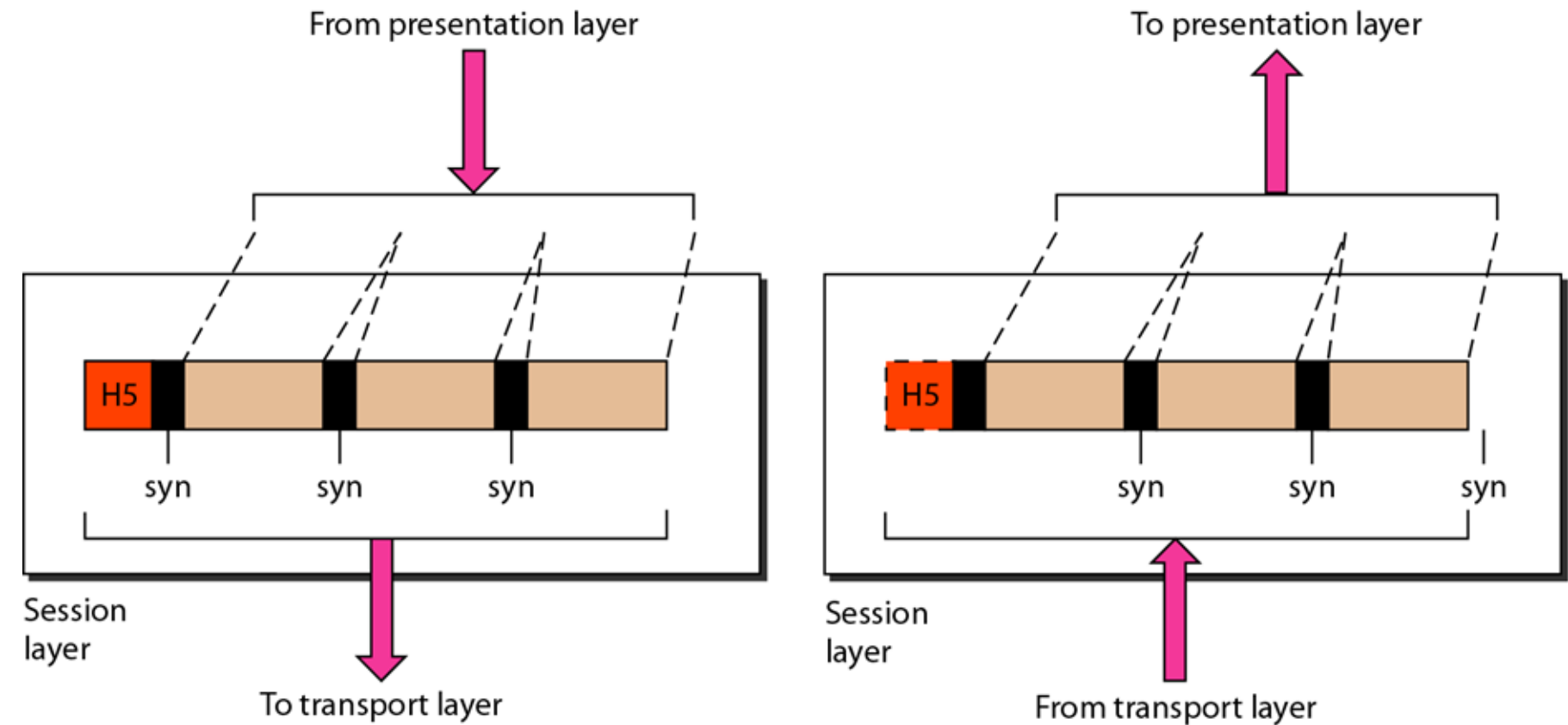
Layer Addresses



Session

- **Setting up, managing, and terminating sessions (connections) between different applications**
 - Keeping different applications data **separate** from other application data
 - Multiple file downloads requested by a particular FTP application
 - Multiple **telnet** (remote connection to a device) connections from a single host
 - Browsing many Web pages at the same time
- **Dialog control**
 - Full/Half duplex: Processes either send and receive data at the same time or at different times
- **Synchronization checkpoints**
 - Allow long transmissions to continue from where they were after the **connection crash**

