# Computer Networks

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Prof. Dr. Wolfgang Effelsberg

Lehrstuhl für Praktische Informatik IV

Universität Mannheim



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# 1.1 Definition of a Computer Network

## Definition

A computer network connects independent computers for the purpose of data exchange.

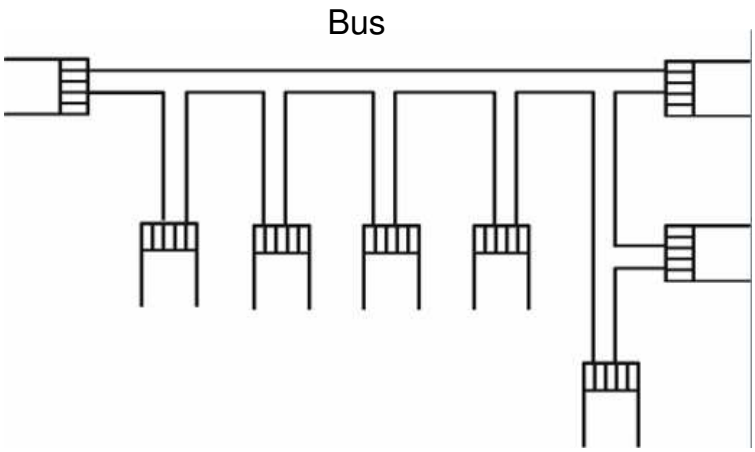
## As opposed to:

- Bus, channel
- Interconnection network for parallel computers (multiprocessor systems)
- Terminal network



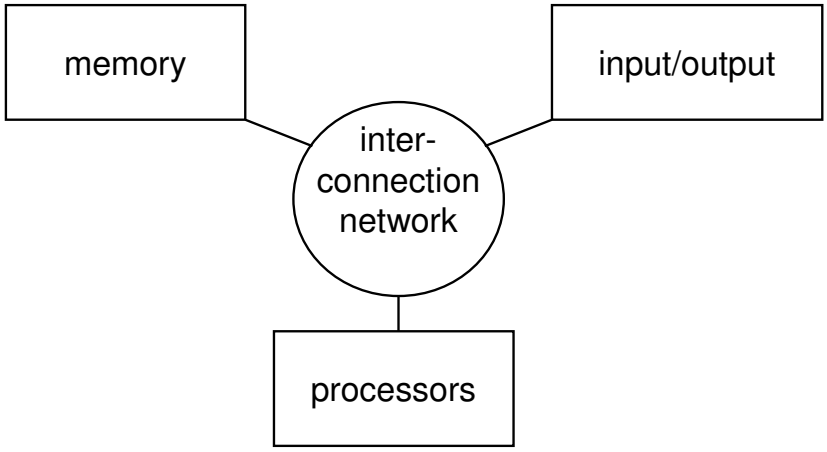
# Bus

A **bus** connects the components of a computer within the box.



# Interconnection Network

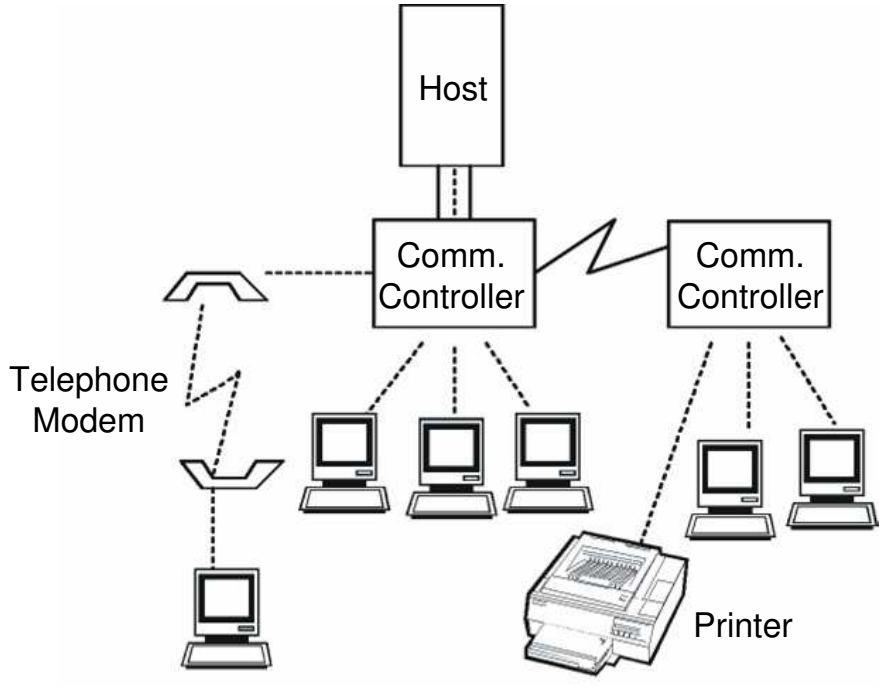
Interconnection network in a multiprocessor




