Network Architecture

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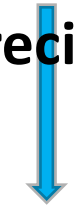
Content

- Structure of Computer Networks
- Network Architecture Models (OSI, TCP/IP)
- TCP/IP Model
- ISO/OSI versus TCP/IP

Computers Networks Structure

- Computer Network Structure – **stack levels**
  - ➢ Functionality :
    - **Interface:** ensure communication between two consecutive levels
    - **Service:** functionality provided by a level

    Result: reducing design complexity
  - ➢ The principle of communication: **transmitter sends at n level what the recipient receives at the n level**



- **Protocol** – Rules and conventions through which the communication take place

Example: link among - levels, protocols and interfaces

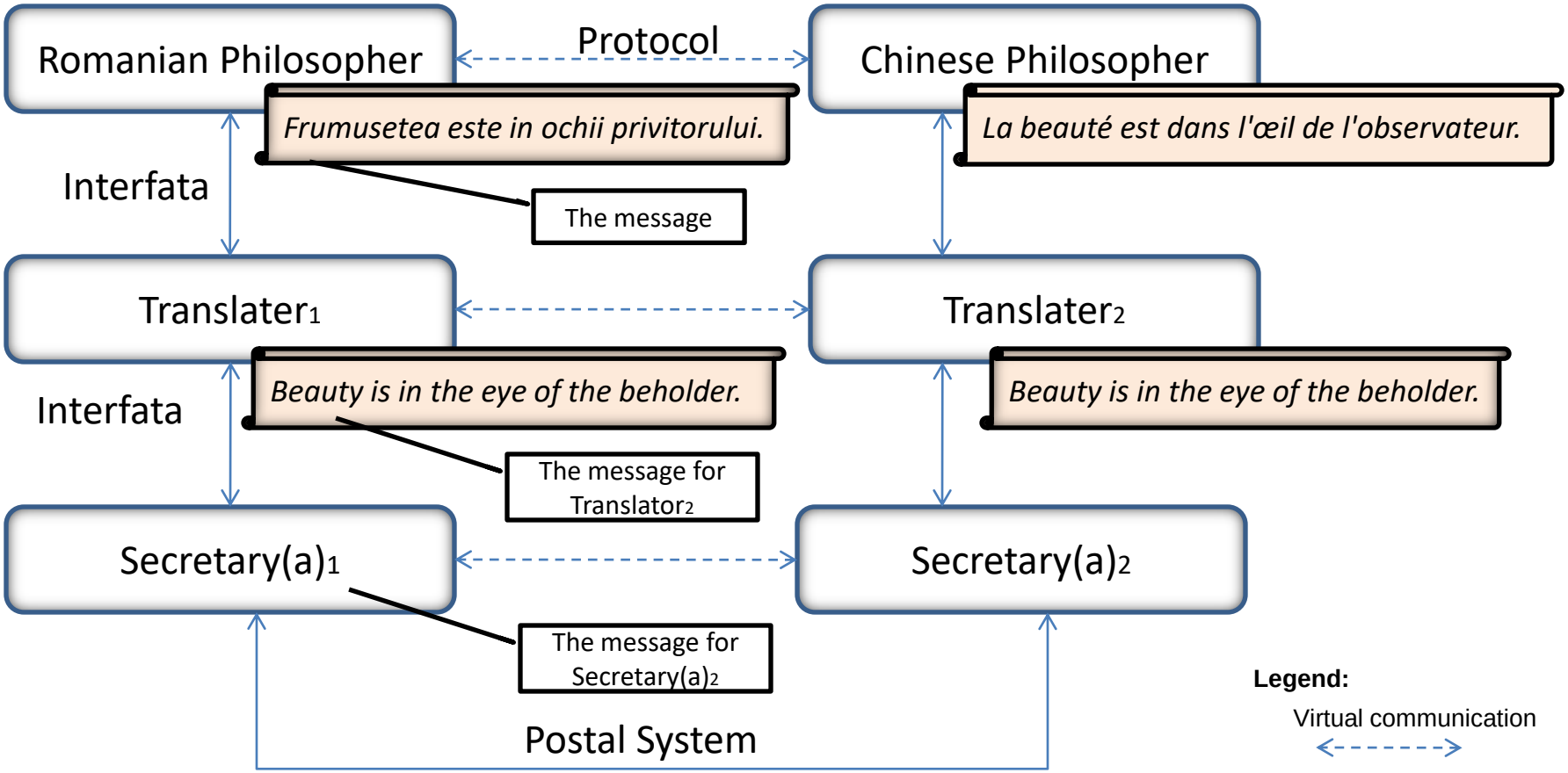
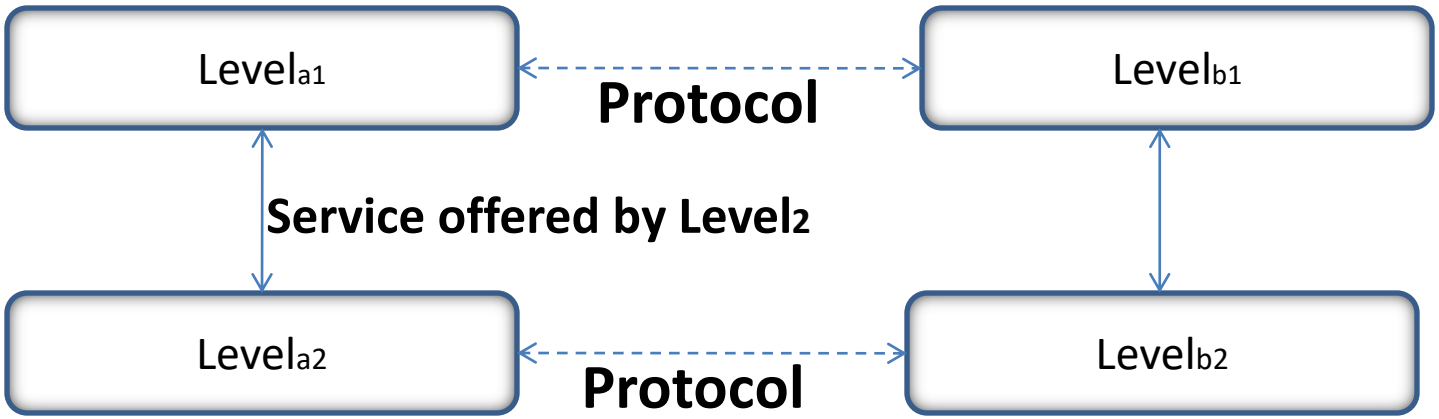


Figure: Architecture philosophe – translator - secretary

Aspects regarding levels design

- Specifying the service is performed by a set of primitives (operations) available to the one who uses the service
- Service!= Protocol



Aspects regarding levels design

- Services types
  - *Connection-oriented*
    - Communication requires a connection
    - Similar to a telephone service
  - *Connectionless*
    - Communication does not require a connection
    - Similar to postal service

Aspects regarding levels design

- **Network architecture**: the set of levels and protocols
  - Architecture specification must provide sufficient information for programs or equipment intended, in order to offer the specific protocols
- **Protocols stack**: list of protocols (on all levels) used by a particular system

