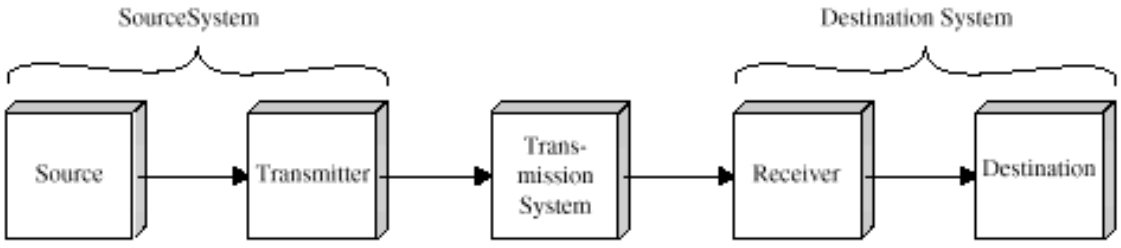
- Communication: transfer of information between entities
- Information: data plus meaning
- Role of Computers in Communication
  - As users - main sources and sinks for info and data
  - As providers - used to implement switching nodes, controllers, concentrators, protocol translators, etc
- Three General Types of Computer Communication
  - Computer-to-computer - including intra-computer communication
  - Human-to-computer - user interface protocols, etc
  - Computer-aided human-to-human - electronic mail, bboard, publishing, etc