n processors



# Terminal Network



# 1.2 Standard Organizations

- International Organization for Standardization (ISO)
- International Telecommunications Union (ITU)
- CEN/ CENELEC/ ETSI (European)
- National Institute of Standards and Technology (NIST)
- and many more



# International Standards Organization (ISO)

**Standardization on an international level**

- Members: National Standards Organization (DIN, ANSI, AFNOR,...)
  - ISO TC 97: Information Processing Systems
  - DIN: Normungsausschuss Informationsverarbeitung (NI)
  - TC 97/SC 6: Data Communications
  - TC 97/SC 18: Text and Office Communications
  - TC 97/SC 21: Open Systems Interconnection
- Steps towards a standard:
  1. Working Draft (WD)
  2. Draft Proposal (DP)
  3. Draft International Standard (DIS)
  4. International Standard (IS)

# International Telecommunications Union (ITU)

Formerly: Comité Consultatif International de Télégraphie et Téléphonique (CCITT)

- ITU-R (ITU Radiocommunication Standardization Sector)
- ITU-T (ITU Telecommunication Standardization Sector)

- International union of telecom organizations
- Plenary assembly every 4 years ( ..., 1980, 1984, 1988, 1992, 1996 ...)
- Standard documents are called „recommendations“
- ITU is a UN organisation



# CEN / CENELEC / ETSI

- European Standards Organizations
- Europe-wide harmonization of national standards
- Often prepare input for ISO and ITU-T

# Internet Standards

- IAB (Internet Activity Board)
  - IETF (Internet Engineering Task Force)
  - IRTF (Internet Research Task Force)
- RFC (Request for Comment) fulfills the role of an internet standard. Surprisingly the definition of RFCs is an informal process!
- Working groups, each with a leader
  - anyone can become a working group member
  - communication mainly by e-mail, occasional IETF meetings
  - typical duration: 9-18 months
  - result: Internet Draft
- Steps towards a standard: Internet Draft  at least two independent implementations; interoperability tests; stability for 4 months  Internet Standard (RFC)



# Industry Consortia

- Association of predominantly industrial partners
- Goal: rapid realiziation of compatible products. Therefore: quick development of a common de-facto standard
- Submission of the results to international standardization organizations
- Exaples:
  - NFS (Network File System)
  - ATM (ATM-Forum)
  - WWW consortium

# 1.3 Protocol Architecture

We structure the complex communication system into ***layers:***

- The lowest layer (layer 1) provides the physical connection.
- Each higher layer adds more functionality, hiding details from the next higher layer.
- „Horizontal“ interfaces between layers are a local matter (there is no need for standardization). They are called „service interfaces“.
- The rules of communication between two entities at the same layer are called „communication protocol“.



# 1.4 The ISO/OSI Reference Model

- OSI = OPEN SYSTEMS INTERCONNECTION
- In short: ISO/OSI Reference Model
- ISO International Standard 7498
- Introduces the layered architecture and basic terminology
- Proposes seven layers and their functionality

# Seven Layers and their Functionality

Terminal A

Terminal B

| | | |
|---|---|---|
| Application layer | Application-specific protocols | 7 |
| Presentation layer | Data representation formats | 6 |
| Session layer | Dialog control | 5 |
| Transport layer | End-to-end data transport | 4 |
| Network layer | Routing | 3 |
| Data Link layer | Next-neighbor error and flow control | 2 |
| Pysical layer | Physical data transfer | 1 |

Physical link



# Seven Layers of the ISO-Reference Model (1)

- The **physical layer** provides the transmission of a digital data stream over a transmission line.
- The **data link layer** provides error and flow control for the physical bit stream. In LANs it also implements medium access control.
- The **network layer** provides routing algorithms to compute end-to-end paths through the network. It also implements packet queueing and forwarding in the “routers”.
- The **transport layer** provides reliable end-to-end data connections from a process at the source node to a process at the destination node.
- The **session layer** coordinates the cooperation (dialog) between applications.