Aspects regarding levels design

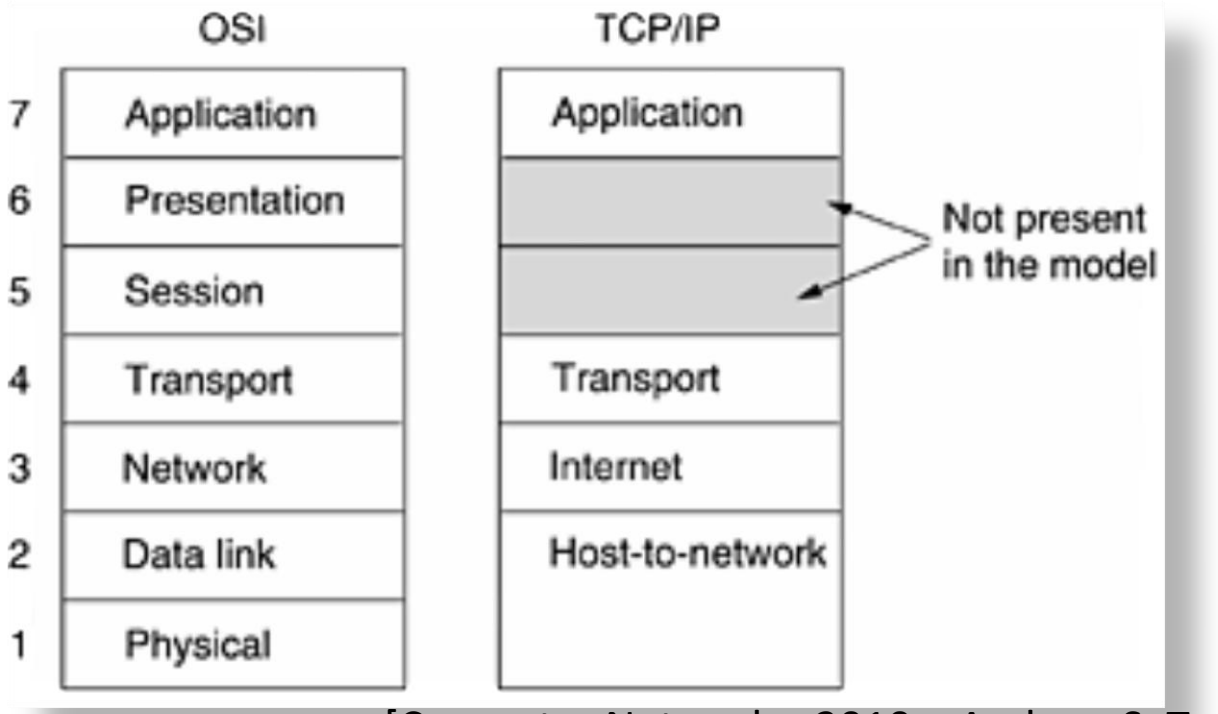
- Each level must identify transmitters & receivers through an *addressing mechanism*
- Data transfer rules identification
  - simplex communication
    - Example: TV
  - half-duplex communication
    - Example: "walkie-talkie"
  - full-duplex communication
    - Example: telephone

Aspects regarding levels design

- In general, communication channels do not preserve the order of the sent messages => need for a protocol that provides a mechanism to reconstruct the correct messages order
- Sometimes the receiver cannot manage the variable length messages => it must be a mechanism to divide/assemble
- High costs in the allocation of separate connections? => Multiplexing - use the same connection for independent conversations
- In general, there are several ways between source and destination => routing mechanism
- Physical communication circuits are not perfect => it asks for an error control mechanism

Reference models for network architecture

- ISO/OSI (*International Standard Organization/ Open System Interconnection*)
- TCP/IP (*Transmission Control Protocol/ Internet Protocol*)



[Computer Networks, 2010 – Andrew S. Tanenbaum, et.al.]

Network Architecture - Equipment

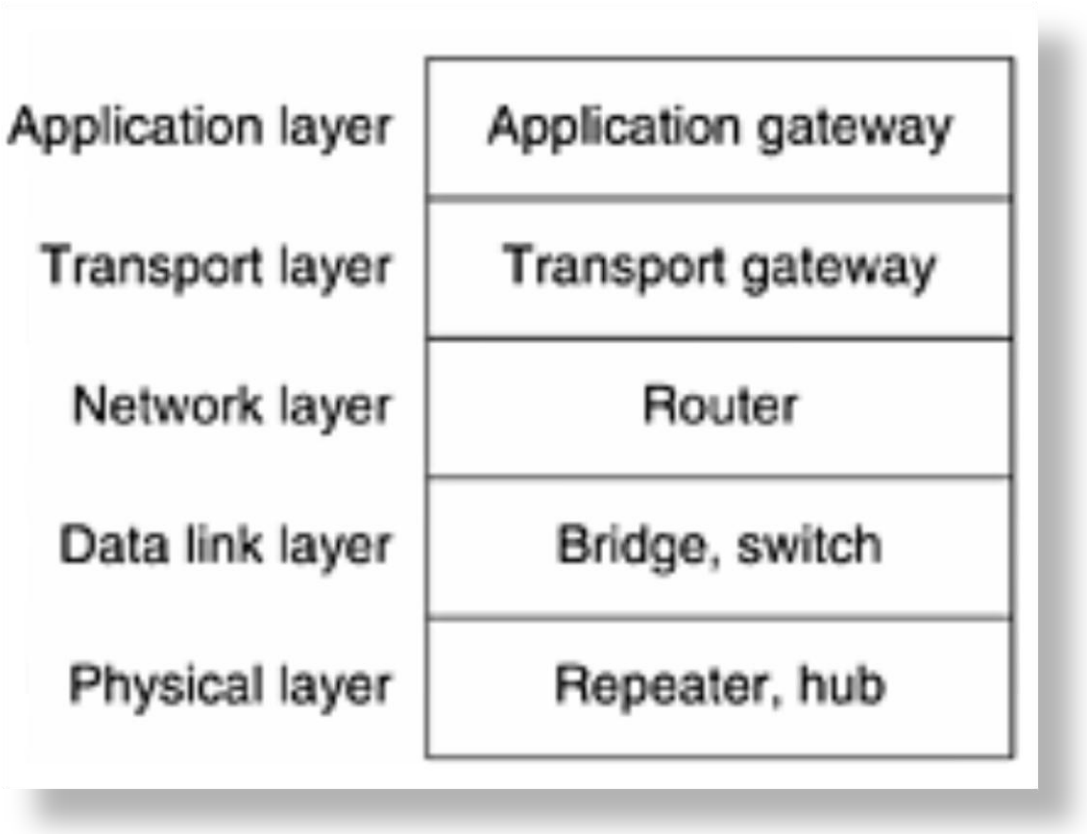
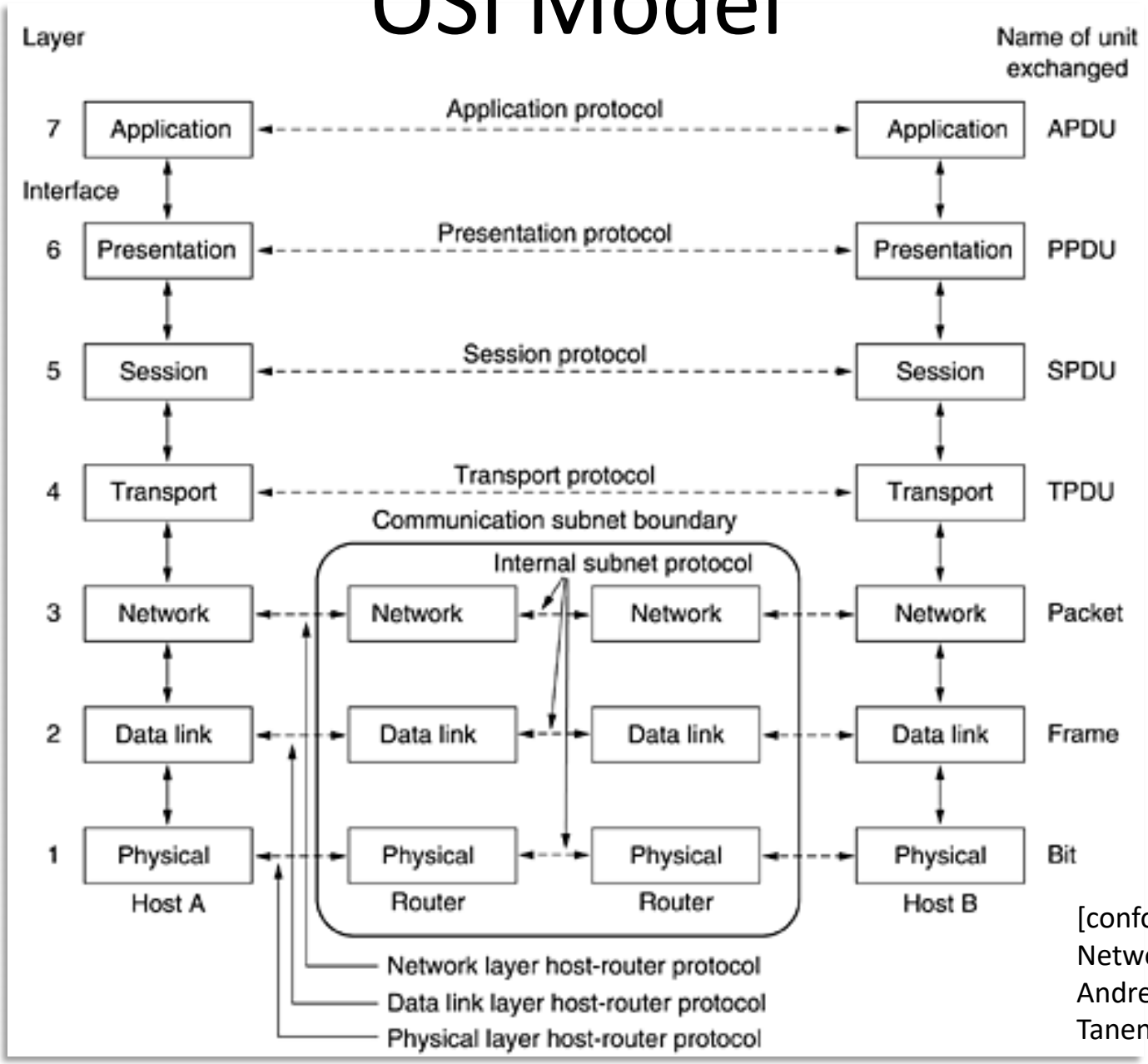