Simplified Communications Model



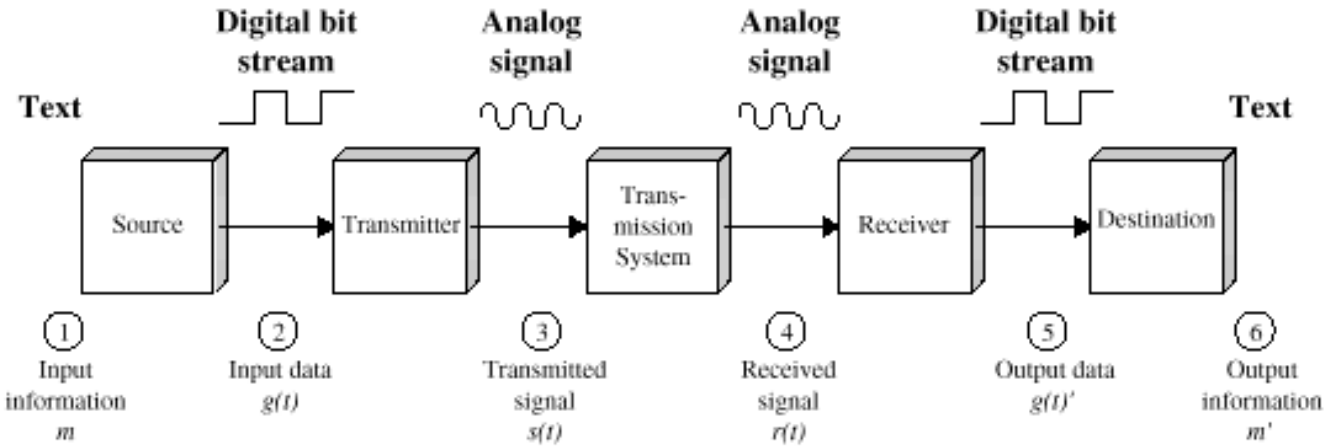
(a) General block diagram

(b) Example

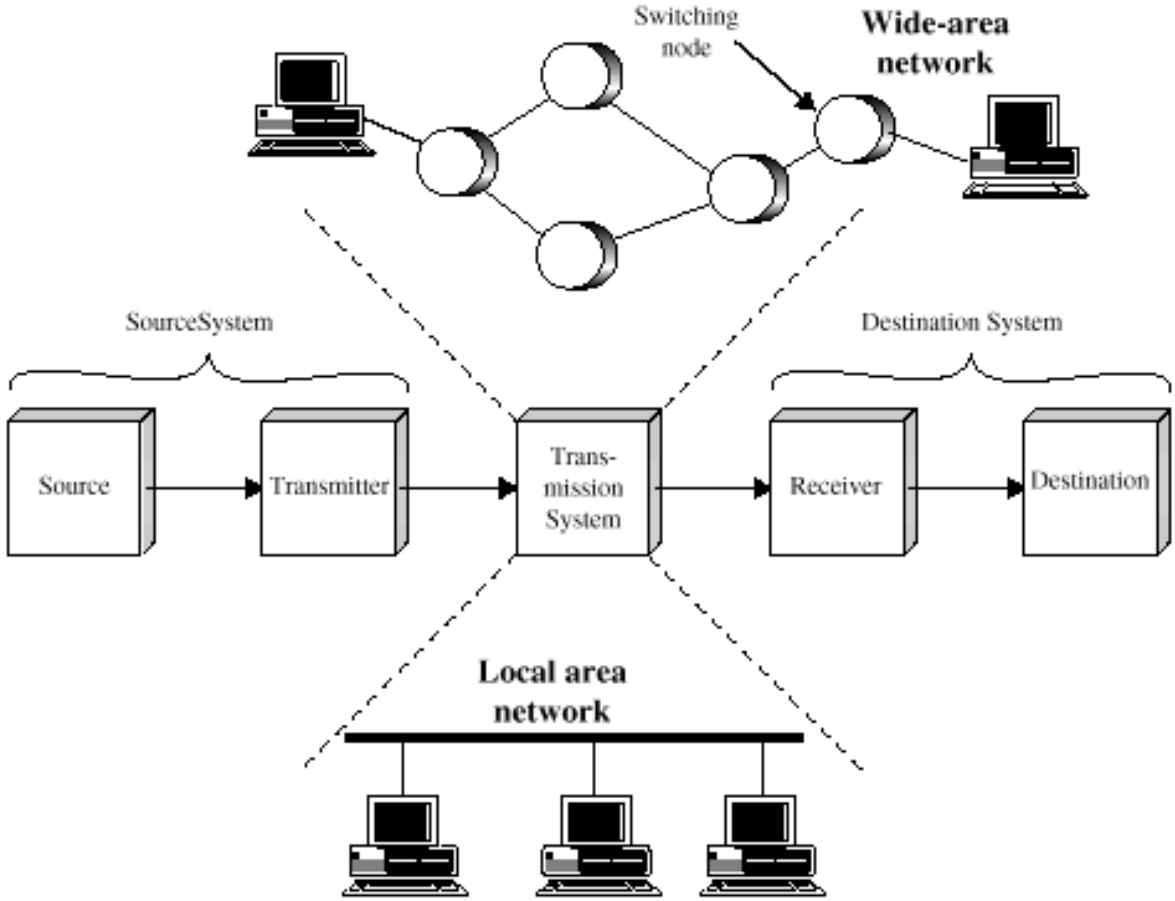
Communication Tasks

- Transmission system utilization
- Interfacing
- Signal generation
- Synchronization
- Exchange management
- Error detection/correction
- Flow control
- Addressing
- Routing
- Recovery
- Message formatting
- Security
- Network management

Simplified Data Communications Model



Simplified Network Model



Computer Network:

An interconnected collection of computers which are:

- Cooperative
  - Cooperative action is required between components
  - No master-slave relationships
- Autonomous
  - All components are capable of independent action
  - Any resource is capable of refusing requests
- Mutually Suspicious
  - Components verify requests