## Seven Layers of the ISO-Reference Model (2)

- The **presentation layer** provides a common transfer syntax for all systems, and conversion rules from the local to the common data representation.
- The **application layer** implements the application-specific protocols.



## Terminology of the ISO Reference Model (1)

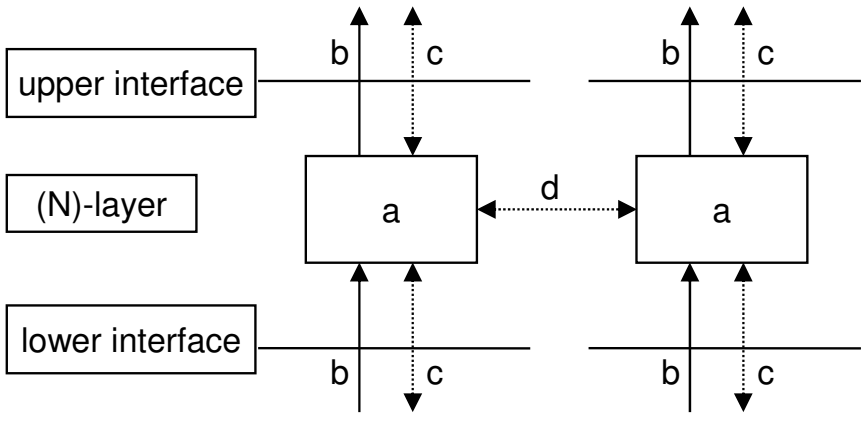
- **Open System**
  - Computer system (hardware, software, periphery, ...) that intends to communicate and implements the OSI standards
- **(N)-Layer**
  - Is formed by all entities of a (N)-hierarchy level in all open systems
- **(N)-Entity**
  - Implementation of a (N)-layer in a system
  - There can be different types of (N)-entities that implement (N)-layer protocols in a different way, e.g., from different manufacturers
- **Peer Entities**
  - Entities of the same layer at different locations.

# Terminology of the ISO Reference Model (2)

- The main task of every layer is to offer ***services*** to the layer above. These services are made up of
  - services implemented within this layer, and
  - the cumulative result of services of all the layers below.
- Layers are connected to the next higher and lower layers by ***service primitives***.
- Direct (local) communication takes place with layers (N+1) and (N-1).
- Indirect communication with peer entities takes place according to the rules of the communication ***protocol***.



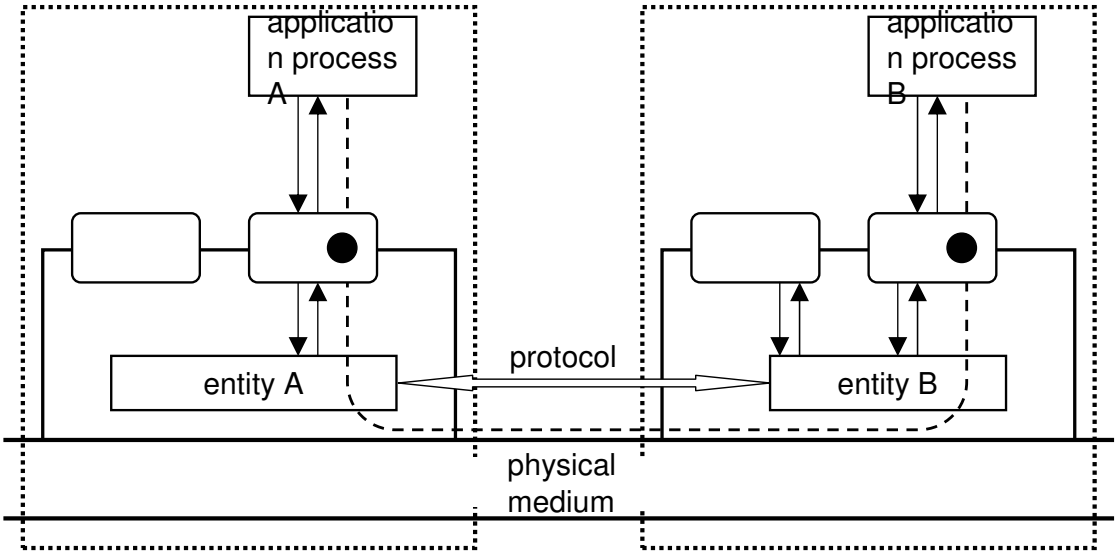
# Terminology of the ISO Reference Model (3)




