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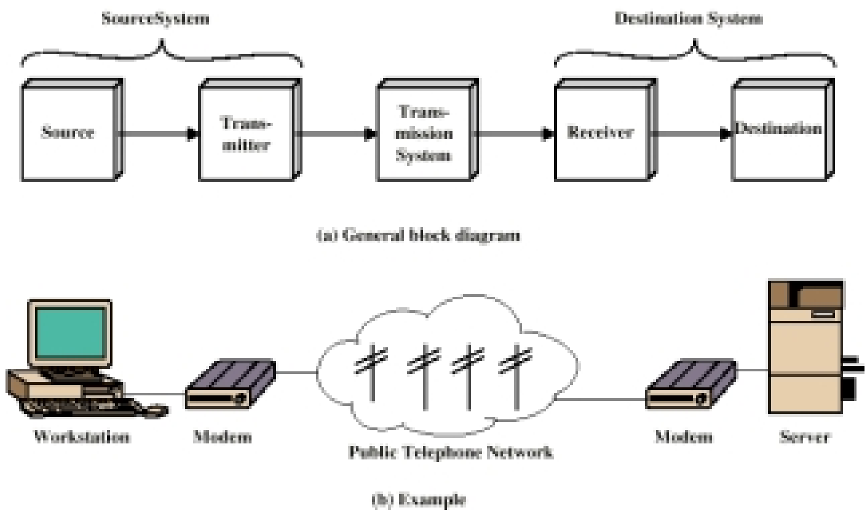
Data and Computer Communications

Chapter 1
Introduction

A Communications Model

- Source
  - generates data to be transmitted
- Transmitter
  - Converts data into transmittable signals
- Transmission System
  - Carries data
- Receiver
  - Converts received signal into data
- Destination
  - Takes incoming data

Simplified Communications Model - Diagram



Key Communications Tasks

- Transmission System Utilization
  - Make efficient use of shared transmission facilities
  - Multiplexing
  - Congestion control
- Interfacing
  - A device must interface with the transmission system
- Signal Generation
  - Signals must be
    - Capable of being propagated through transmission system
    - Interpretable as data at the receiver

Key Communications Tasks

- Synchronization
  - Receiver must know
    - When a signal begins to arrive and when it ends
    - Duration of a signal
- Exchange Management
  - Both devices may transmit simultaneously or take turns
  - Amount of data sent at one time
  - Data format
  - What to do if an error occurs

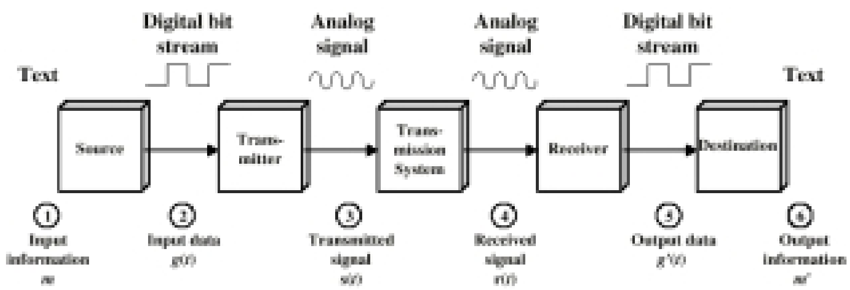
Key Communications Tasks

- Error detection and correction
  - Required when errors cannot be tolerated
- Flow Control
  - Assure that source does not overwhelm destination by sending data faster than can be processed
- Recovery
  - Required when an information exchange is interrupted due to a fault in the system
  - Resume activity at point of interruption or
  - Restore system state to condition prior to beginning of exchange

Key Communications Tasks

- Addressing and routing
  - A source system must indicate the identity of intended destination
  - Transmission system maybe a network through which various paths (routes) must be chosen
- Message formatting
  - Both parties must agree on form of data to be exchanged
- Security
  - Sender assured only intended receiver receives data
  - Receiver assured data not altered in transit and actually came from purported sender
- Network Management
  - Configure system, monitor its status, react to failures and overloads.