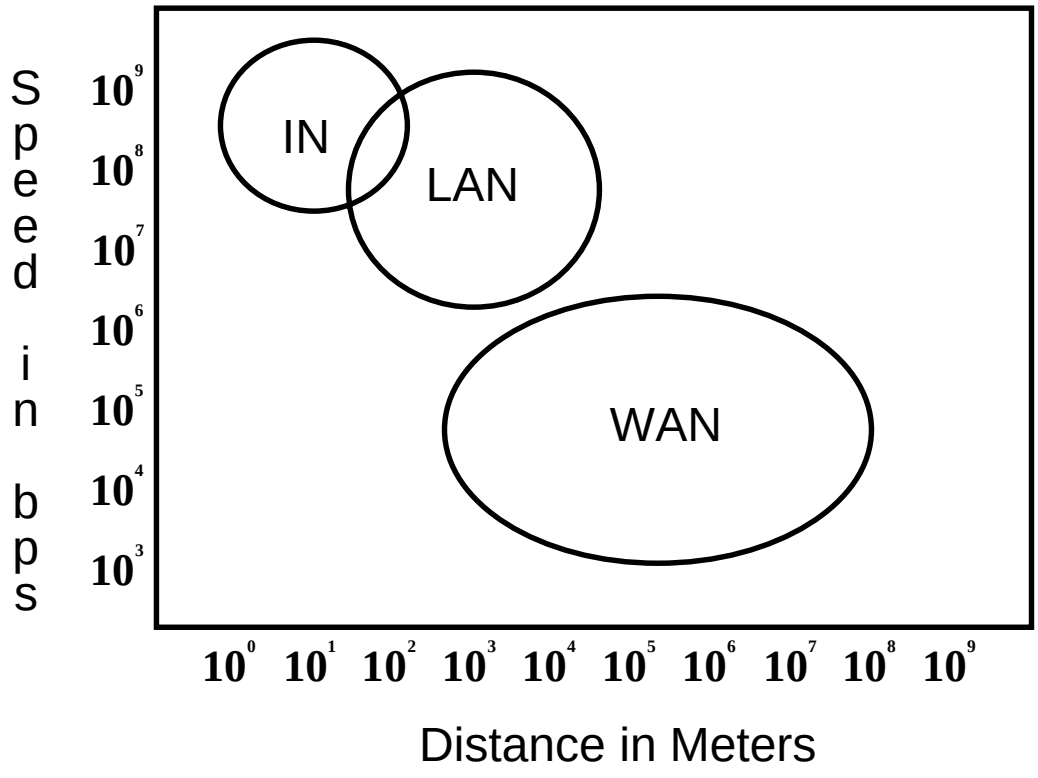
Background of Computer Network Evolutions

Two technological advances in computer and communication fields:

- Hardware and software technologies of computer
- Digital transmission
- Fiber optics
- Digital signal processing
- VLSI technologies, etc

- Network Goals
  - Resource (and Load) Sharing
  - Reduced Cost
  - High Reliability
- Applications of Computer Networks
  - Reservation systems
  - Electronic mail systems
  - Remote teller banking systems
  - Credit verification systems
  - Access to remote data systems
- Trends in Computer Networks
  - Higher speed network > 100 Mbps
  - Wider geographic coverage
  - Integrated services: text, graphics, voice, audio, image, video,...

Distance-Speed in Networks



IN: Interconnection Network

LAN: Local Area Network
WAN: Wide Area Network

Distributed Processing

A Distributed processing system is one in which the computing functions are dispersed physically among several computing stations (nodes). It has to satisfy the following five characteristics.

- A multiplicity of general-purpose resources (both physical and logical) that can be assigned to specific tasks on a dynamic basis.
- Physical distribution of these resources, interacting through a communication network.
- A high-level operating system to unify and integrate the control of the distributed resources.
- System transparency, permitting services to be requested by name only (not by location).
- Cooperative autonomy

Protocols and Network Architecture

- Protocols: A set of rules governing the exchange of data between two or more (peer) entities. The key elements of a protocol are syntax, semantics(procedures), and timing
  - Syntax - format, size, and contents of protocol messages or packets
  - Procedures - semantics of messages, actions to take in response to reception of different messages
  - Timing - speed matching etc., when to discard a message, retransmit, give up, etc.

Protocols can quickly become very complicated (and thus incorrect)

Solution: Modularity - implement functionality with several protocols with “clean” interfaces between implementations of the different 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 for layer N + 1.

Interfaces - primitive objects, operations, and services provided by one layer to its higher layers.

