CPSC 471: Computer Communications

Introduction to Networks and Network Architecture

Figures from Computer Networks: A Systems Approach, version 6.02dev (Larry L. Peterson and Bruce S. Davie)

Applications

- Know the Internet through use of applications
  - World Wide Web (WWW)
  - Email
  - Streaming Video/Audio
    - Examples?
  - Real-time Audio/Video
    - Examples?

WWW Application Example

- URL (Uniform resource locater)
  - https://www.fullerton.edu/ecs/cs/degree/undergrad.php
    - Use HTTP (Hyper Text Transfer Protocol)
    - Name of the machine: www.fullerton.edu
    - Location of webpage: /ecs/cs/degree/undergrad.php
- 17 messages for one URL request
  - 6 to find the IP (Internet Protocol) address
  - 3 for connection establishment of TCP (Transmission Control Protocol)
  - 4 for HTTP request/reply and acknowledgements
  - 4 messages for tearing down TCP connection

Requirements

- Different requirements for different users
  - Application Programmer
    - Requires certain network services and bandwidth and delays
  - Network Operator
    - Requires network system characteristics that are easy to administer/manage
  - Network Designer
    - Requires cost-effective design for supported users

Nodes and Links

- Computers are “nodes”
- Physical medium that connects computers are “links”
  - May be point-to-point or multiple-access

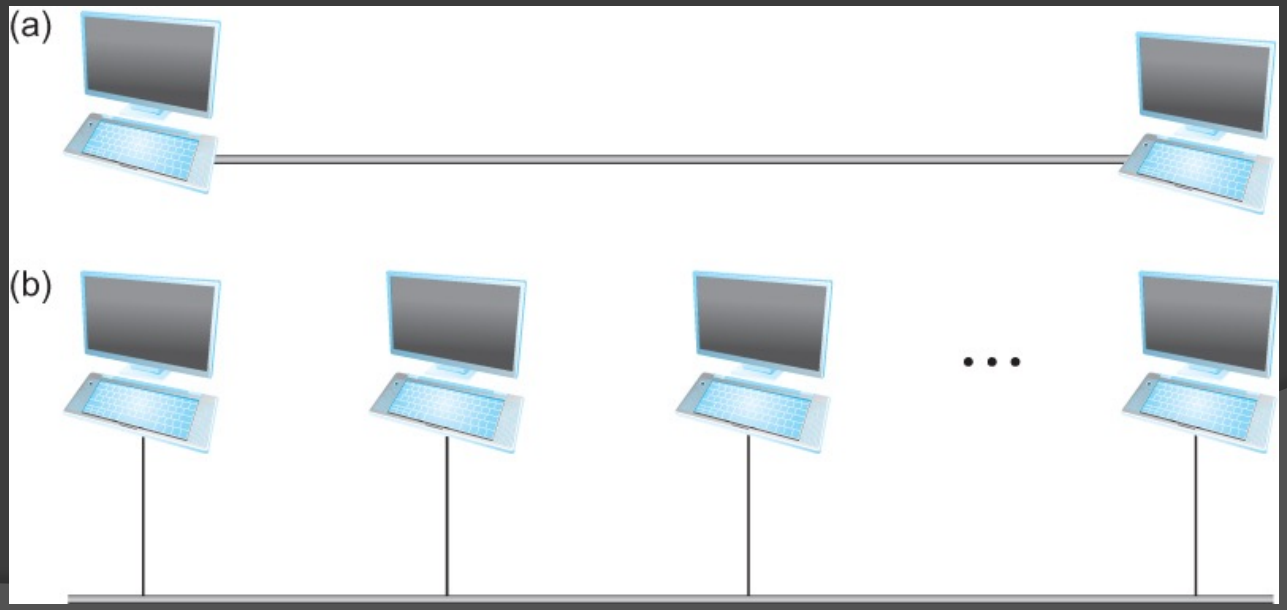

Figure 2

Switched Networks

- Circuit Switched
  - Telephone Network, Optical Networking
- Packet Switched
  - Majority of computer networks
  - Send blocks of data (packets)
  - Uses Switches
    - Store-and-forward