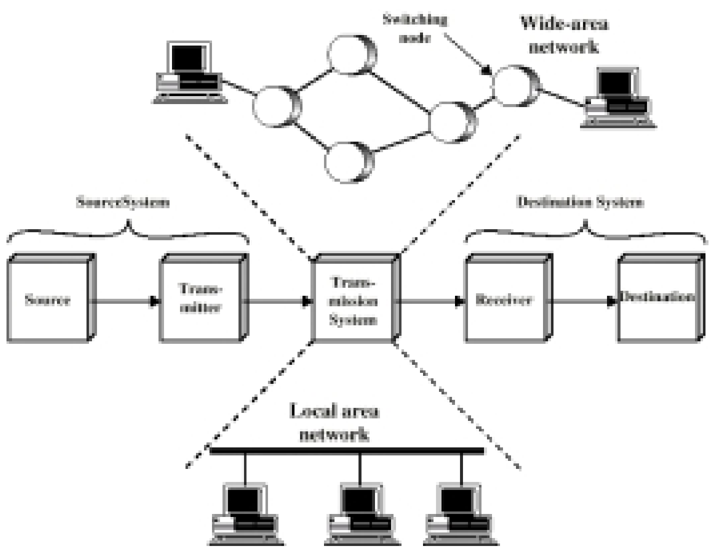
Simplified Data Communications Model



Networking

- Point to point communication not usually practical
  - Devices are too far apart
  - Large set of devices would need impractical number of connections
- Solution is a communications network
- Communication networks classified into
  - Wide area networks (WANs)
  - Local area networks (LANs)

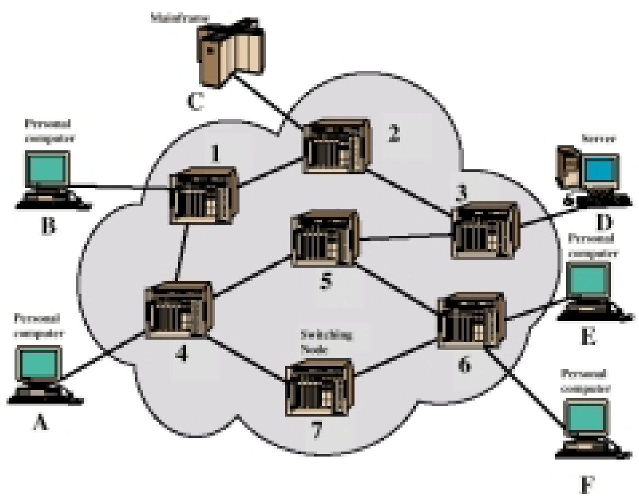
Simplified Network Model



Wide Area Networks

- Large geographical area
- Crossing public rights of way
- Rely in part on common carrier circuits
- Consists of a number of interconnected switching nodes
- Alternative technologies
  - Circuit switching
  - Packet switching
  - Frame relay
  - Asynchronous Transfer Mode (ATM)

Simple Switched Network

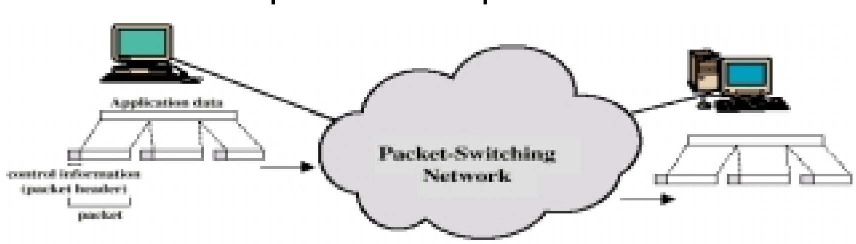


Circuit Switching

- Dedicated communications path established for the duration of the conversation
  - e.g. telephone network
- The path is a connected sequence of physical links between nodes
- Inefficient
  - Channel capacity dedicated for duration of connection
  - If no data, capacity wasted
- Set up (connection) takes time
- Once connected, transfer is transparent
- Developed for voice traffic (phone)

Packet Switching

- Station breaks long message into packets sent one at a time to the network
- Packets pass from node to node between source and destination
- Data sent out of sequence
- Used for computer to computer communications