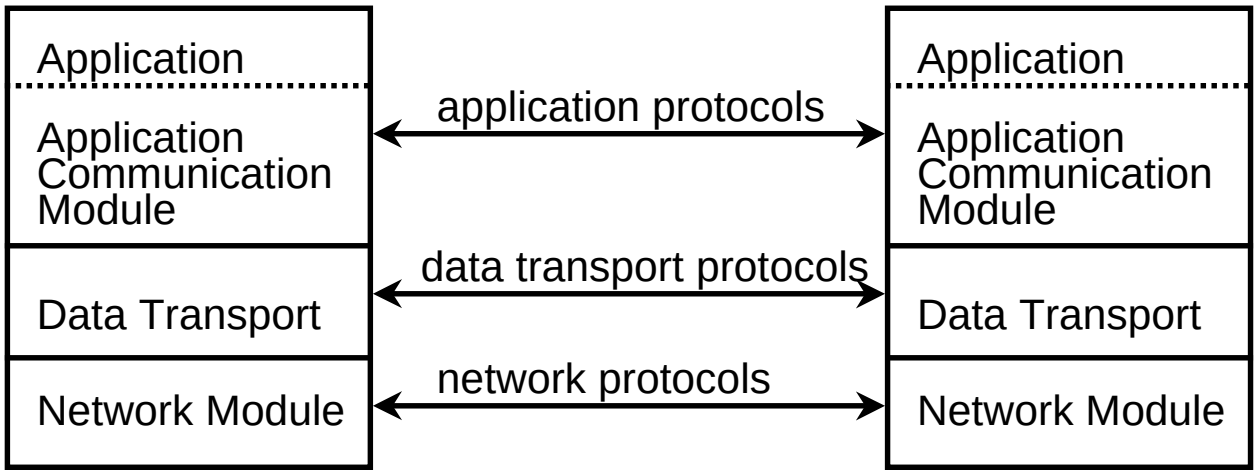
Network Architecture

The layers, sublayers, interfaces, and protocols that make up a coherent network design

Layered Architecture

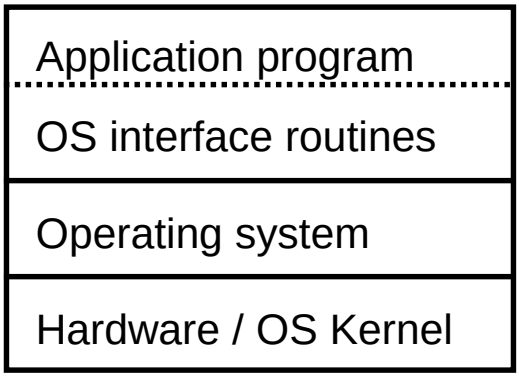
Protocols divided into two or more layers s.t. protocols at layer N are implemented entirely in terms of the interfaces provided by layer N - 1 and are only used by the interfaces they provide to layer N + 1.

Three Basic Layers/Levels

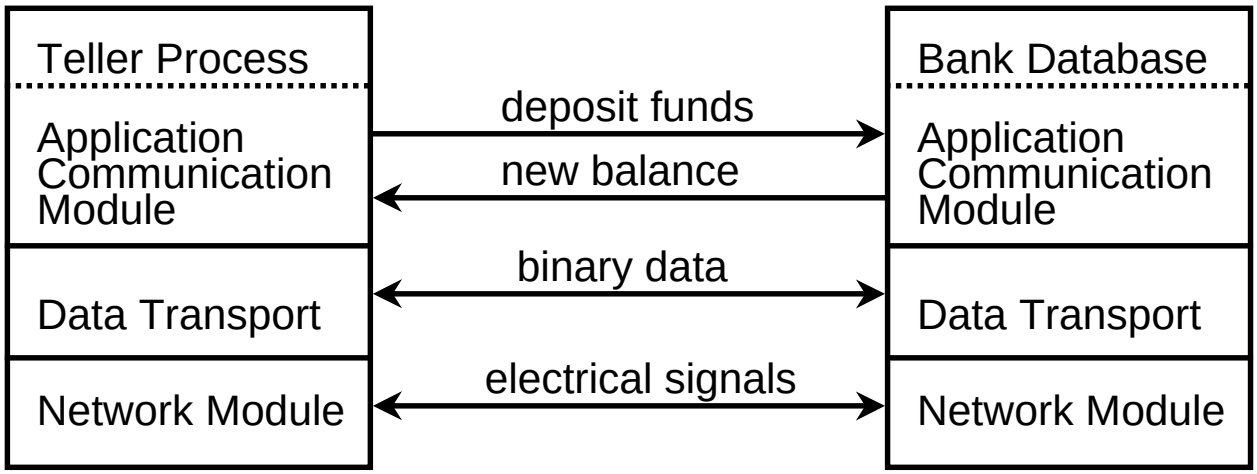


ACM	application communication services and protocols implemented in terms of the transport of binary data, as provided by the DTM
DTM	end-to-end (process) transport of binary data, including addressing and flow control - implemented in terms of facilities provided by the NM
NM	Basic data delivery service, implemented in hardware and low-level software. Analogous to service of postal and telephone system

Analogy: Operating System Layers



Example: Banking Transaction System



Application communication module encodes transaction in bits, which are reliably transmitted by data transport layer, which uses network layer to do that actual transportation

Why these levels?