a = Peer Entities
b = Layer Service
c = Service Primitives
d = Protocol

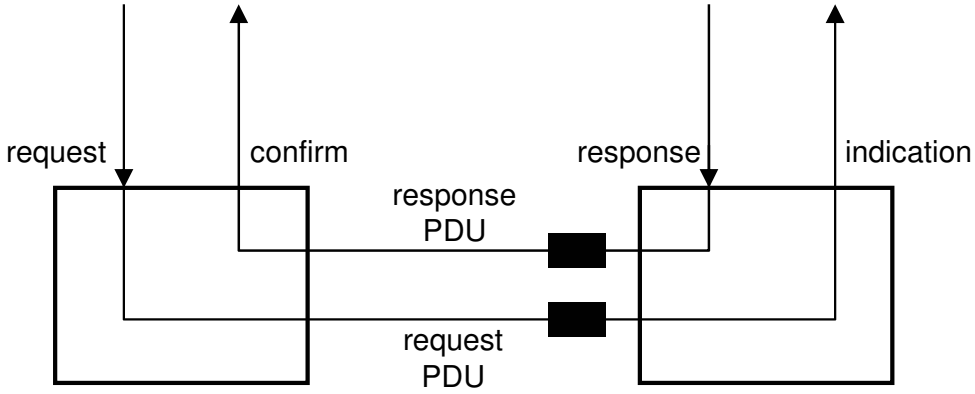
# Protocol

A **protocol** is the set of rules for data exchange between two entities of the same layer.