Packet Switching

- Advantages
  - Line efficiency
    - Single node to node link can be shared by many packets over time
    - Packets queued and transmitted as fast as possible
  - Data rate conversion
    - Each station connects to the local node at its own speed
    - Nodes buffer data if required to equalize rates
  - Packets are accepted even when network is busy
    - Delivery may slow down
- Priorities can be used

Frame Relay

- Packet switching systems have large overheads to compensate for errors
- Modern systems are more reliable
- Errors can be caught in end system
- Most overhead for error control is stripped out
- Original packet switching networks designed with a data rate of 64 Kbps
- Frame relay designed with a data rate of 2 Mbps

Asynchronous Transfer Mode

- ⌘ ATM is evolution of frame relay
- ⌘ Frame relay uses variable length packets called frames
- ⌘ ATM uses fixed length packets called cells
- ⌘ Little overhead for error control
- ⌘ Data rate from 10Mbps to Gbps
- ⌘ Constant data rate using packet switching technique

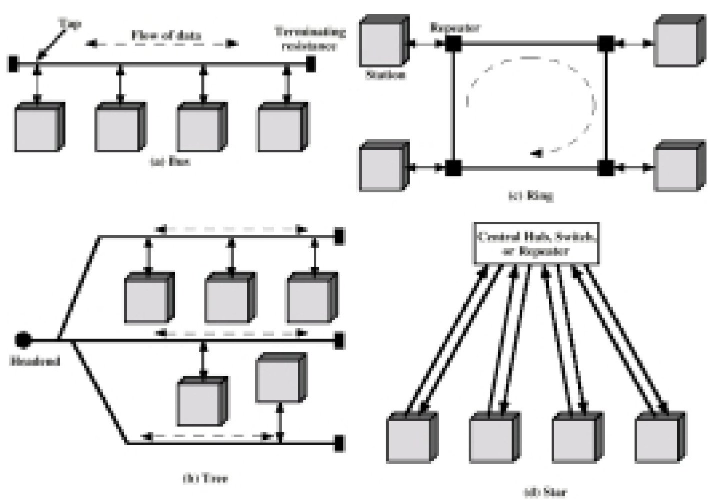
Integrated Services Digital Network

- ⌘ ISDN designed to replace public telecom system
- ⌘ Defined by standardization of user interfaces
- ⌘ Implemented as a set of digital switches and paths
- ⌘ Entirely digital domain
- ⌘ Supports voice and non-voice applications
- ⌘ Support for switched and non-switched applications
- ⌘ Reliance on 64 Kbps connections
  - Basic service: 192 Kbps
  - Primary service: 1.544 Mbps and 2.048 Mbps

Local Area Networks

- Smaller scope
  - Building or small campus
- Usually owned by same organization as attached devices
- Data rates much higher
- Usually broadcast systems
- Now some switched systems and ATM are being introduced

LAN Topologies



Protocols & Protocol Architecture

- In addition to data path, we need to account for other factors in communication network:
  - Source must identify the destination to the network
  - Source must make sure that destination is prepared to accept data
  - Security must be accounted for; data should go to the intended user on the receiver
  - Incompatible file formats may need to be translated
- Computer Communication
  - Exchange of information between computers for cooperative action

Protocols

- Communication must follow some mutually acceptable conventions , referred to as protocol
- Set of rules governing the transfer of data between entities
- Used for communications between entities in different systems
- Communicating entities must speak the same language
- Entities: anything capable of sending or receiving information
  - User applications, e-mail facilities, terminals
- Systems: physically distinct object that contains one or more entities
  - Computer, terminal, remote sensor