- Application
  - Dependent on application specific semantics and data representation
- Transport
  - Application-independent services, I.e., end-to-end transport, thus separated from, and shared by all applications
- Network
  - Implemented differently (hardware) or provided by separate organization

Data Transport Layer

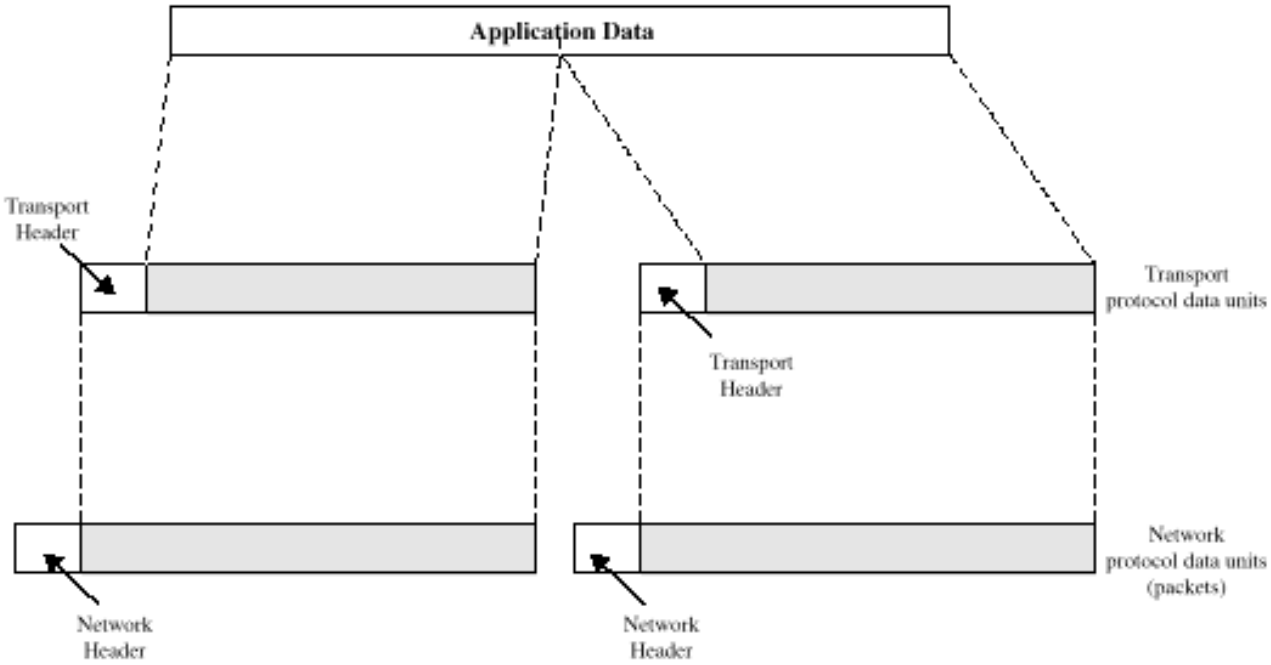
The data transport layer tries to provide a communication facility that is generally useful and cost-effective for most applications, analogous to OSs. Like OS, the data transport provides

- Services that are useful to variety of applications, eliminating the need for each application to develop it separately
- Sharing a communication resources, e.g., network interfaces and memory (for buffers and communication code), thereby reducing the cost to the system and applications and improving the utilization of these resources