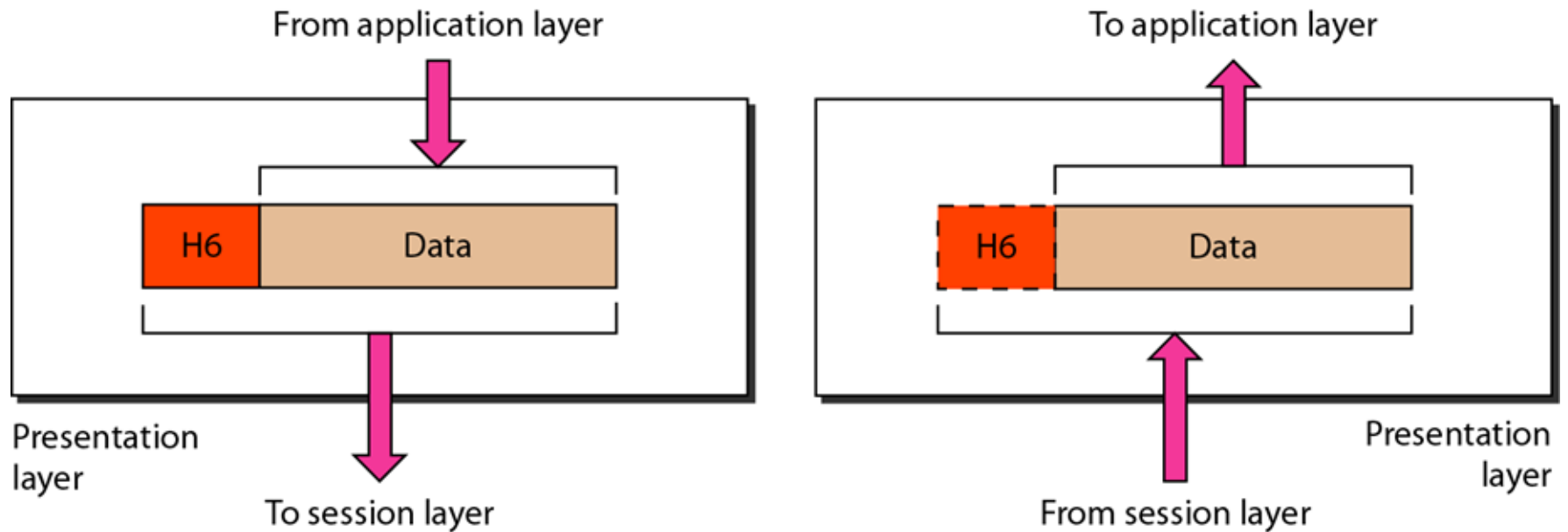
Figure 2.12 *Session layer*



Presentation

- Translation
 - Allows devices with different data representations to communicate (interoperability).
 - Sender format ☐ **common format**
☐ Receiver format
 - The input of "Cisco" on a Mainframe terminal, which is working with an EBCDIC code set, would result in "¢¹½³?" on a PC, because it uses ASCII.
- Encryption/decryption
- Compression => Less bits (multimedia applications)