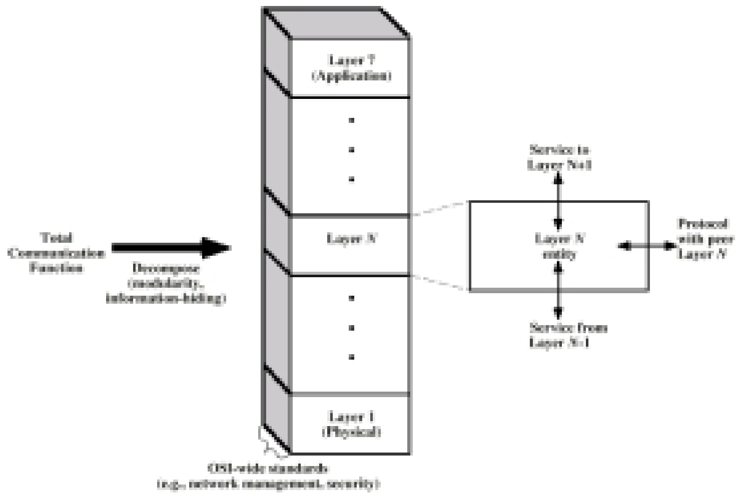
Key Elements of a Protocol

- Syntax
  - Data format and size
  - Signal levels
- Semantics
  - Control information
  - Error handling
  - Actions to take in response to reception of different messages
- Timing
  - Speed matching
  - Sequencing
  - When to discard a message, retransmit, give up

Protocol Architecture

- Protocols can quickly become very complicated (and thus incorrect)
- Implement functionality with several protocols
- Layering is a popular way of structuring such a family of network protocols
- Each layer represents a new level of abstraction with well defined function
- Layer N defined in terms of layer N-1 only, providing total interface to layer N+1

Protocol Architecture



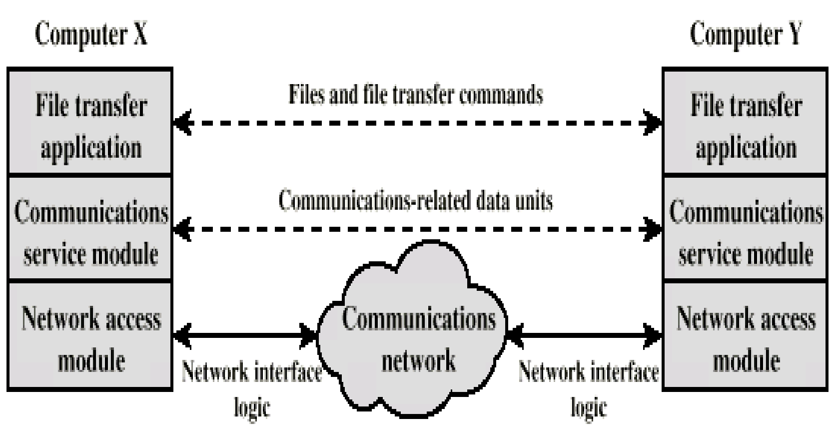
Protocol Architecture

- Interfaces are primitive objects, operations, services provided by one layer to its higher layers
- Task of communication broken up into modules
- For example file transfer could use three modules
  - File transfer application
  - Communication service module
  - Network access module

Protocol Architecture

- File transfer application
  - Transmitting passwords, file commands, file records
  - Perform format translation if necessary
- Communication service module
  - Assure that the two computers are active and ready for data transfer
  - Keep track of data being exchanged to assure delivery
- Network access module
  - Interface and interact with the network

Simplified File Transfer Architecture



A Three Layer Model

- Communications involve three agents: applications, computers, and networks
- File transfer operation:
  - Application=>Computer=>Network=> Computer=>Application
- Communication tasks organized into three layers
  - Network access layer
  - Transport layer
  - Application layer

Network Access Layer

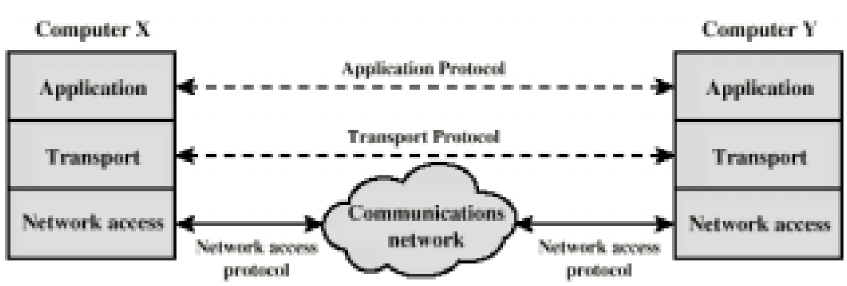
- Exchange of data between the computer and the network
- Sending computer provides address of destination
- May invoke levels of service such as priority
- Dependent on type of network used (LAN, packet switched, circuit switching, etc.)
- Communication software above network access layer need not know type of network