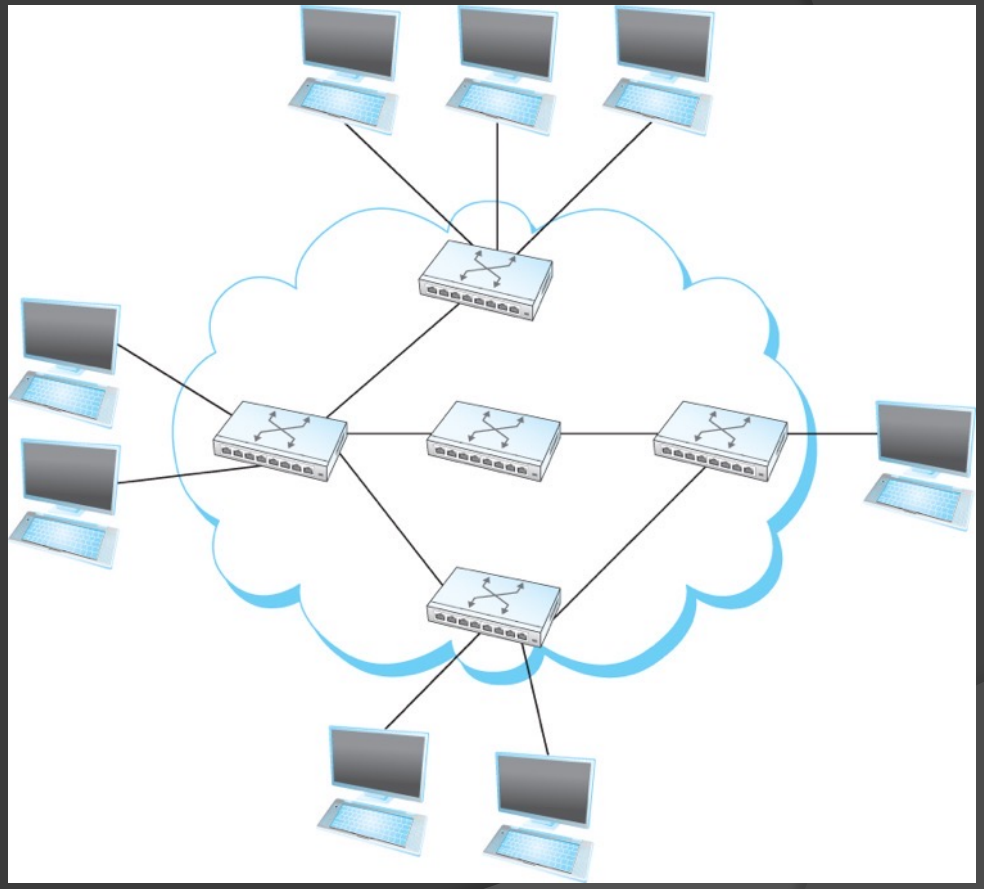

Figure 3

internetwork or internet

- Independent networks are connected by a node
  - A router or gateway

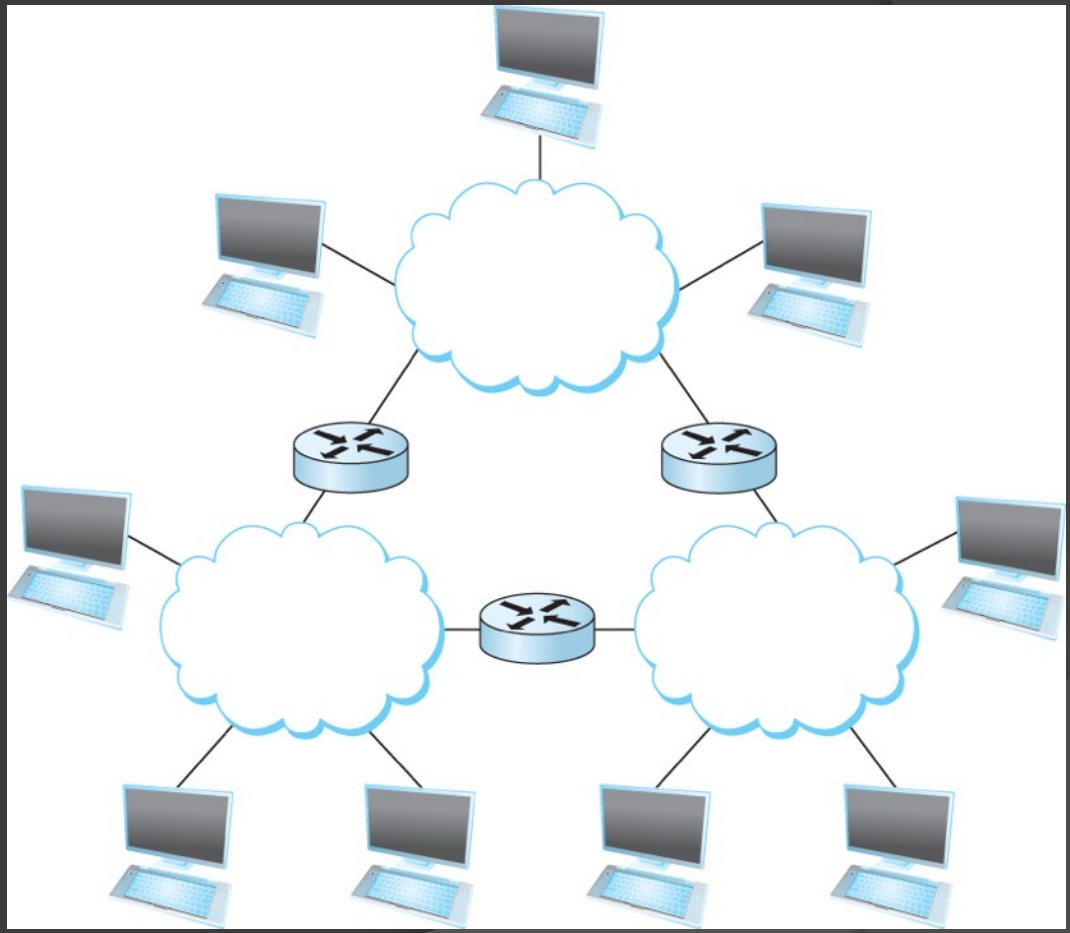

Figure 4

Network Types

- PAN: Personal Area Network
- LAN: Local Area Network
- MAN: Metropolitan Area Network
- WAN: Wide Area Network
- The Internet

- SAN: Storage Area Network
  - High performance storage servers and data vaults

Addressing

- Each node needs an identifier
- Unicast: Source sends to one destination
- Broadcast: Source sends to all nodes
- Multicast: Source sends to some, but not all nodes

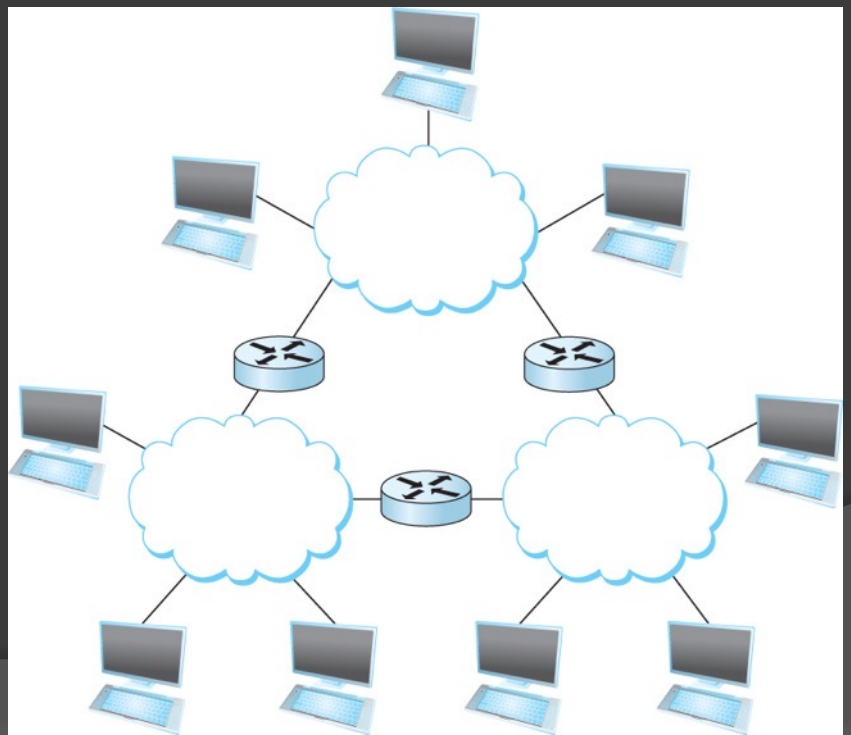

Figure 4

How to share a link?