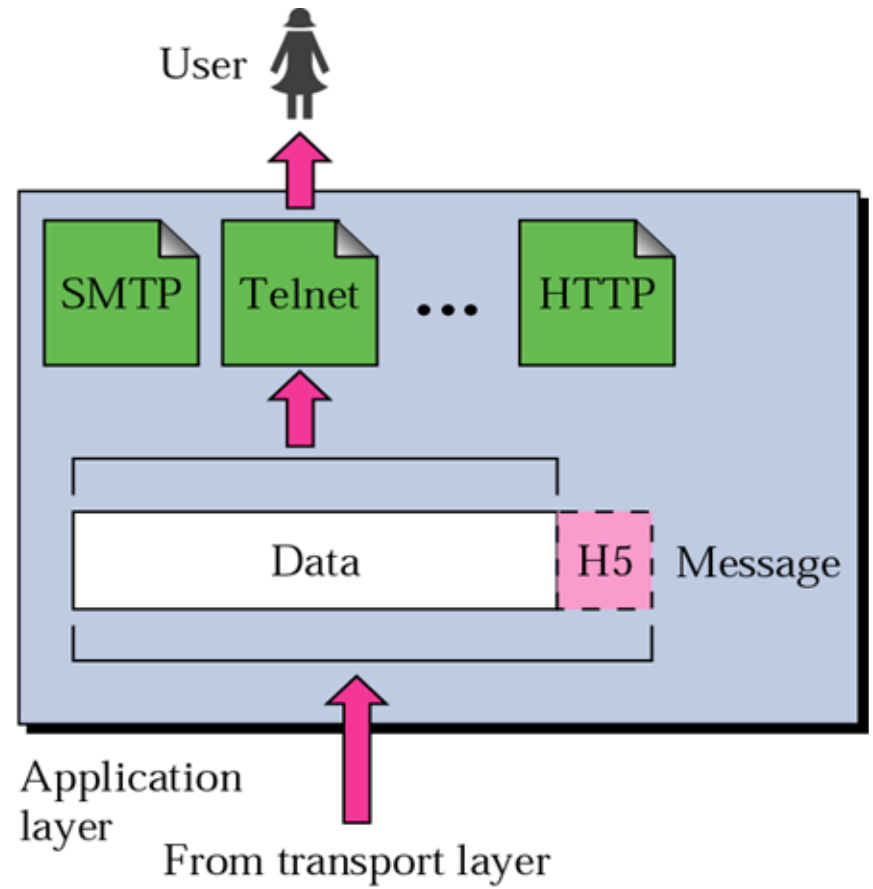
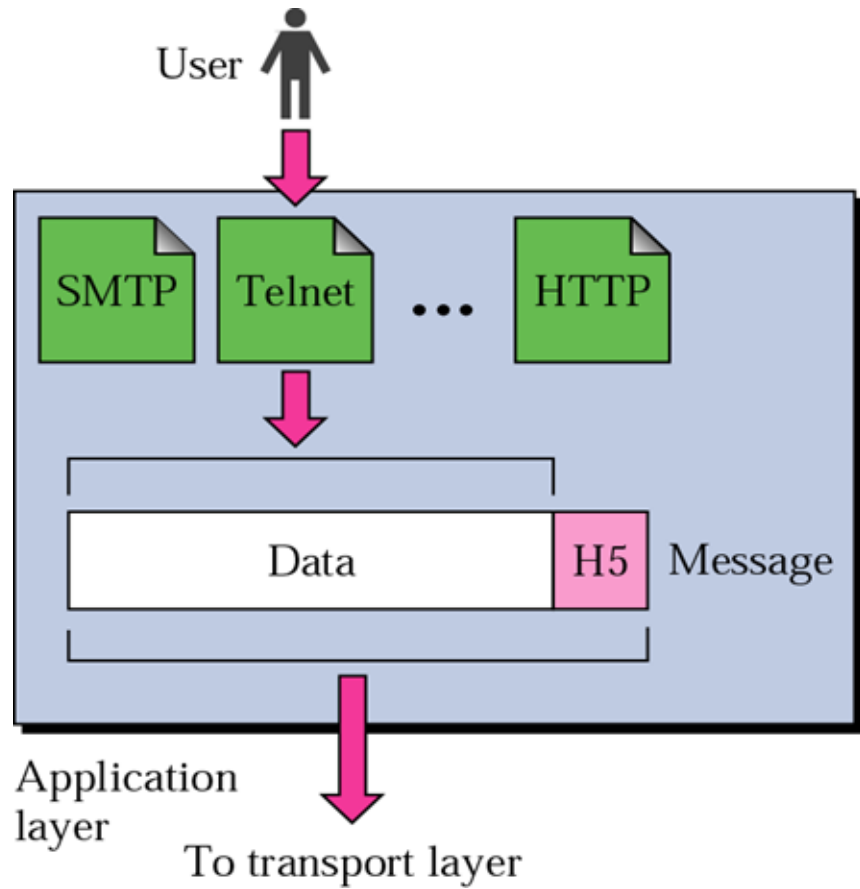
Figure 2.13 *Presentation layer*



Application

- User interface and Network services that allow user applications to access the network
 - Internet Browser uses the HTTP application-layer protocol to access a WWW
 - Telnet => remote host access
 - File transfer, access and management
 - Mail services

Figure 2.15 *Application layer*



TCP/IP Protocol Suite

- Developed in 1970s
- Is a suite of protocols named after the two most important protocols TCP and IP but includes other protocols such as UDP, etc
- Consists of Five layers
- The first four lower layers correspond to the first four layers of the OSI model.
- **The three top layers** in the OSI model, however, are represented in TCP/IP by a **single layer** called the **application layer**.