Transport Layer

- Data must be exchanged reliably and in same order as sent
- Contains mechanisms for reliable data transportation
- Independent of network being used
- Independent of application
- Provides services useful to variety of applications
- Sharing of communication resources

Application Layer

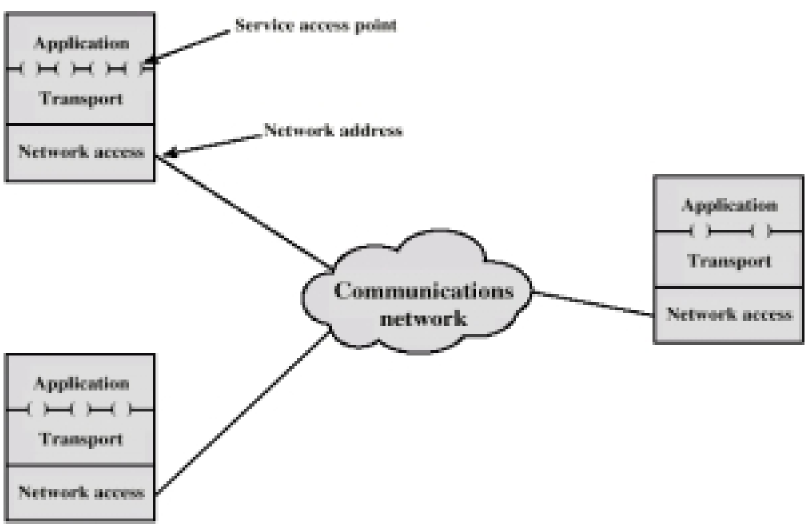
- Contains logic needed to support various user applications
  - e.g. e-mail, file transfer
- Separate module for each application



Addressing Requirements

- Every entity in overall system must have a unique address
- Two levels of addressing required
- Each computer needs unique network address
- Each application on a (multi-tasking) computer needs a unique address within the computer
  - The service access point or SAP

Protocol Architectures and Networks



Protocol Data Units (PDU)

- At each layer, protocols are used to communicate
- Control information is added to user data at each layer
- Transport layer may fragment user data
- Each fragment, called a transport protocol data unit, has a transport header added
  - Destination SAP
  - Sequence number
  - Error detection code
- Network PDU adds network header
  - network address for destination computer
  - Facilities requests like priority level

Protocol Data Units (PDU)

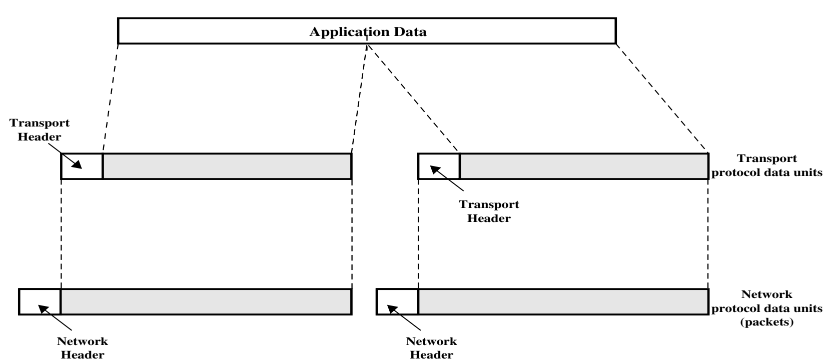
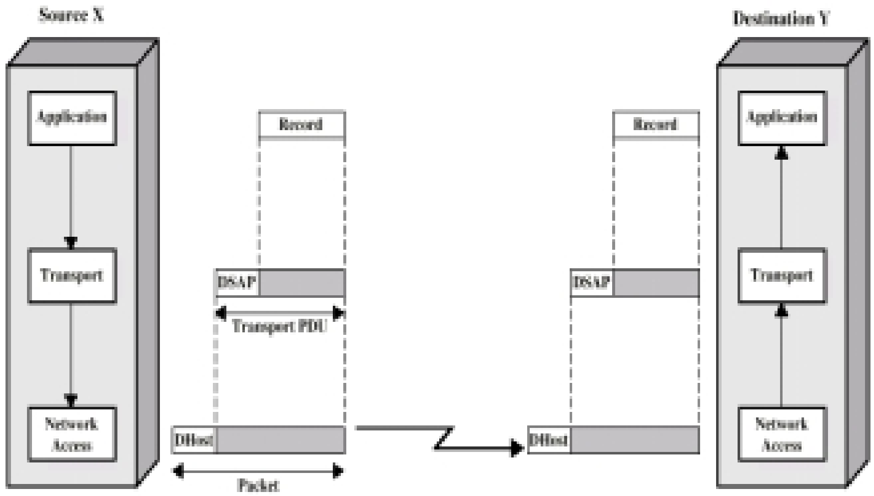