- Multiplexing (multiplex and demultiplex)

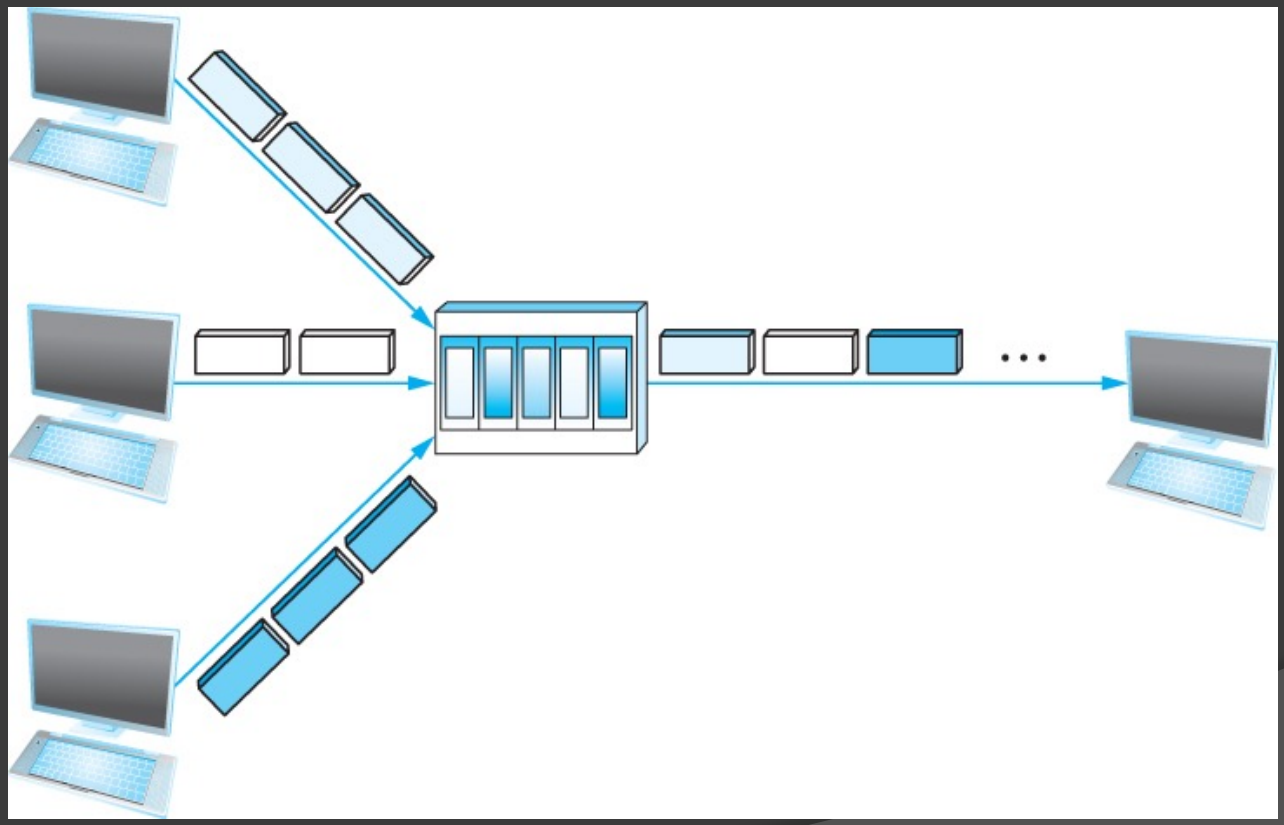

Figure 6

Multiplexing

- Synchronous Time-Division Multiplexing (STDM)
  - Round-robin division of time for each flow
- Frequency-Division Multiplexing
  - Transmit each flow using a different frequency
    - E.g., coaxial cable
- Drawbacks
  - What if a flow has nothing to send?
  - Fixed number of flows

Statistical Multiplexing

- Like STDM, link is shared over time
- Unlike STDM, data is transmitted from each flow based on demand
- Packet
  - Limited-size block of data
  - Source may need to split message/data into multiple packets

Switch Design

- Use a first-in, first-out (FIFO) queue
- Use round-robin
  - Allocate bandwidth (give more time) for flows which need particular Quality of Service (QoS)
- If switch is overloaded, it will drop (discard) packets

Logical Channels

- Provided to applications for common services
- Questions
  - Ok if some messages fail to arrive?
  - Must messages arrive in same order?
  - Privacy?