Figure: Devices and appropriate levels

OSI Model- motivation

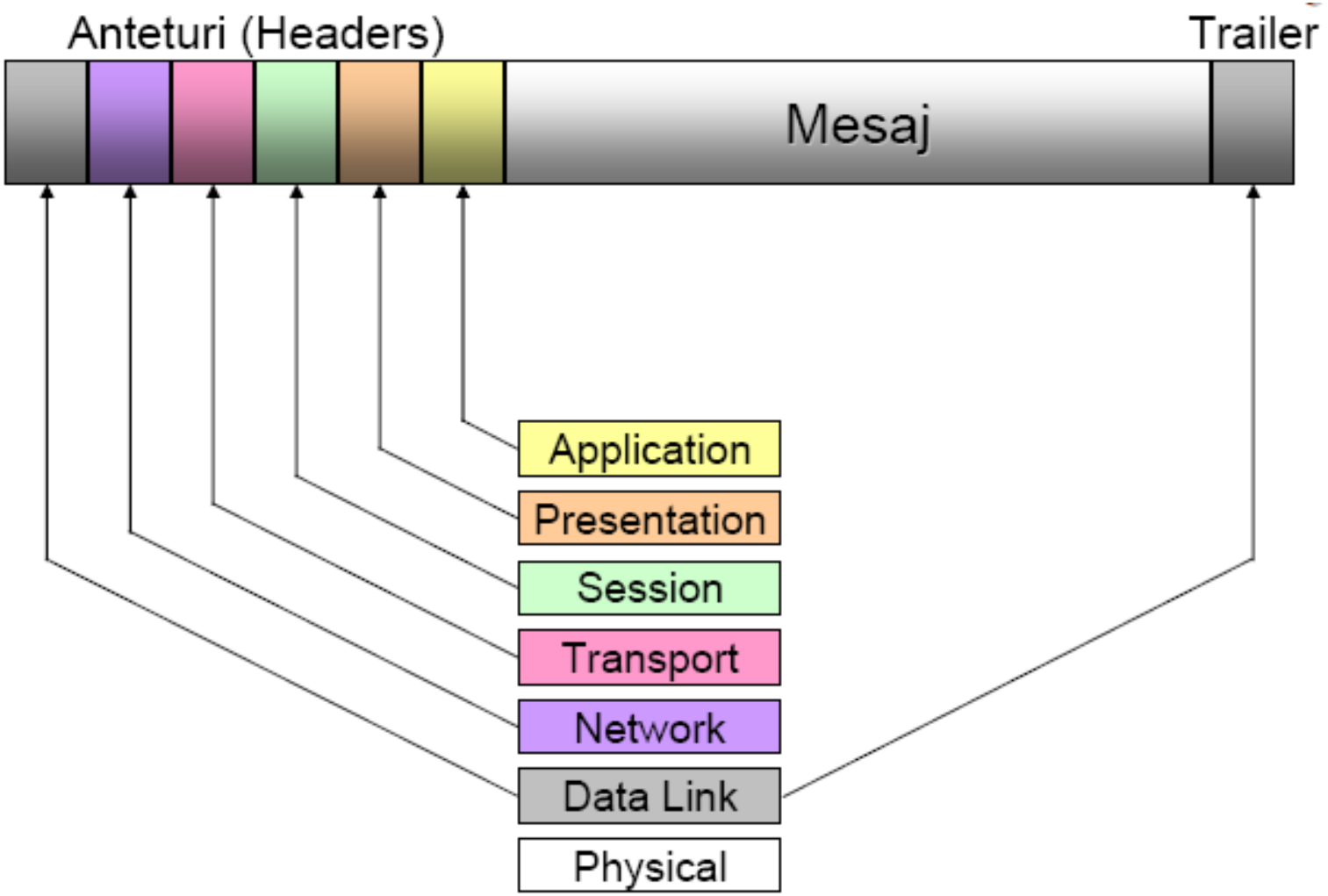
- The need for a different level of abstraction => to create a new level
  - Obs. The number of levels must be optimal, therefore each level has different functions and the whole architecture is functional
- A level has a clear role; a level function must take into account protocols that are standardized at international level
- Minimizing the flow of information between levels is accomplished through good boundary levels => Levels can be modified and implemented independently
- Each level offers services for superior level (using services from previous levels)
- "*peer*" levels of different systems communicate via a protocol

OSI Model



[conform Computer Networks, 2010 – Andrew S. Tanenbaum, et.al.]

OSI Model – message structure

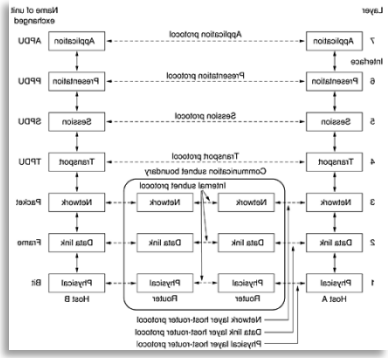


[Retele de calculatoare – curs 2007-2008, Sabin Buraga]

OSI Model – structure

- Physical Level
- Data Link Level
- Network Level
- Transport Level
- Session Level
- Presentation Level
- Application Level

OSI Model



Physical Level: data transmission medium

Role: ensure that the sequence of bits transmitted from the transmitter reaches the receiver

– Transmission media:

- Wired (twisted pair, coaxial cable, optical fiber)
- Wireless (electromagnetic spectrum - radio, microwave, infrared, ...) -> next course

OSI Model

- **Physical Level:**

Data transmission:

- Analog (continuous values)
  - Example: telephone systems
- Digital (discrete)
  - Example: computers

Data conversion from analog to digital and vice versa:

- Modem: digital date are transmitted in analog format
- Codec (coder/decoder): analog data are transmitted in digital format

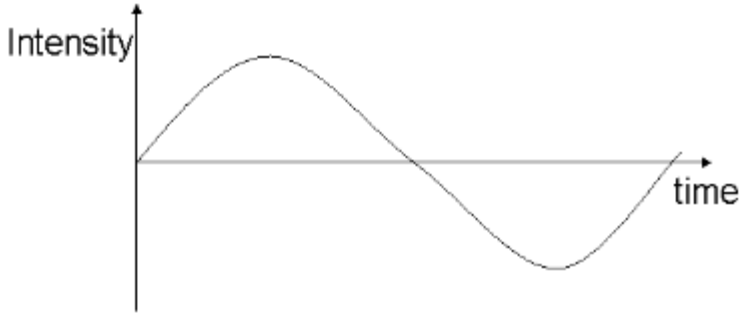


Figure. Analog Signal

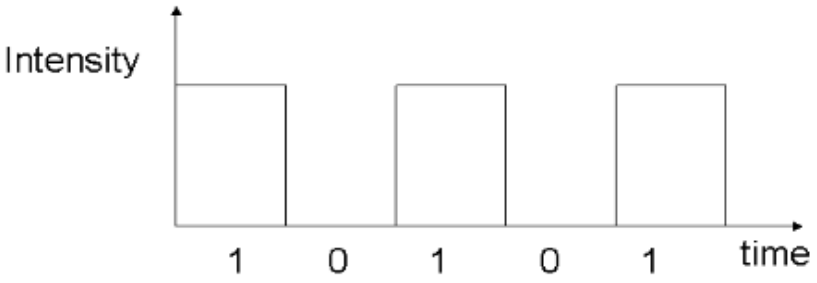


Figure. Digital Signal

OSI Model

- **Physical Level - aspects**
  - ***Bandwidth***: the number of bits that can be transmitted over the network in a given period of time (data transfer speed)
    - Usually expressed in *bits/seconds*
  - ***Latency***: represents the maximum time required for a bit to propagate in a network, from one end to another and is expressed in units of time
    - RTT(*Round Trip Time*) – the necessary time for a bit to cross from one end to the other and back to the environment