Figure 1.17 Layers in the TCP/IP protocol suite

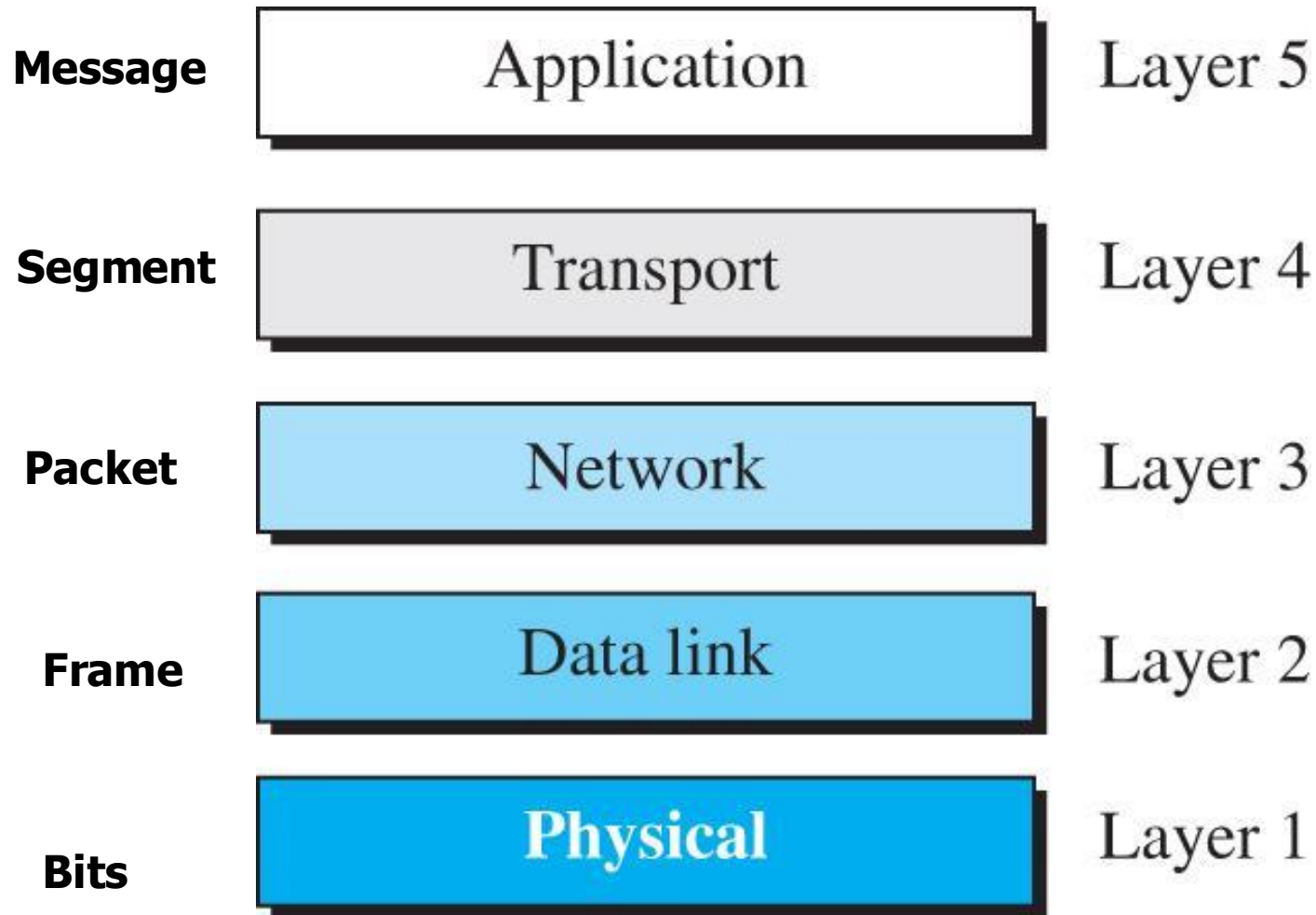