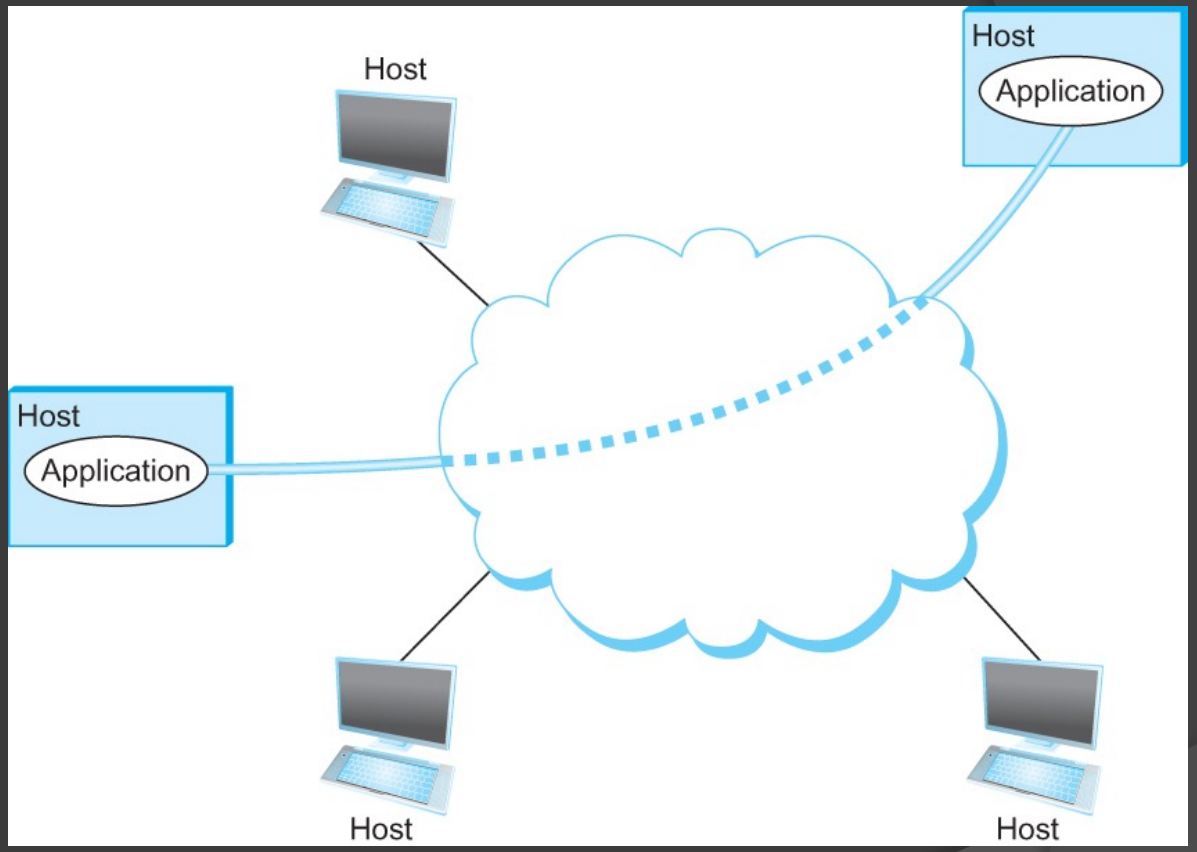

Figure 7

Clients and Servers

- Example (early network) applications
  - File Transfer Protocol (FTP)
  - Network File System (NFS)
- Client requests file access
- Server supports access to file
- Reading File
  - Client: request (small), Server: file data (large)
- Writing File
  - Client: file data (large), Server: confirmation (small)

Channel Types

- Request/receive channels (e.g., file transfer)
  - Guarantee message delivery
  - Only one copy delivered
  - Privacy
- Message stream channels (e.g., videoconferencing)
  - Guarantee messages arrive in order sent
  - Support multicast
  - Privacy

New Channel Types

- Invent new types of channels for new applications
  - For a good fit for application requirements
- Where to put complexity of channel design?
  - At ends of channel?
  - On the switches?

Reliability/Classes of Failures

- Nodes/links may not always be functioning correctly, why?
- Bit errors: e.g., “1” turned into a “0”, why?
  - Often burst errors occur (several consecutive bits corrupted)
  - 1 of 10^6 to 10^7 bits on copper-based cable
  - 1 of 10^{12} to 10^{14} bits for optical fiber
  - Detect these errors with high probability, correct them if possible
    - Need ECC (Error Correction Code) (preferred) or EDC (Error Detection Code)

Classes of Failures

- Packet loss, why?
  - Distinguish between a lost packet and a packet that is late in arriving
- Node or Link-level failure
  - Packet-switched network can sometimes route around a failed node or link
  - Must distinguish between a failed computer and a slow computer
  - Must distinguish between a cut link and a faulty link

Network Architectures

- Guide the design and implementation of networks
  - Provide general, cost-effective, fair, and robust connectivity to many computers
  - Evolve to accommodate changes in technologies and application requirements
- Abstraction
  - Provide a model/interface for an important aspect of the system, but hide complexities
  - Leads to layering

Layered Network Architecture

- Why layer?
- Host-to-host
  - Abstracts away the complex network topology between hosts
- Process-to-process
  - Handles occasional packet loss
  - Etc.