Basic parameters to ensure network performance

OSI Model

- **Physical Level - aspects**

Modification suffered by signals during propagation:

- **Attenuation:** energy loss during signal propagation through a transmission medium
- **Noise:** signal change caused by external factors (e.g. lightning, other electronic equipment, etc.)
  - Diaphony = noise from the signal transmitted by a neighboring transmission medium
- **Distortion**- is a deterministic change of a signal

OSI Model

- **Physical Level - conclusions**

  Offers transportation services, on which we can identify a number of possible problems

  – Data can be altered / destroyed due to the noise
  – If the destination cannot process the data in the right time, some will be lost
  – If the same transmission medium is used by multiple transmitters, packages may alter each other
  – It is less expensive to build logical connections to share the same physical medium, than create independent physical links

A new level?

OSI Model

- **Data Link Level:**
  - Offers:
    - mechanisms to detect and correct errors
    - regulatory mechanisms for dataflow
    - control mechanism for media access
    - Services at the network level
    - The data unit used at this level is called *frame*

OSI Model

- **Data Link Level:**
  - The data are encapsulated in *frames*
  - Analogy: *frame*= digital envelope

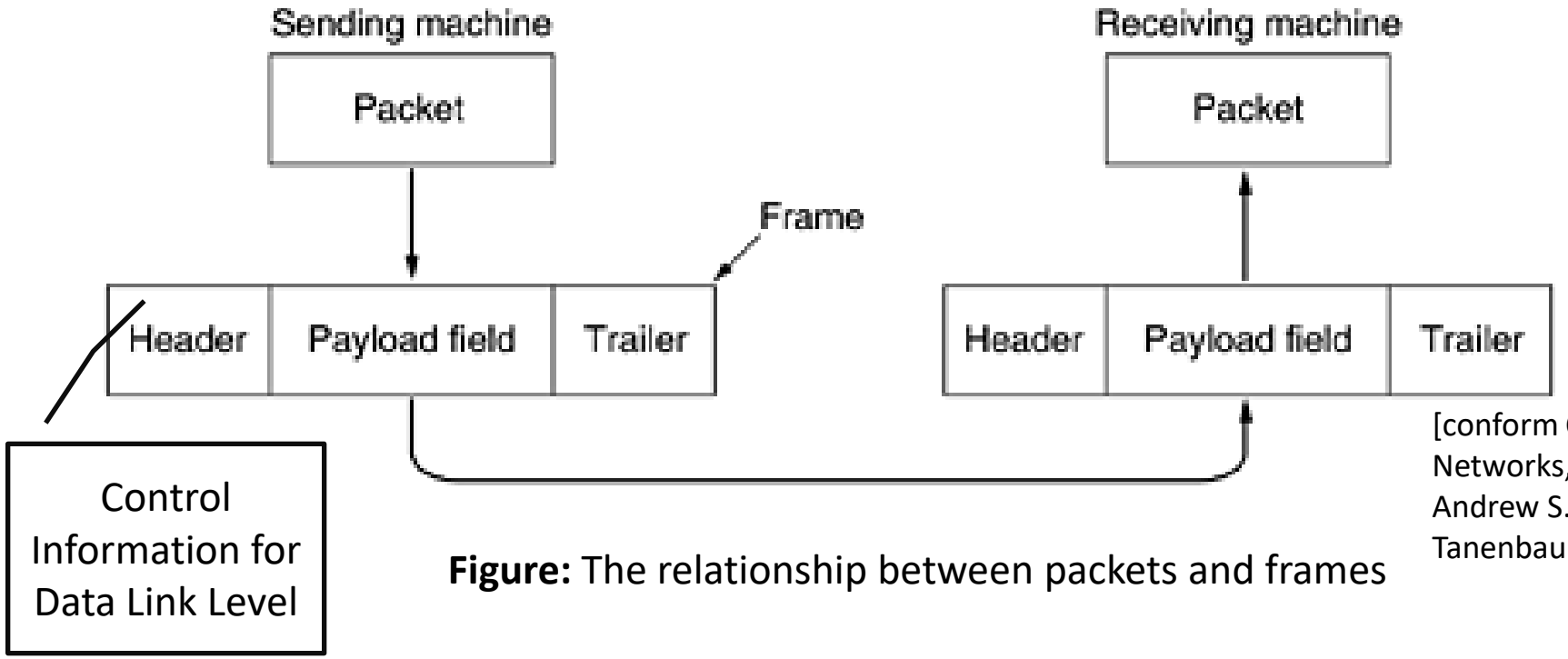


Figure: The relationship between packets and frames

[conform Computer Networks, 2010 – Andrew S. Tanenbaum, et.al.]

OSI Model

- **Data Link Level:**
  - It provides services at the network level
    - Unconfirmed connectionless service
      - » The transmitter sends independent frames to the receiver without waiting for any confirmation
      - » A lost frame is not recovered
    - Confirmed connectionless service
      - » The sent frames are confirmed
      - » The frames are not sent in order
    - Confirmed connection-oriented services
      - » A connection is established before the transmission
      - » Frames are numbered to keep the right order

OSI Model

- **Data Link Level:**
  - Divided into two sublevels:
    - **LLC** (Logical Link Control)
      - Role: Provides an independent view of the medium at a superior level
    - **MAC** (Medium Access Control)
      - Role: Used to determine who is to transmit into *multi-access channel*

OSI Model

- **Data Link Level:**

MAC (Medium Access Control)

  - Context of the problem: the same physical environment is used by more emitters (uniquely identified by a physical address or MAC address) operating simultaneously, for example:
    - Half-duplex transmission between entities that use the same physical environment for both directions
    - communication by radio when there are stations that emit on the same wavelength (Wireless Ethernet - IEEE 802.11, Bluetooth, etc.)

OSI Model

- **Data Link Level:**

MAC (Medium Access Control)

- Strategies:
  - **Static allocation**
    - » FDM (Frequency Division Multiplexing)
    - » TDM (Time Division Multiplexing)
  - Accepting the possibility of collisions and retransmitting packets affected by collisions - **dynamic allocation**

    Collision = data is simultaneously transmitted

    General mechanism: a station that has data to send, transmit them immediately; if the collision appears, the resend action is performed

OSI Model

- **Data Link Level:**

  Medium Access Control – **protocols:**

  - **ALOHA**
    - Pure ALOHA : "*send whenever you want*"
    - Slotted ALOHA
  - **CSMA (Carrier Sense - Multiple Access):** protocol with transmission detection ("*free channel before sending*?")
    - *1-persistent CSMA*
    - …
    - *p-persistent CSMA*

OSI Model

- **Data Link Level:**
  - Medium Access Control – **protocols:**
    - **CSMA** (Carrier Sense - Multiple Access)
      - CSMA/CD *(CSMA with Collision Detection)*
        - » *"free channel while transmit?"*
        - » Based on Ethernet LAN (IEEE 802.3)
    - **MACA (Multiple Access with Collision Avoidance)**
      - The basis for wireless networks (IEEE 802.11)
    - **MACAW**
      - Improves MACA

Standard IEEE	Description
802	Group standards for LAN and MAN
802.2	LLC (Logical Link Control)
802.3	Ethernet (Carrier Sense Multiple Access with Collision Detect (CSMA/CD))
802.3u	Fast Ethernet
802.3z	Gigabit Ethernet
802.11 a/b/g/n/ac	Wireless (WLAN)
802.15	Wireless PAN (802.15.1 Bluetooth, ...)
802.16	Wireless WAN