Figure 1.7 Protocol Data Units

Operation of a Protocol Architecture



Protocol Architectures

- Two protocol architectures as the basis for development of interoperable communications standards
  - TCP/IP protocol suite
  - OSI reference model
- TCP (Transmission Control Protocol)/IP (Internet Protocol) is the most widely used interoperable architecture
- OSI (Open Systems Interconnection) model is the standard model for classifying communications functions

TCP/IP Protocol Architecture

- Developed by the US Defense Advanced Research Project Agency (DARPA) for its packet switched network (ARPANET)
- Used by the global Internet
- No official model but a working one
  - Application layer
  - Host to host or transport layer
  - Internet layer
  - Network access layer
  - Physical layer

Physical Layer

- Physical interface between data transmission device (e.g. computer) and transmission medium or network
- Characteristics of transmission medium
- Nature of signals
- Data rates

Network Access Layer

- ⌘Exchange of data between end system and network
- ⌘Destination address provision
- ⌘Invoking services like priority
- ⌘Different standards are used for circuit switching, packet switching (X.25), LANs (Ethernet)
- ⌘Mainly concerned with access and routing data between two computers in same network

Internet Layer (IP)

- ⌘Systems may be attached to different networks
- ⌘Routing functions across multiple networks
- ⌘Implemented in end systems and routers
- ⌘Routers connect two networks and relay data from one network to the other

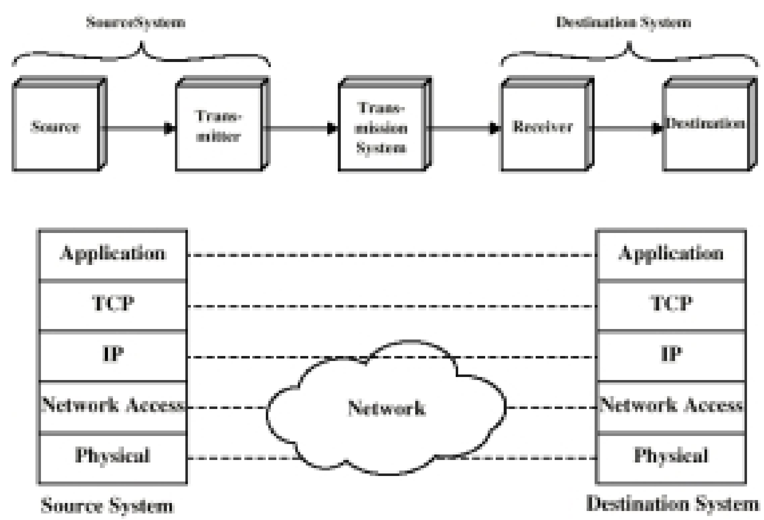
Transport Layer (TCP)

- Reliable delivery of data
- Ordering of delivery
- Most common protocol is the transmission control protocol (TCP)

Application Layer

- Contains logic to support various user applications
- Separate module for each application
  - e.g. http, ftp, telnet