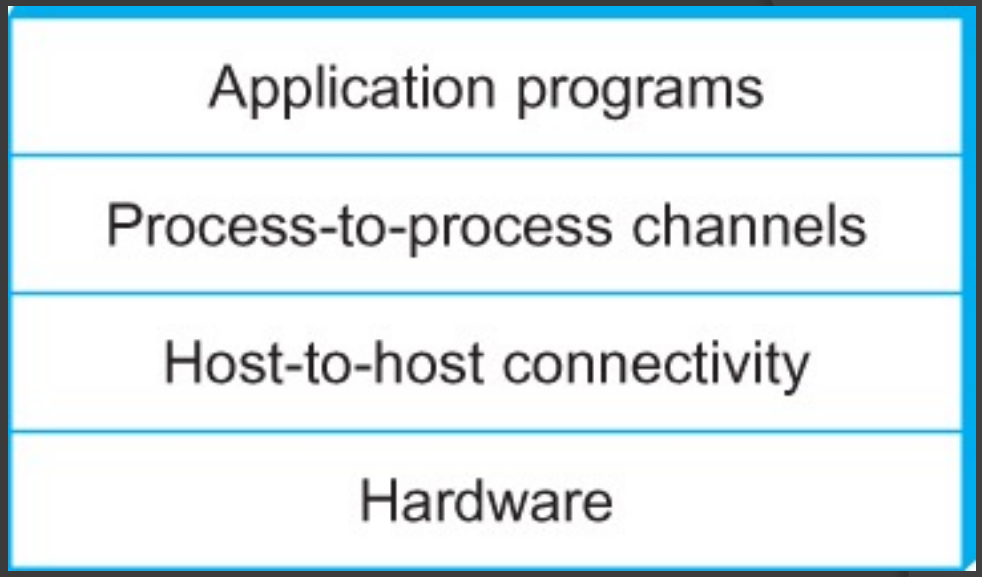

Figure 8

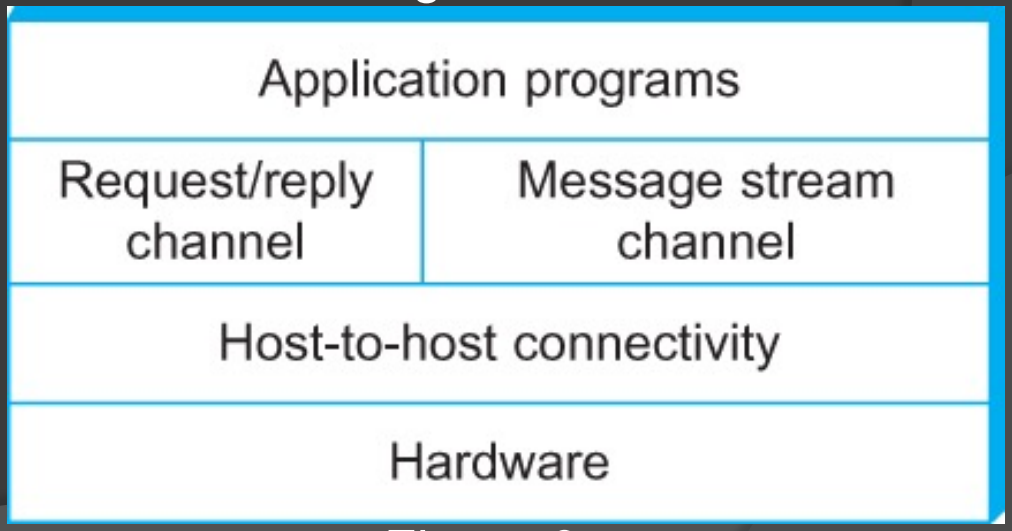

Figure 9

Protocols

- Abstract objects that make up layers of a network system
- Provides communication service that higher-level objects use to exchange messages
- Define service and peer interfaces

Protocol Interfaces

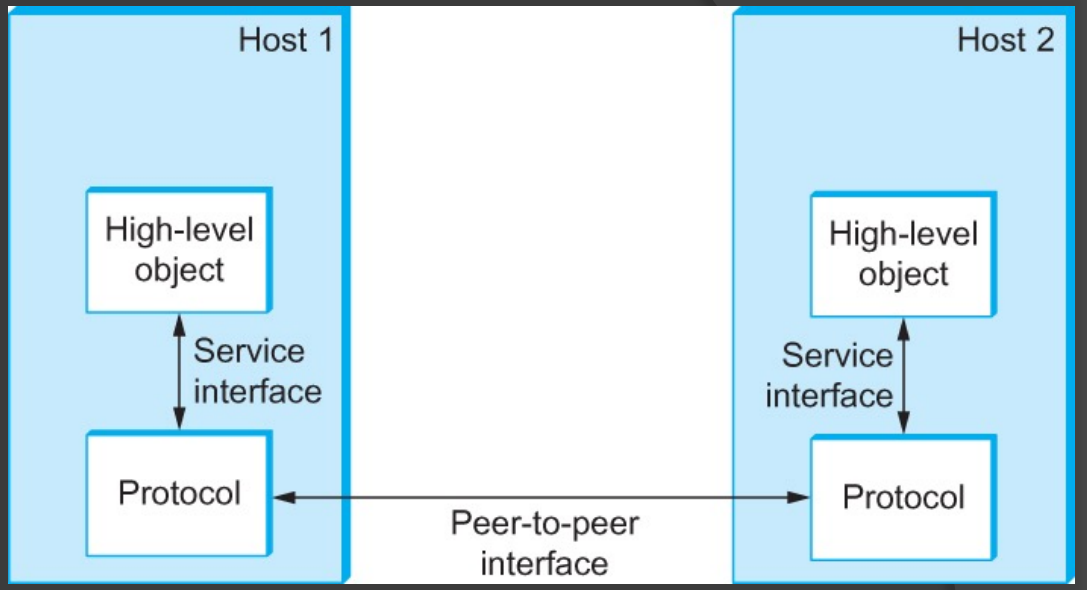

Figure 10

- Service Interface
  - For other objects on same computer that want to use its communication services
  - Local servicing
- Peer Interface
  - Defines the form and meaning of messages exchanged between protocol peers to implement the communication service

Protocol Graph and Protocol Stack

- Protocols communicate with peers by passing messages to lower-level protocols (which exchange with their peers)
  - Except at hardware level