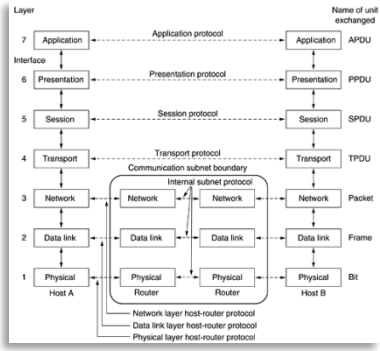
Medium Access Control – Standards Example

OSI Model

- **Data Link Level -** equipment
  - ***Bridges***
    - Resend frames between two networks (LAN)
    - It doesn't change the frame content and only headers can be modified
    - Improve safety and performance transmission
    - Can provide flow control and congestion data
    - Retransmission is done via static routes or using a spanning tree

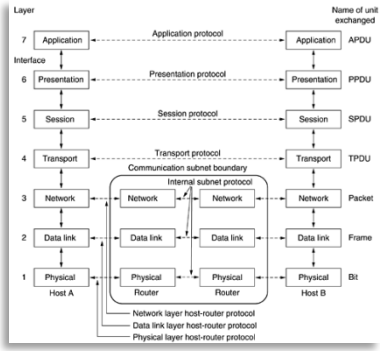
      STP (IEEE 802.1D) – Spanning Tree Protocol
  - **Other equipment? (Course 1)**

OSI Model



- **Network Level:**
  - **Retrieves packages from the source and transfer them to the destination**
  - **It provides services to transport level**
    - **What services?**
      - Internet community proposes:
        - » Connectionless services: SEND PACKET, RECEIVE PACKET
        - » Packages (called ***datagrams***) are independent and are managed individually
        - » Datagram services are similar to a typical post system

OSI Model

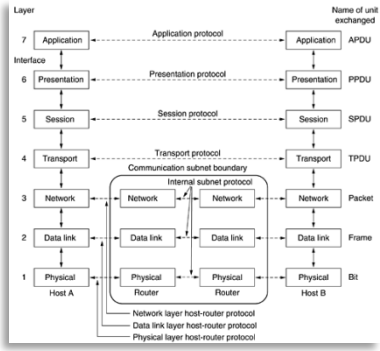


- **Network Level:**
  - **Retrieves packages from the source and transfer them to the destination**
  - **It provides services to transport level**
    - **What services?**
      - Telephone companies propose:
        - » Connection-oriented service – safe services
        - » Before the transfer some negotiations are initiated to establish a connection (VC-virtual circuit)
        - » These services are similar to the telephony system

OSI Model

- **Network Level:**
  - Used Protocols
    - X.25 (Connection-oriented)
    - IP
  - Problems
    - Protocol conversions and addresses
    - Error control (flow, congestion)
    - Dividing and recomposing packages
    - Security – encryption, *firewall*

OSI Model



- **Transport level:** it offers safe and cost-effective data transport from the source machine to the destination machine, independent of physical network or networks currently in use

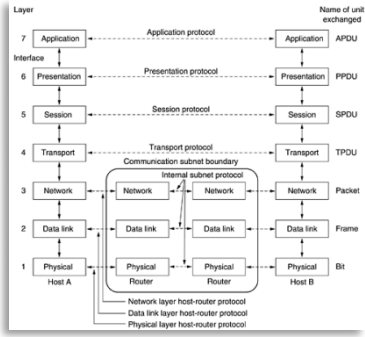
Services: provides connection-oriented and connectionless services

Differences between the transport and network layer?

OSI Model

- **Transport level:**
  - **Primitives:**
    - LISTEN – it's a blocking operation until a process tries to connect
    - CONNECT – trying to establish a connection
    - SEND – send data
    - RECEIVE – it's a blocking operation until data is received
    - DISCONNECT – connection release
  - **Performance -** quality of service (QoS - Quality of Service): establishing /releasing the connection, error rate, protection, priority, resilience (the probability that a connection shut down because various internal reasons), duplicate packets, flow control

OSI Model

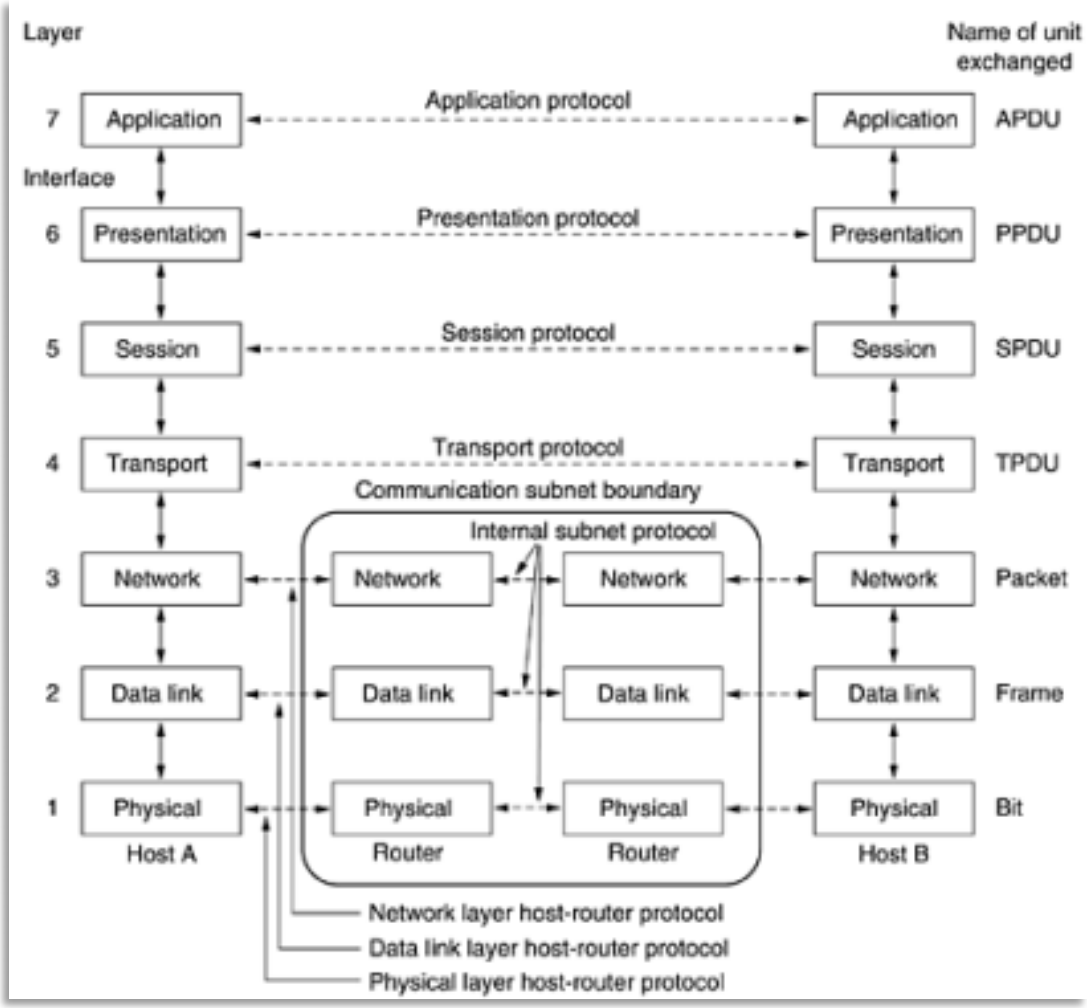


- **Session level:** refers to problems linked to session settings (dialogue control services, synchronisation etc.)
- **Presentation level:** handle data presentation, codified them into standard format
  - To ensure communication among computers with different representations, the presentation level ensures the conversion of internal data in standardized network representation and vice versa

Modelul OSI

- **Application level:**

manage network services: virtual terminal, file transfer, electronic mail, remote execution of applications, ...