# Service Events and Protocol Data Units

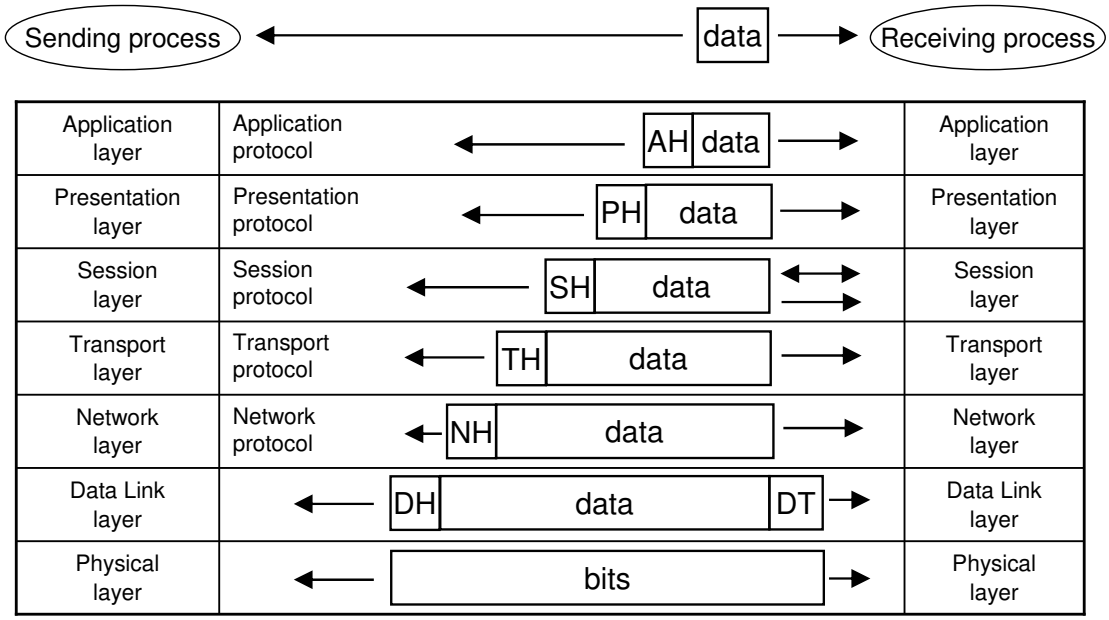


# Types of Service Primitives

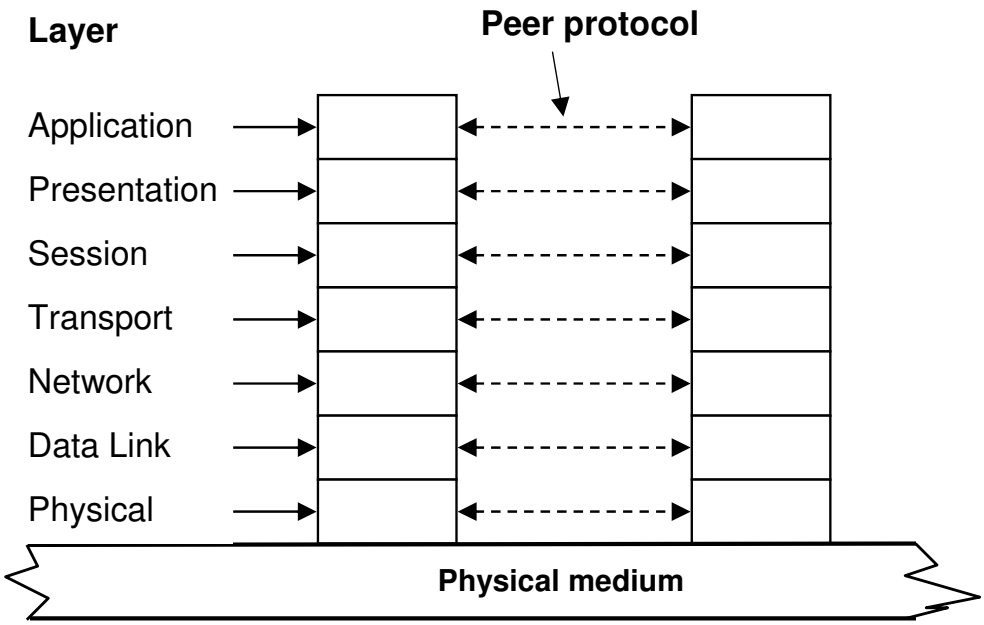
- Request
  - request of a service by the user
- Indication
  - indicates to the user that a service has been requested by the remote user or that an event has occured in the layer
- Response
  - acknowledgement of a preceeded indication by the user
- Confirmation
  - acknowledgement of a preceeded request to the local requestor



# Headers and Trailers in the Layered Model

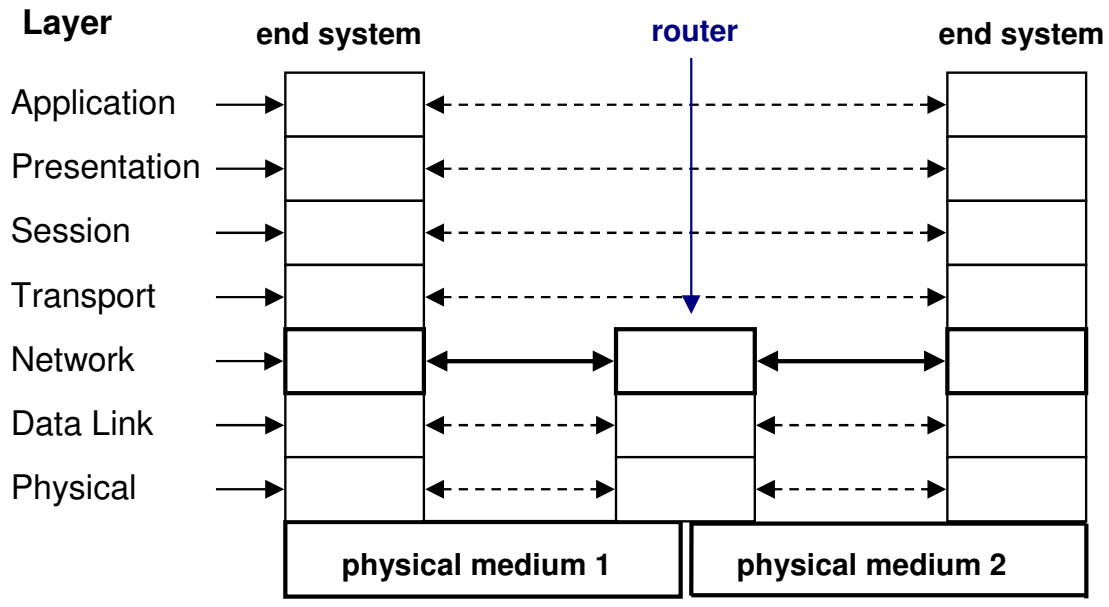


# Reference Model and Peer Protocols






# Router



# Layer Models of Different Network Arcitectures

| Layer | ISO | Internet | SNA |
|---|---|---|---|
| 7 | Application | smtp<br>ftp<br>telnet<br>http<br>… | End user |
| 6 | Presentation | | NAU services |
| 5 | Session | | Data flow control |
| 4 | Transport | TCP, UDP | Transmission control |
| 3 | Network | | Path control |
| | | IP | |
| 2 | Data Link | Data link control | Data link control |
| 1 | Physical | Physical | Physical |