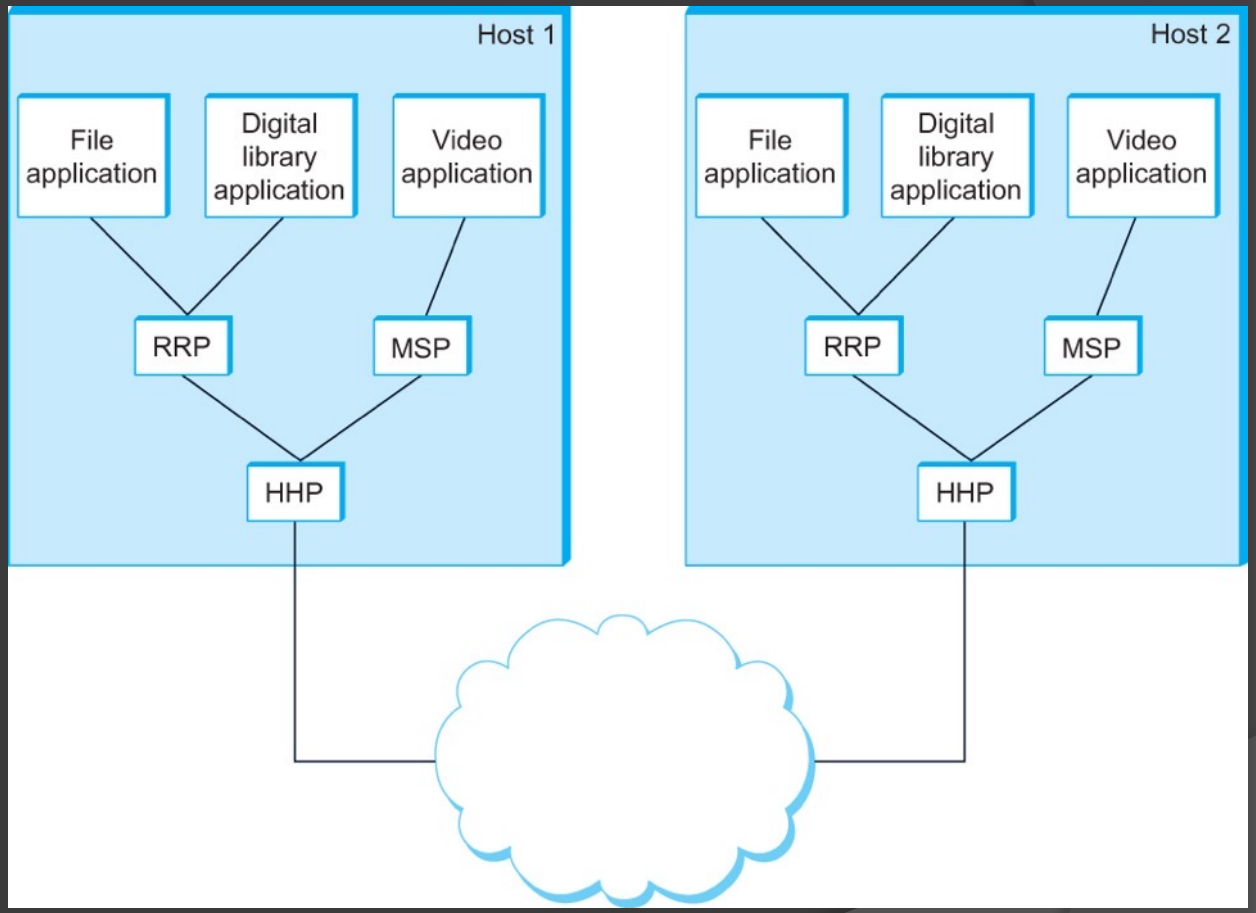

Figure 11

RRP: Request-Reply Protocol
MSP: Message Stream Protocol
HHP: Host-to-Host Protocol

Definitions/Standardization

- Protocol
  - Module that implements service and peer interfaces
- Protocol Specification
  - Operations defined by the service interface and the form/meaning of messages exchanged between peers
- Network Architecture
  - Rules that govern the form/content of a protocol graph
- Standardization
  - Internet Engineering Task Force (IETF)
  - International Standards Organization (ISO)

Encapsulation

- How to keep track of which app data came from?
- Header
  - Peer-to-peer control information attached at front of message
- Trailer
  - Like header, but attached at end of message
- Body or Payload
  - The rest of the data being transmitted on behalf of app
- Also include demultipexing information (demux key)
  - Often placed in header

Encapsulation

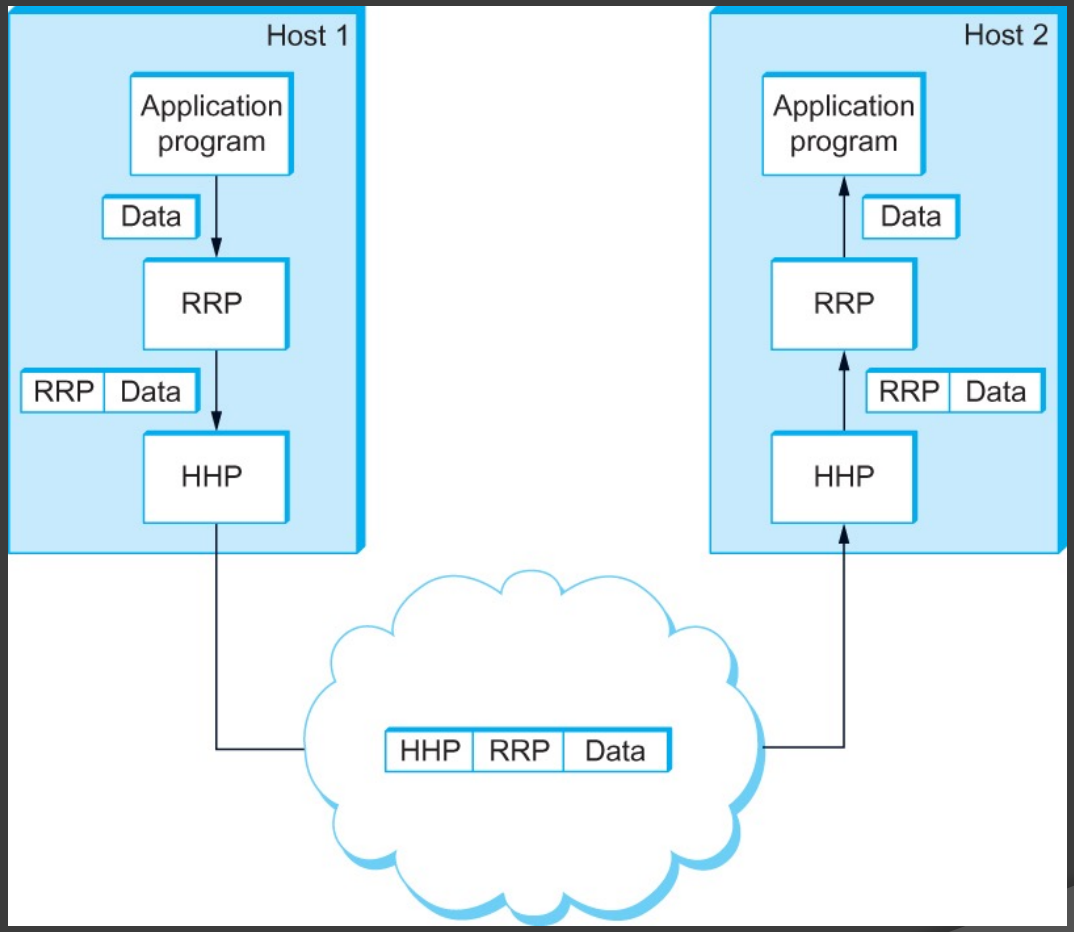

Figure 12

OSI Architecture (7-layer model)

- Open Systems Interconnection
  - Defined by the ISO
  - A reference model for a protocol graph