TCP/IP Model

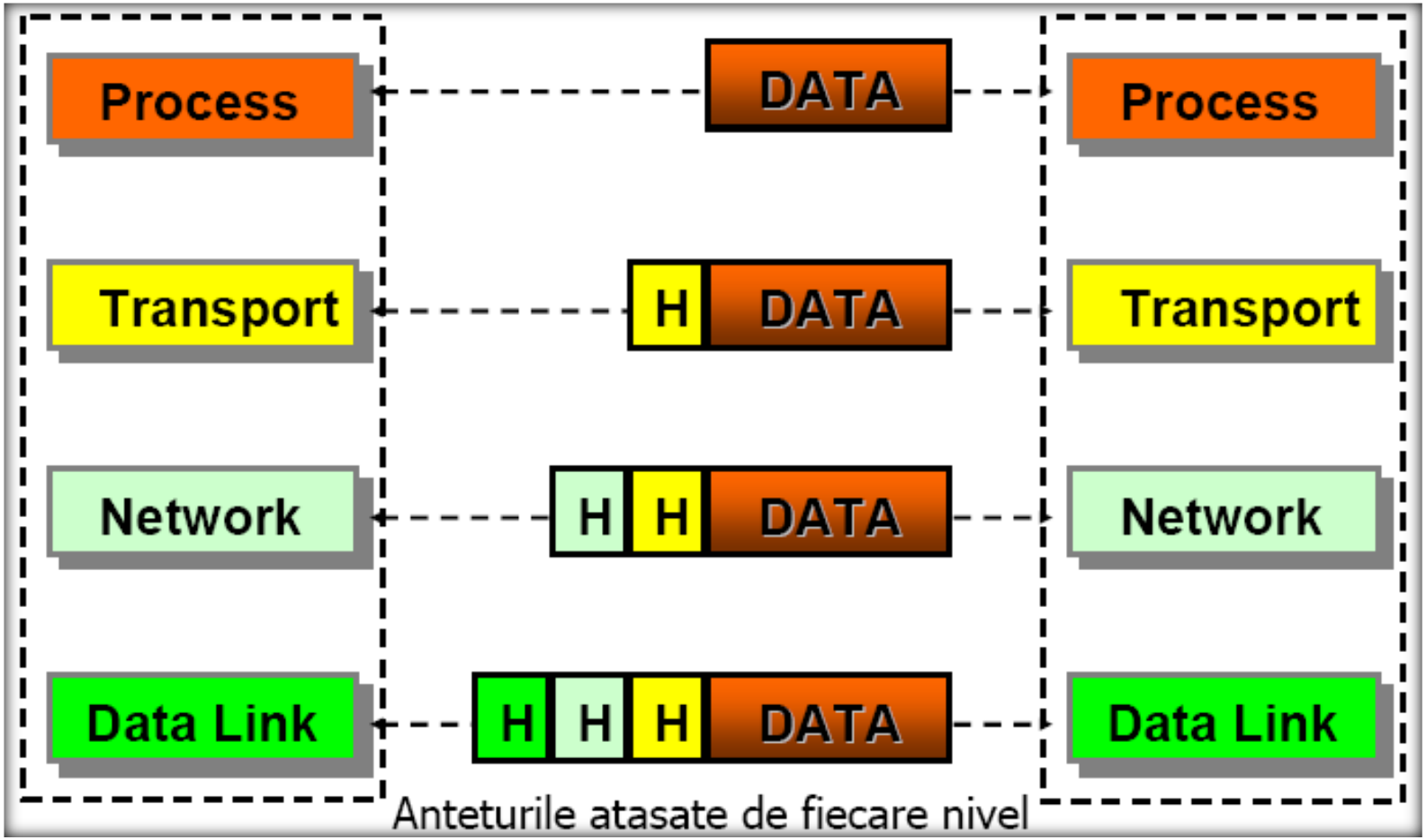
- **Terms:**
  - end-system – *host*
  - network - provides support for data transfer between end systems
  - internet - collection of networks (interconnected)
  - Sub-network - part of the internet
  - intermediate system - connects two sub-networks

OSI versus TCP/IP

TCP/IP Model	TCP/IP - Protocols	OSI Model
Application	FTP, Telnet, HTTP,…	Application
		Presentation
Transport	TCP, UDP, …	Session
		Transport
Internetwork	IP, …	Network
Host to Network	Ethernet, …	Datalink
		Physical

Figure: Overview of models OSI and TCP / IP

TCP/IP Model



[Retele de calculatoare – curs 2007-2008, Sabin Buraga]

TCP/IP Model

- It provides the ability to interconnect multiple network types
- Network and Transport levels are the kernel of this model
- Successfully implemented over Ethernet (IEEE 802.3) - supported by many implementations of the physical layer (coaxial cable, twisted pair, fiber optic)

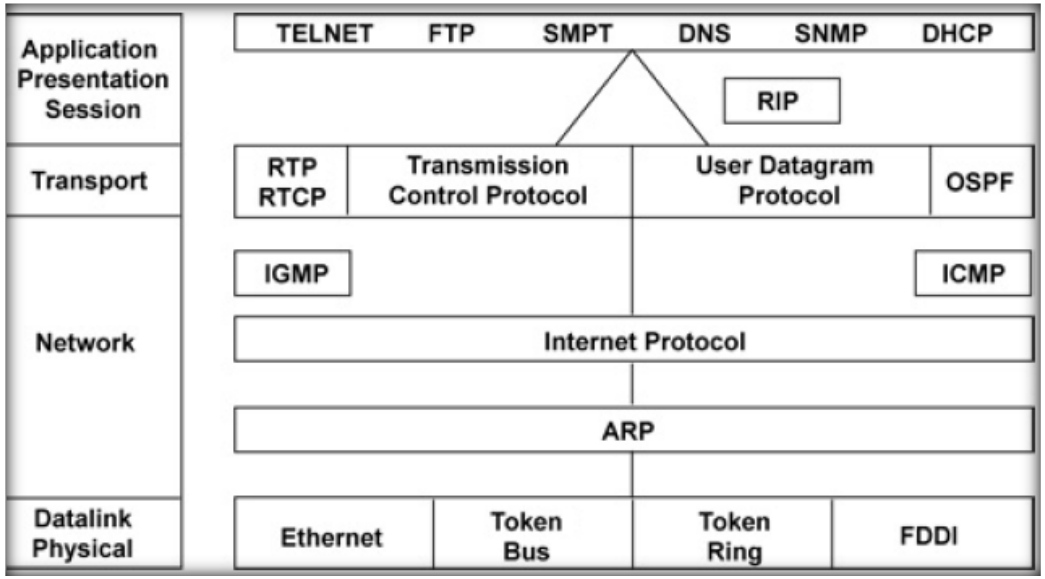
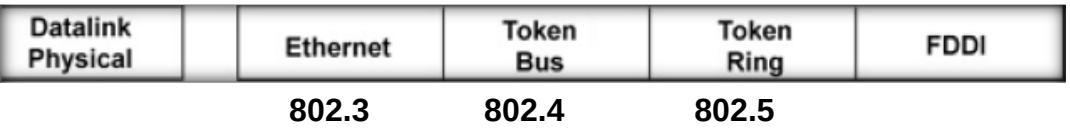