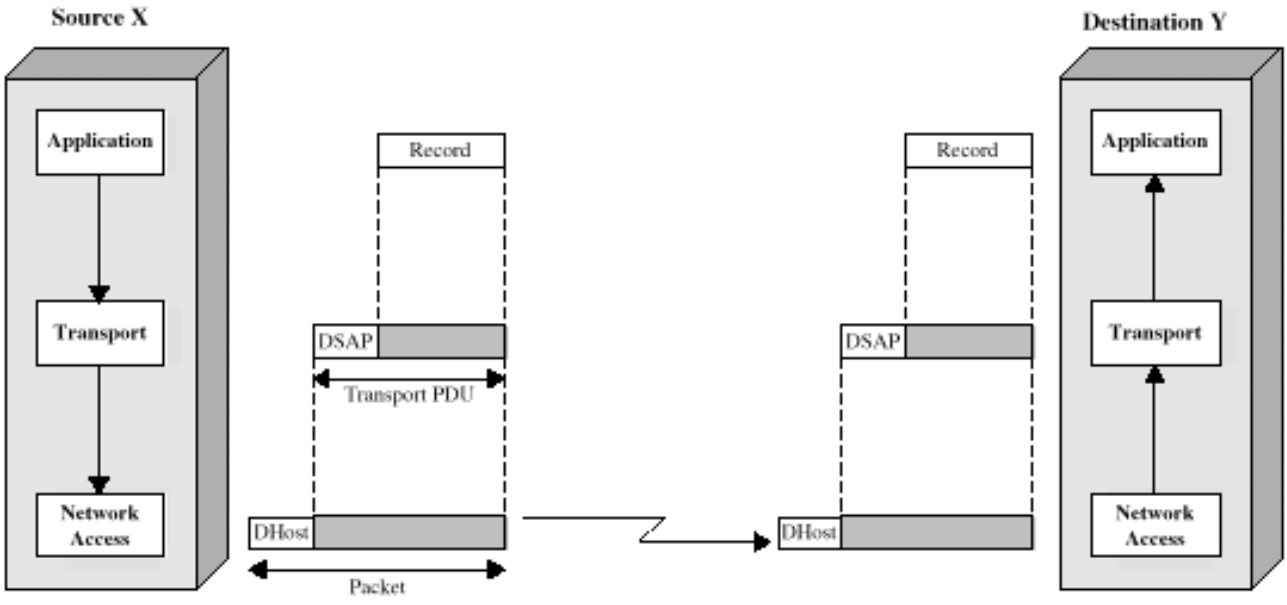
Networks and Internetworks Layer

The network interface provides *a logically fully connected network* to the data transport layer

Protocol Data Units



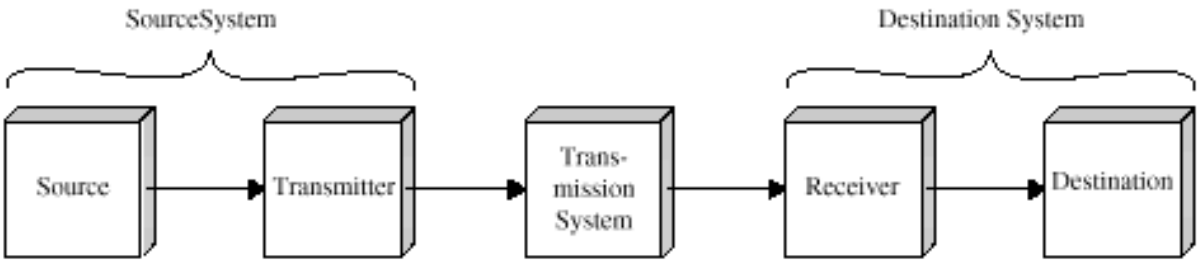
Operation of a protocol architecture

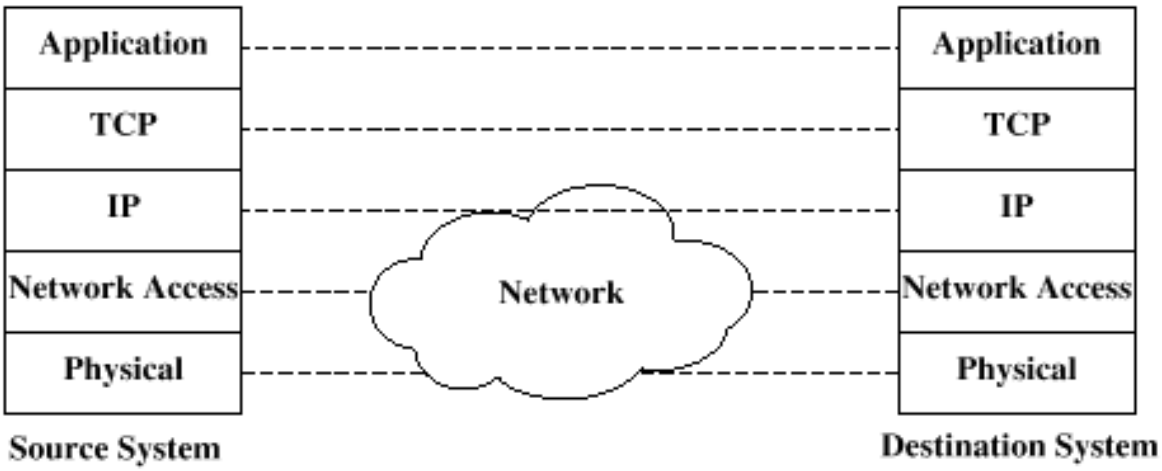


TCP/IP Protocol Architecture

- used in the grandparent of all computer networks, the ARPANET, and its successor, the Internet