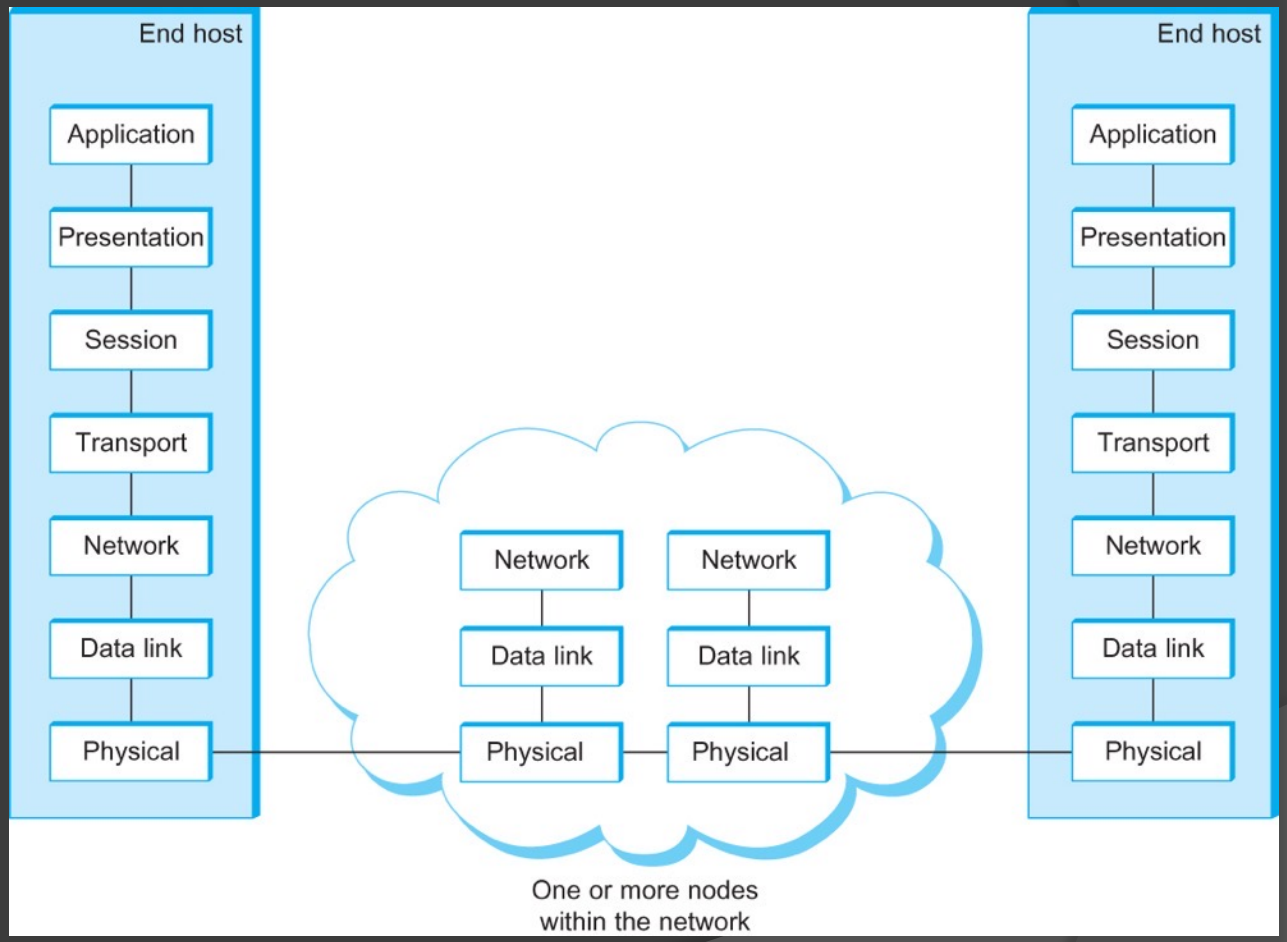

Figure 13

OSI Architecture (7-layer model)

- Physical Layer
  - Handles transmission of raw bits over a communication link
- Data Link Layer
  - Collects a stream of bits into frames
  - Network adaptors and device drivers
- Network Layer
  - Handles routing among nodes in a packet-switched network
- Transport Layer
  - Implements a process-to-process channel

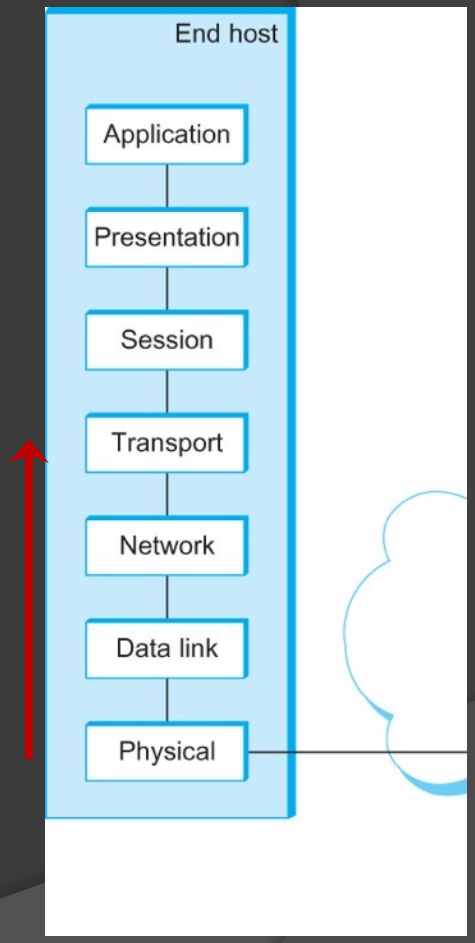

Figure 13

OSI Architecture (7-layer model)

- Session Layer
  - Ties together different transport streams that are part of the same application
    - E.g., manage audio and video streams for teleconferencing
- Presentation Layer
  - Concerned with data format between peers
    - Is integer 16, 32, or 64 bits long?
    - Is MSB transmitted first or last?
      - Similar to big endian/little endian
    - How is a video stream formatted?
- Application Layer (e.g., HTTP, etc.)

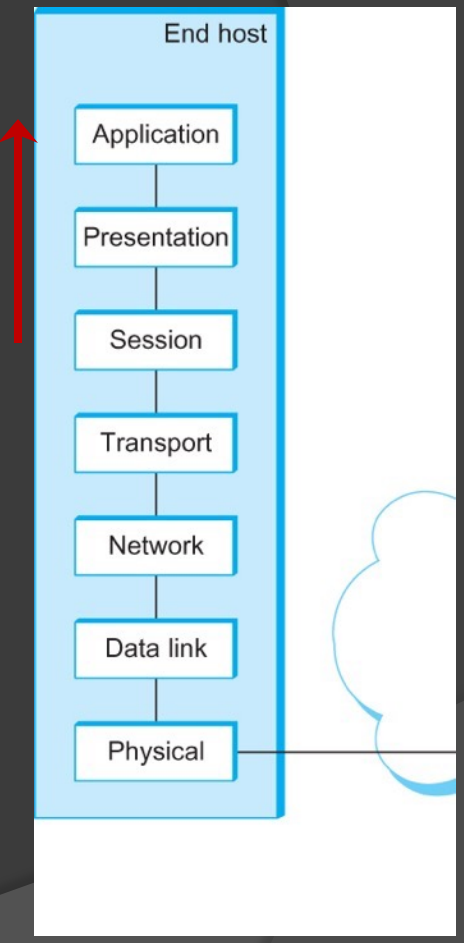

Figure 13

Internet Architecture

- Also called TCP/IP architecture
  - Transmission Control Protocol (TCP)
  - Internet Protocol (IP)
- Evolved from ARPANET