TCP/IP Protocol Architecture Model



OSI Model

- Open Systems Interconnection
- Developed by the International Organization for Standardization (ISO)
- A model for computer communications architecture
- Framework for developing protocol standards
- Seven layers
- TCP/IP is the de facto standard

OSI Layers

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

OSI La

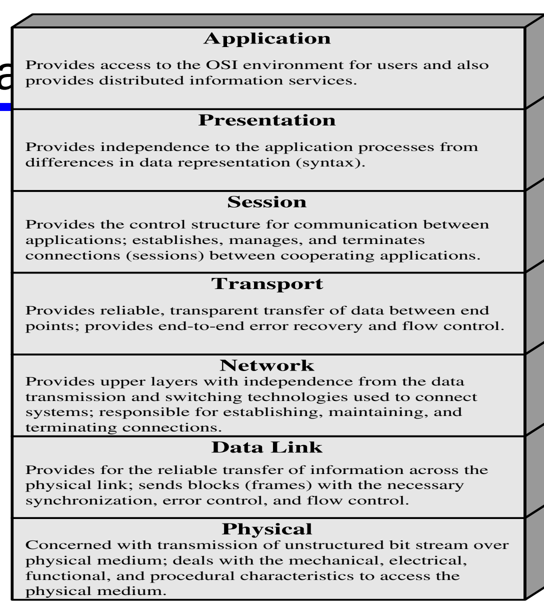


Figure 1.10 The OSI Layers

OSI Layers

- Physical layer:
  - Transmits unstructured bit stream over transmission medium
  - Mechanical, electrical, functional, and procedural characteristics to access medium
- Data link layer:
  - Reliable transfer of information across physical layer
  - Sends blocks/frames with synchronization, error control, and flow control

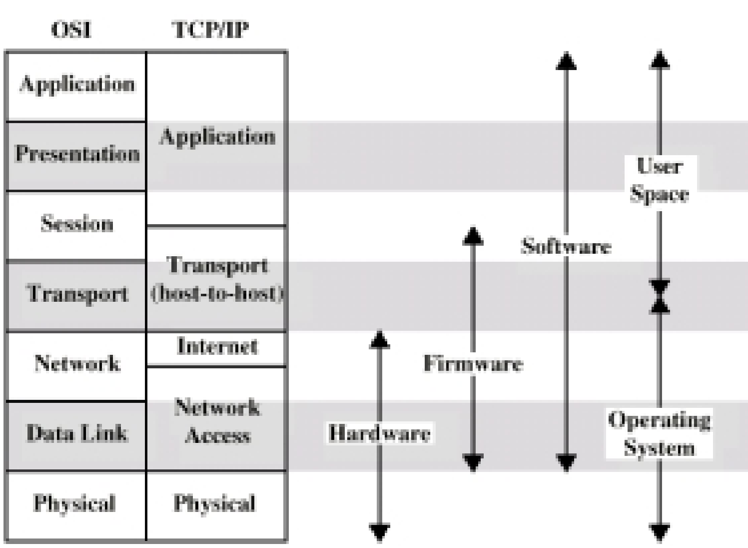
OSI Layers

- Network layer:
  - Separates data transmission and switching technologies from upper levels
  - Establishes, maintains, and terminates connections
- Transport layer:
  - Reliable and transparent transfer of data between end points
  - End-to-end error recovery and flow control

OSI Layers

- ⌘Session layer:
  - Control structure for communication between applications
  - Establishes, maintains, and terminates sessions between cooperating applications
- ⌘Presentation layer:
  - Makes applications independent from differences in data presentation
- ⌘Application layer:
  - Access to the OSI environment
  - Distributed information services

OSI vs. TCP/IP



Standards

- Required to allow for interoperability between equipment
- Govern physical, electrical, and procedural characteristics of communication equipment
- Advantages
  - Ensures a large market for equipment and software
  - Allows products from different vendors to communicate
- Disadvantages
  - Freeze technology
  - May be multiple standards for the same thing

Standards Organizations

- Internet Society
- ISO (International Organization for Standardization)
- ITU-T (International Telecommunication Union)
  - formally CCITT (International Telegraph and Telephone Consultative Committee)
- ATM forum