Figure. The TCP / IP - protocols

TCP/IP Model

- **"Physical" level**
  - Ensure the connection between host and the network



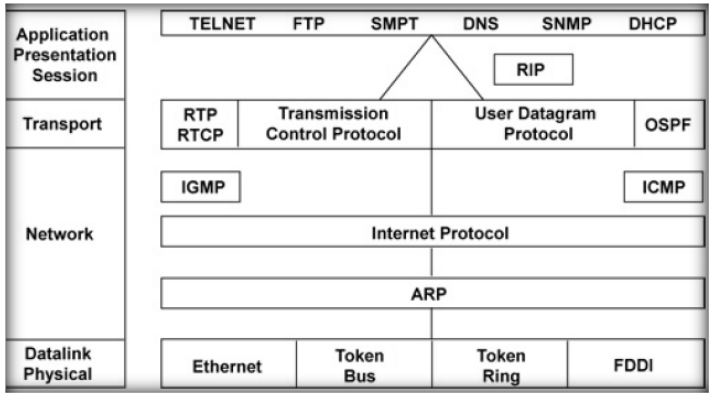


Figure. TCP/IP Model

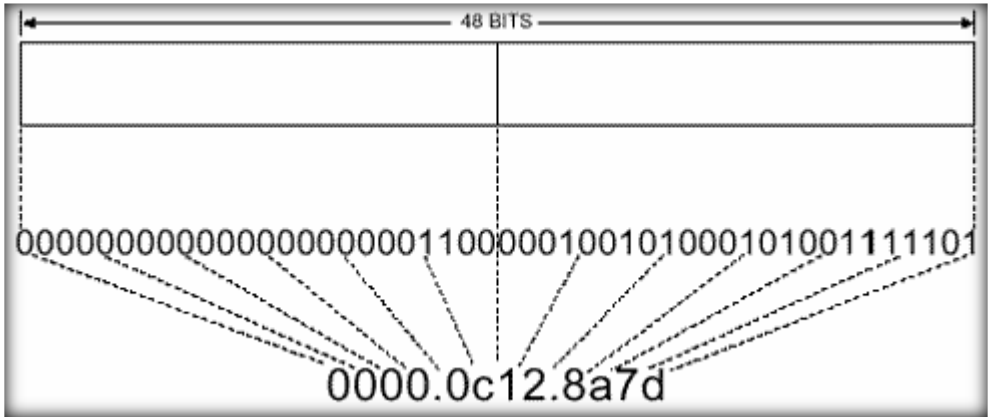
Ethernet

- It provides multiple access (shared transmission medium) in a network
- Collision Detection: CSMA / CD (Carrier Sense Multiple Access with Collision Detection)
- Each Ethernet interface has a unique address 48 bits: hardware address (MAC) - e.g. C0: B3: 44: 17: 21: 17
  - Addresses are assigned to NIC (Network Interface Card) producers by a central authority

TCP/IP Model

Ethernet

- Each interface (board) network has a unique MAC address (some operating systems allow it to be modified by software)



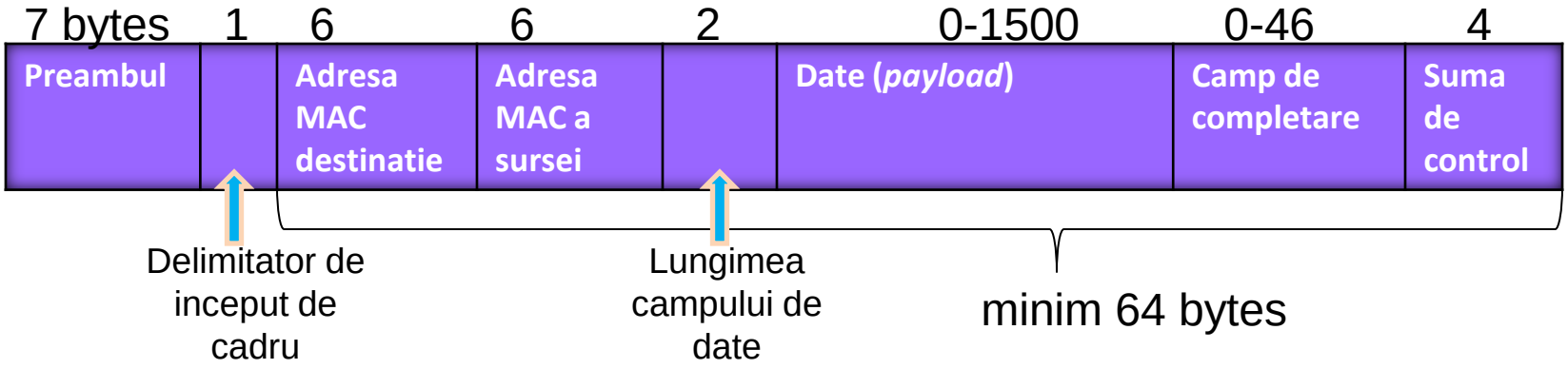
- The first 24 bits identify the manufacturer

[conform Retele de calculatoare – curs 2007-2008, Sabin Buraga]

TCP/IP Model

Ethernet

- A frame format:



- Broadcast: the address has all bits set to 1
- Each network interface inspecting the destination address in each frame
- If the destination address does not match with the hardware address or the broadcast address, then the frame is ignored

TCP/IP Model

Ethernet – standards (examples):

- 10 BASE5: 10 Mbps using thick coaxial cable (Thick Ethernet)-1980
- 1BASE5: 1 Mbps using two Ethernet cables (Unshilded Twisted Pair)
- 10BASE-T: 10Mbps using 2 pairs UTP– 1990
- 10BASE-FL: 10 Mbps optical fiber with point-to-point link
- 10BASE-FB: 10Mbps backbone with optical fiber
- 100BASE – FX: 100MBps CSMA/CD with two optical fiber, full duplex
- … etc

TCP/IP Model

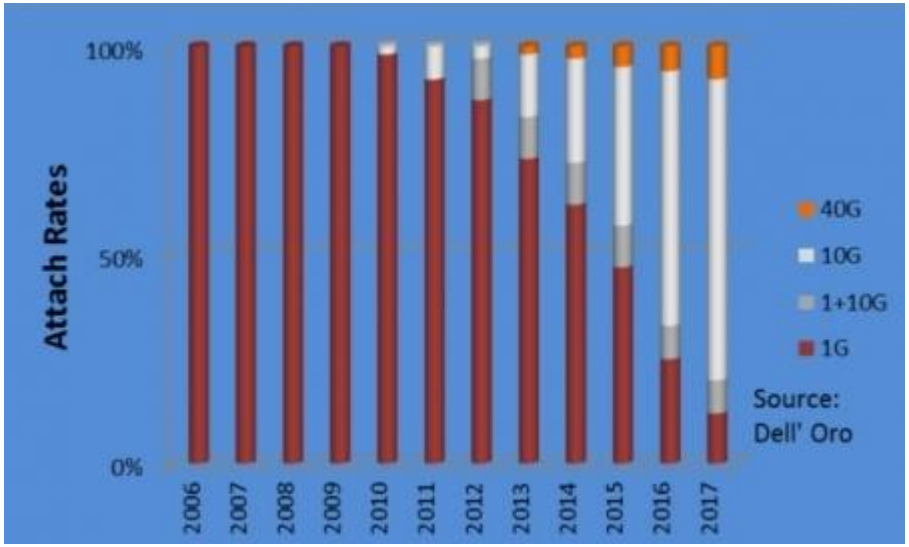
Ethernet versus Fast Ethernet

	Ethernet	Fast Ethernet
Viteza	10 Mbiti/s	100 Mbiti/s
Protocolul MAC	CSMA/CD	CSMA/CD
Diametrul retelei	2.5 km	205 m
Topologie	Magistrala, stea	Stea
Tip cablu	Coax, UTP, fibra	UTP, fibra
Standard	802.3	802.3u
Cost	c	2*c

[conform Retele de calculatoare – curs 2007-2008, Sabin Buraga]

TCP/IP Model

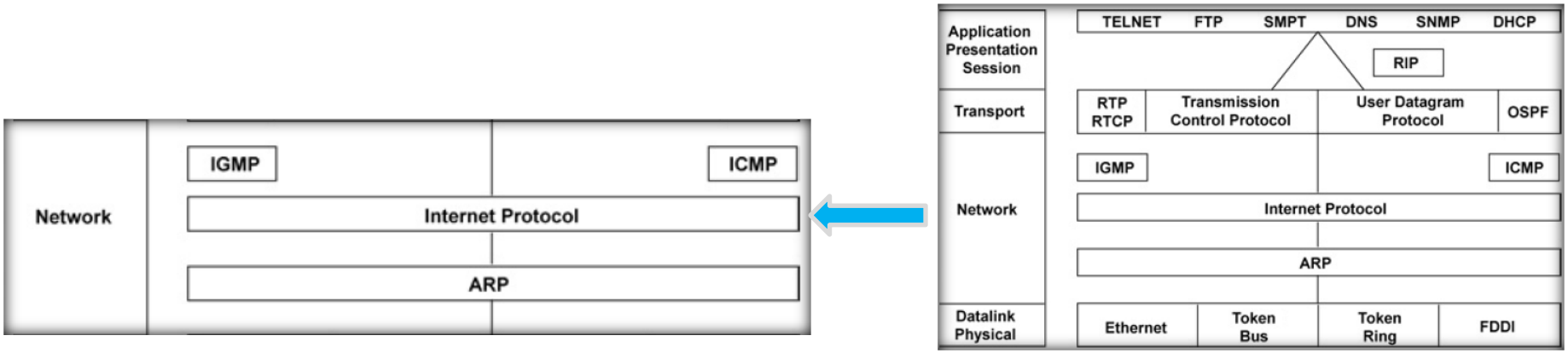
- **Gigabit Ethernet**
  - Implementations for both copper wires (802.3ab), and fiber (802.3z)
  - The difference from other Ethernet implementations is at physical level
- **10 Gigabit Ethernet**
  - Implementations for fiber (802.3ae)
  - Operates at distances of 40km (useful for MAN and WAN)
  - Frame format is similar to other implementations of Ethernet



[http://www.networkcomputing.com/networking/will-2014-be-the--year-of-10-gigabit-ethernet/a/d-id/1234640?]