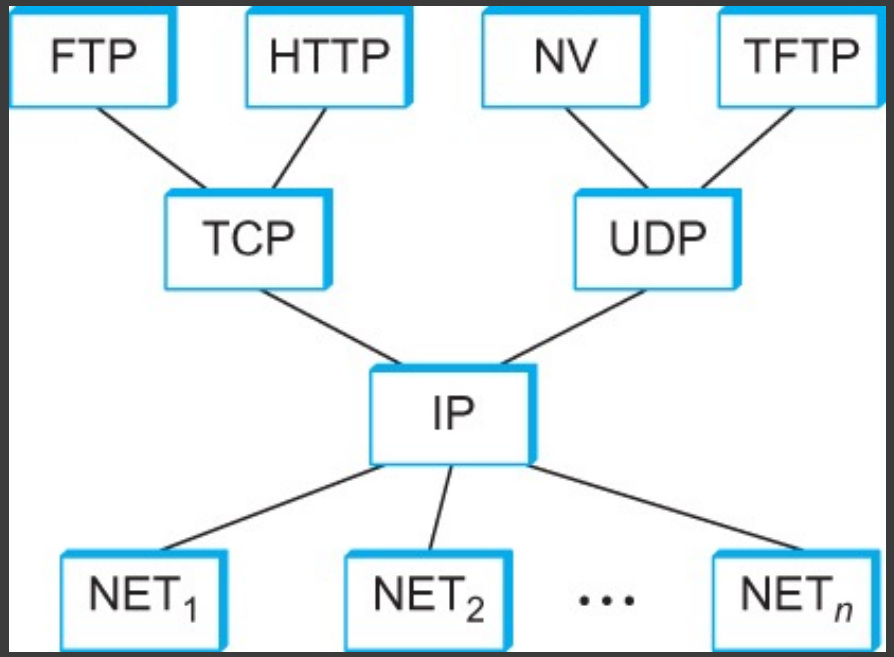

Figure 14

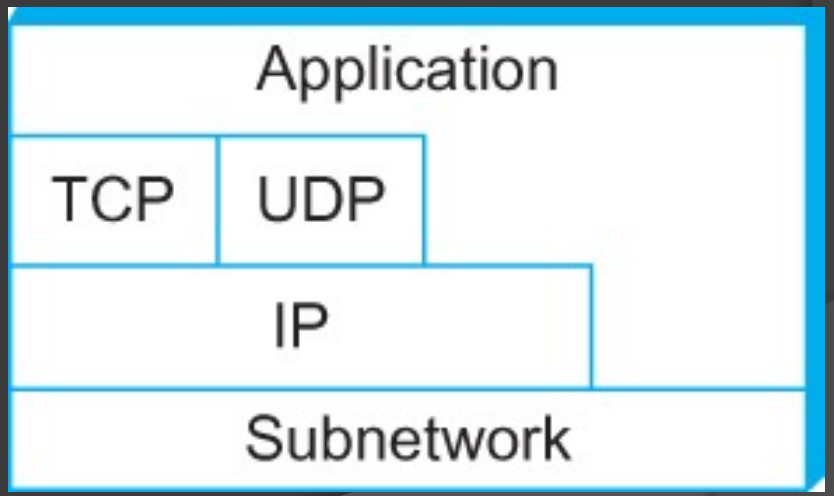

Figure 15

Subnetwork

- A variety of network protocols implemented by hardware and software
  - Hardware
    - Network adapter
  - Software
    - Network Device Driver
- Ethernet and wireless protocols at this layer

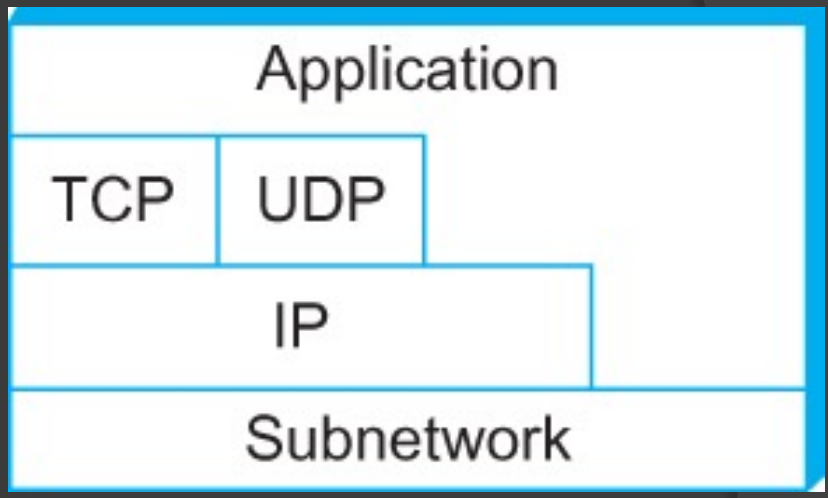

Figure 15

IP and Transport Layers

- Internet Protocol (IP) or Internetworking or Network Layer
  - Supports interconnection of multiple networking technologies into one network
- TCP/UDP or Transport Layer
  - Provide alternative logical channels to application programs
  - Transmission Control Protocol (TCP)
    - Provides a reliable byte-stream channel
  - User Datagram Protocol (UDP)
    - Provides an unreliable datagram delivery channel

Application Layer

- Contains application protocols such as:
  - HTTP
  - FTP
  - Telnet (remote login)
  - Simple Mail Transfer Protocol (SMTP)
  - Etc.
- Enables the interoperation of popular applications

OSI Model vs. Internet Architecture

OSI Model	TCP/IP or Internet Arch.
7: Application	Application
6: Presentation	--not present--
5: Session	--not present--
4: Transport	Transport
3: Network	Internet
2: Data Link	Host-to-network
1: Physical	Host-to-network

Adapted from Figure 1-21, *Computer Networks*, 4th Ed., Andrew S. Tanenbaum