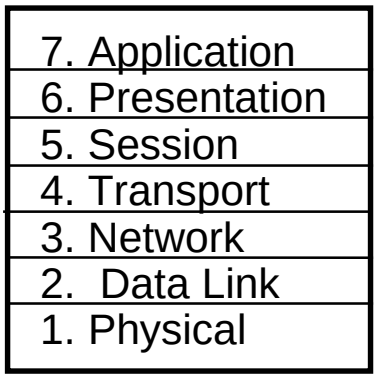
- Application layer (TELNET, FTP, SMTP, ...)
- Host-to-host, or transport layer (TCP, UDP)
- Internet layer (IP)
- Network access layer
- Physical layer





ISO OSI Model

- Seven layers



Presentation

Provides independence to the application processes from differences in data representation (syntax)

Session

Establishes, manages, and terminates connections (sessions) between application processes

Transport

Provides reliable, transparent transfer of data between end points; provides end-to-end (host-to-host) error recovery and flow control

Network

Provides upper layers with independence from the data transmission and switching technologies used (routing, congestion control)

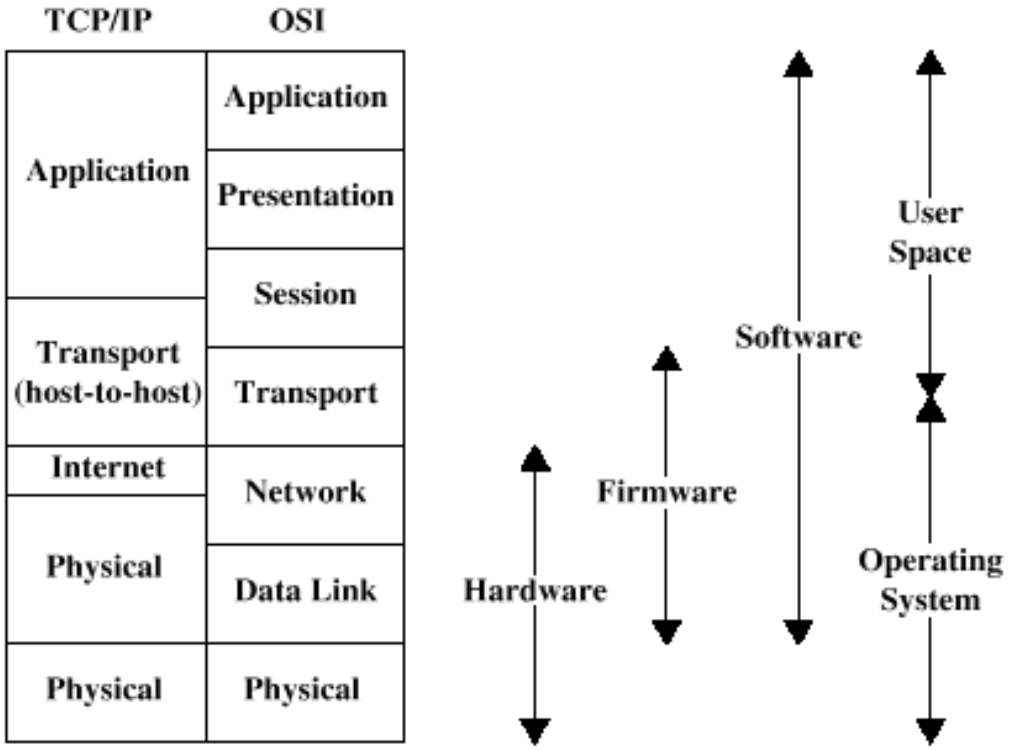
Data Link

Provides for the reliable transfer of information across the physical link; sends blocks of data (frames) with necessary synchronization, error control, and flow control

Physical

Concerned with transmission of unstructured bit stream over physical medium; deals with the mechanical, electrical, functional, and procedural characteristics to access the physical medium (voltages, pin assignments, bit times, ..)

Correspondence between two Protocol Architectures



Problems with Layering

- Inefficiency - each layer introduces overhead
- Restrictive - layer N may need access to lower layers than N - 1
- Redundancy - of functions such as flow control error handling, addressing, packetizing, and encapsulation between layers