Figure 2.12: *TCP/IP and OSI model*

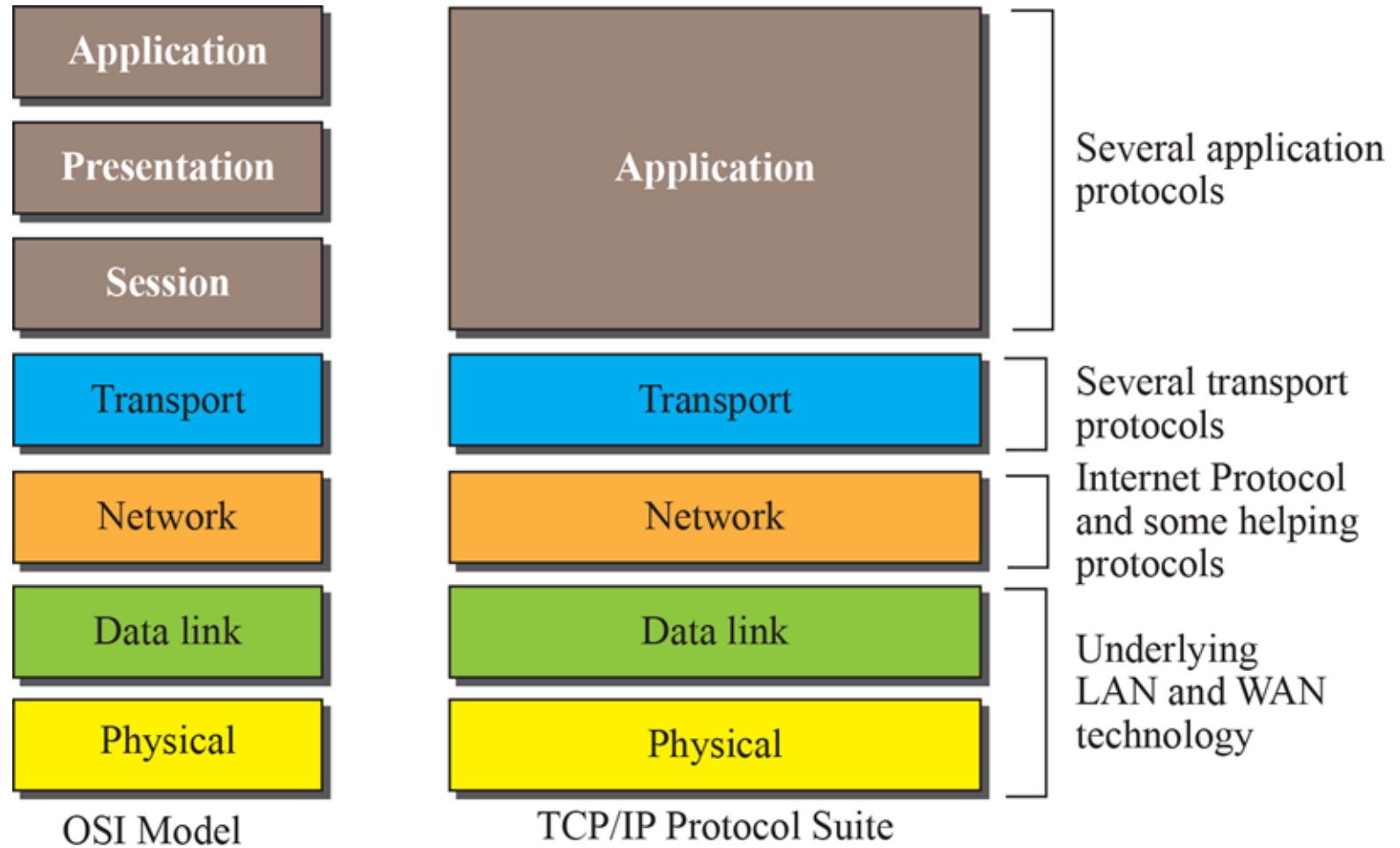