TCP/IP Model

- **Network Level**
  - It allows hosts to emit packet in any network; packages travel independently up to destination



- Highlights:
  routing packets
  congestion avoidance

TCP/IP Model

- **Network Level**
  - Level design aimed at achieving the following objectives:
    - The services offered are independent from the technology used (e.g. routers)
    - Provide transport level services, which allow it to operate independently of number, type and topology
    - It provides a unique mechanism to address LANs and WANs

TCP/IP Model

- **Network Level**
  - **IPv4** (see course 3)
  - **IPv6** (see a future course)
  - *Routing*
    - OSPF(*Open Shortest Path First*) – RFC 1131
    - BGP(*Border Gateway Protocol*) – RFC 1105
  - Multicast:
    - IGMP (*Internet Group Management Protocol*) – RFC 1112, 1054
  - Control:
    - ICMP (*Internet Control Messages Protocol*) - RFC 792,777
    - SNMP (*Simple Network Management Protocol*) – RFC 1157
    - ICMPv6

TCP/IP Model

- **Transport level**
  - Ensures the realization of communication between the source host and destination host
  - Protocols
    - ***TCP*** (*Transmission Control Protocol*) - RFC 793,761
    - ***UDP*** (*User Datagram Protocol*) – RFC 768
    - **Other Protocols: SCTP** (*Stream Control Transmission Protocol*) – RFC 4960, 3286 (2960, 3309);**DCCP** (*Datagram Congestion Control Protocol*) – RFC 4340, 4336;

TCP/IP Model

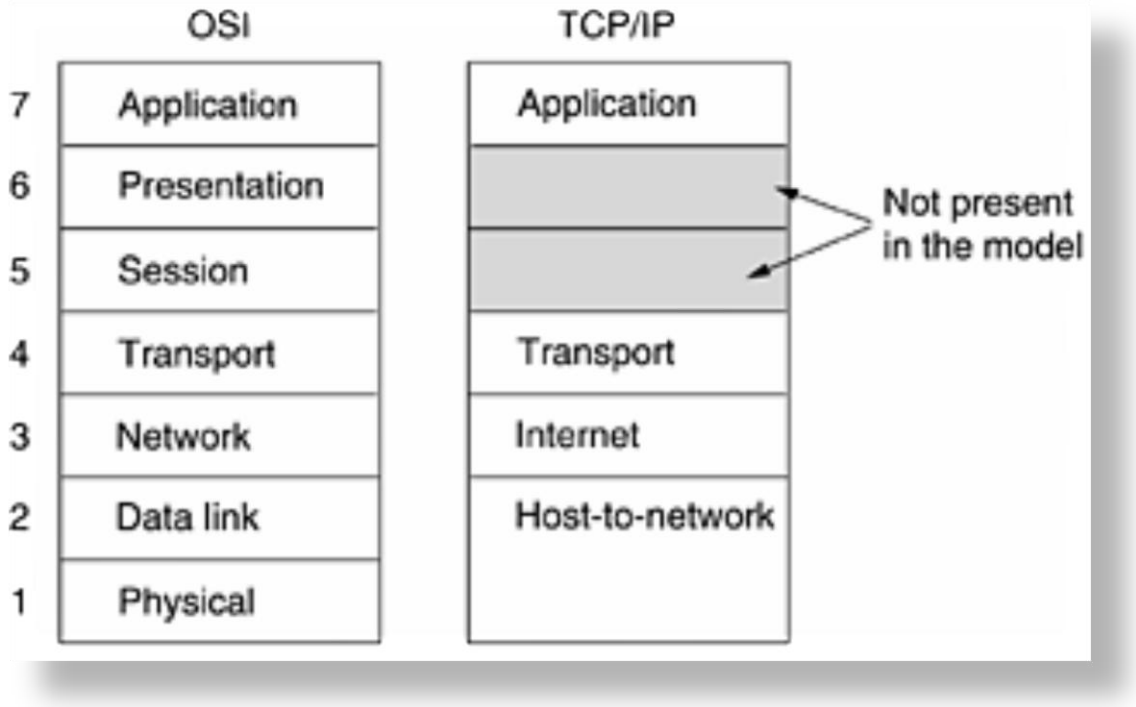
- **Application Level:**
  - Contains high level protocols
  - SMTP (*Simple Mail Transfer Protocol*) – RFC 5321 (821)
  - POP3(*Post Office Protocol*) – RFC 1081
  - TELNET – RFC 854,764
  - FTP (*File Transfer Protocol*) – RFC 454
  - NFS (*Network File System*) – RFC 1095
  - DNS (*Domain Name System*) – RFC 1034,1035
  - HTTP (*HyperText Transfer Protocol*) – RFC 2616
  - RTP (*Real-time Transport Protocol*) – RFC 3550 (1889)
  - SIP (*Session Initiation Protocol*) – RFC 3261
  - …etc

TCP/IP Model

- Organizations involved in standardization:
  - ISOC – *Internet Society*
  - IAB – *Internet Architecture Board*
  - IETF – *Internet Engineering Task Force*
  - IRTF – *Internet Research Task Force*
  - InterNIC – *Internet Network Information Center*
  - IANA – *Internet Assigned Number Authority*
- RFC (*Request For Comments*) documents
  - Edited by Network Working Group (IETF)
  - RFC 1800 (Internet Official Protocol Standards)
  - More details -> www.ietf.org

OSI versus TCP/IP

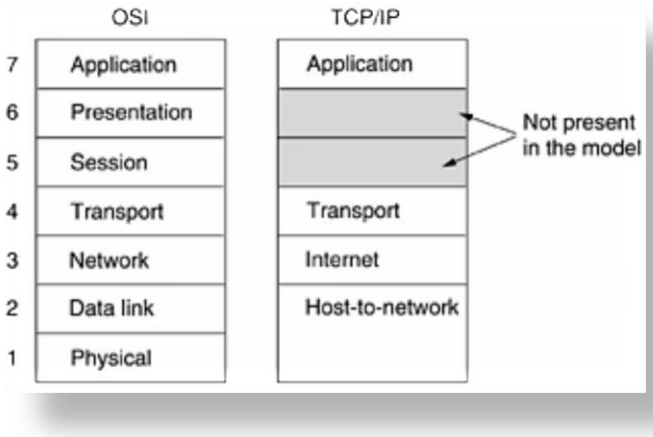
- **Similarities:**
  - Both are based on a protocol stack
  - The layer functionalities are somehow similar
  - Both have an application layer on top
  - Are based (directly or not) on transport level



[conform Computer Networks, 2010 – Andrew S. Tanenbaum, et.al.]

OSI versus TCP/IP

- **Differences:**
  - ISO/OSI is a theoretical model; TCP/IP is effective in implementation
  - OSI makes explicit the distinction between service, interface and protocol; TCP / IP does not
  - ISO / OSI provides protocols that ensure reliable communication (detection and treatment of errors at each level); TCP/IP verifies communication at transport level
  - OSI support both types of communication at network level (connectionless and connection oriented); TCP/IP has connectionless services at network level and both types at transport level



[conform Computer Networks, 2010 – Andrew S. Tanenbaum, et.al.]

Summary

- Computer Networks Structure
- Network Architecture Models (OSI, TCP/IP)
- TCP/IP Model
- ISO/OSI versus TCP/IP

Questions?