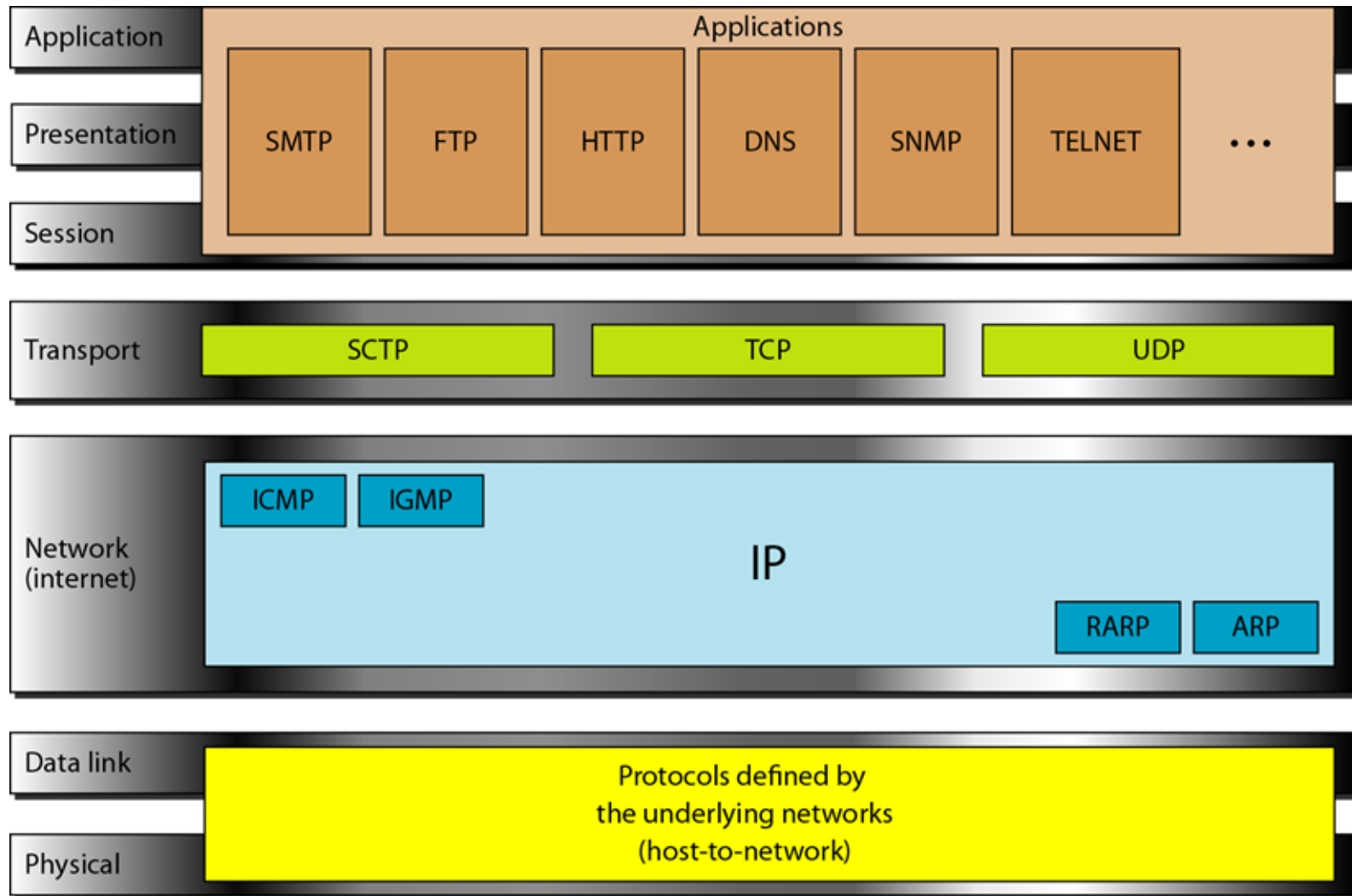


Figure 2.16 *TCP/IP and OSI model*



Original TCP/IP Model (4-layers)

