
Data Communication Networks

Introduction

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Introduction

- The course introduces the underlying concepts and principles of data networks.
- It presents different components of a network and how these components fit together.
- The layers of functionalities implemented in network nodes are investigated and the underlying design concepts are discussed.
- The course is designed at a graduate level with practical assignments and short projects

General Information

- Lecturer: Mohammad Reza Pakravan
- Contact info:
 - E-mail: pakravan@sharif.edu
 - Office: Room 605
 - Office Phone: 6616-5922
- Course Schedule and Location:
 - Sunday /Tuesday, 13:30 -15:00, EE-201

Text References

- Required Textbook

- Andrew Tanenbaum. Computer Networks, Fourth Edition, Prentice Hall (ISBN 0-13-349945-6).

- Additional textbooks and References

- W. Stallings. Data and Computer Communications. Prentice Hall.
- J. Walrand. Communication Networks: First Course. Aksen Associates.
- D. Comer. Internetworking with TCP/IP, Volume I, Prentice Hall.
- W. Stevens. TCP/IP Illustrated: The Protocols, Vol 1. Addison-Wesley.
- D. Comer. Computer Networks and Internets. Prentice Hall.
- L. Peterson and B. Davie. Computer Networks: A Systems Approach. Morgan Kaufman.

- Some of the course material are presented from other sources

Course Outline

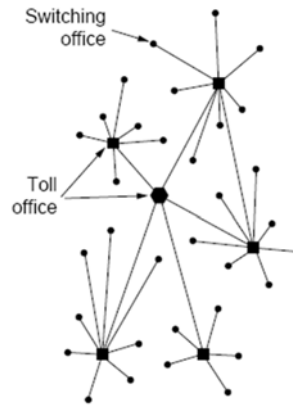
- Introduction.
- The Physical Layer.
- The Data Link Layer.
- Multiple Access Protocols.
- The Network Layer.
- The Transport Layer.
- The Application Layer.

Course load

- Course work consists of
 - ❑ Following up on presented lectures
 - ❑ Reading text book
 - ❑ Learning how to use network simulation and modeling tools
 - ❑ Preparing reports on course labs and assignments
- Grading Policy
 - ❑ Course Labs and Assignments: 30%
 - ❑ Midterm: 30%
 - ❑ Final: 40%

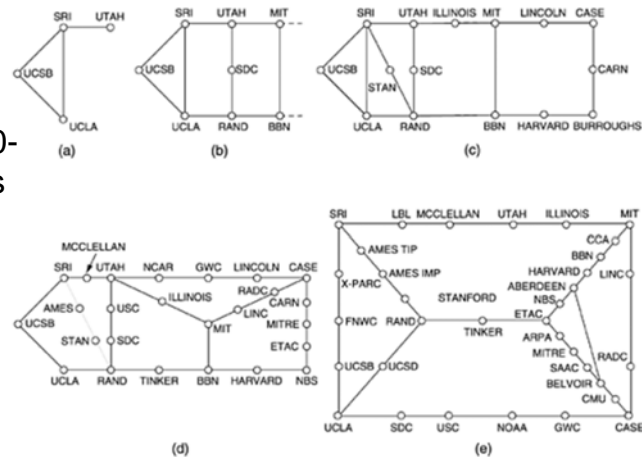
Brief History of Data Networks

- 1961-1964 Idea of store and forward distributed communication in packet networks by L. Kleinrock, D. Watts and P. Baran
 - More suitable for computer communication
 - More resilient to node failure
- Creation of ARPANET in late 1960's
 - To build a network that withstands destruction of some of its nodes
 - First Network started operation in 1969



Example Networks

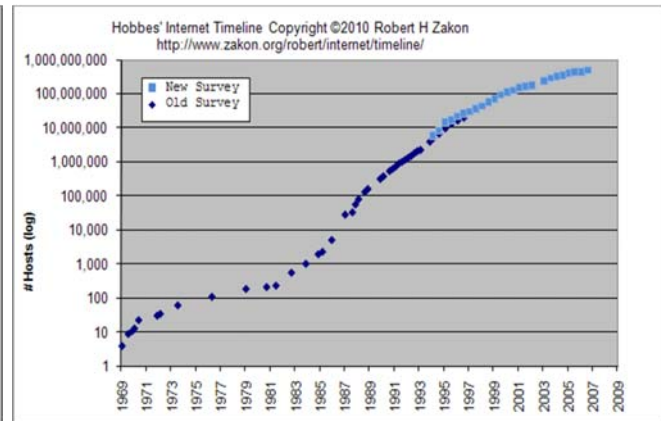
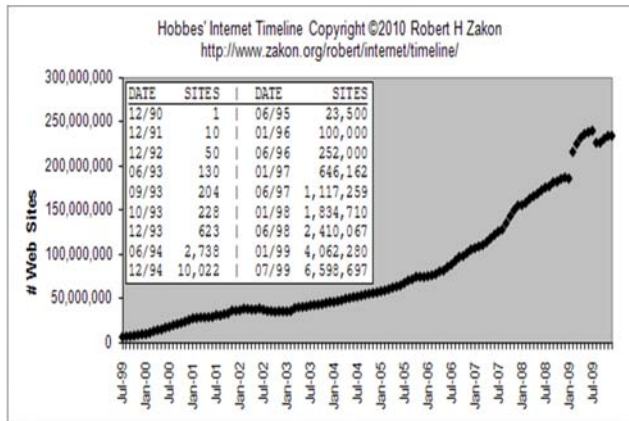
- Development of TCP/IP in 1970's (V. Cerf) and its full deployment over ARPANET in 1981-83
- Rapid expansion of ARPANET in 1970-1980's to include most key universities in USA and Europe
- NSFNET : U.S. National Science Foundation Network for Academia
 - ❑ First TCP/IP WAN early 1980s.
 - ❑ Three generations of networks were developed in a ten year time frame
 - ❑ Key factor in rapid development of US in ICT sector



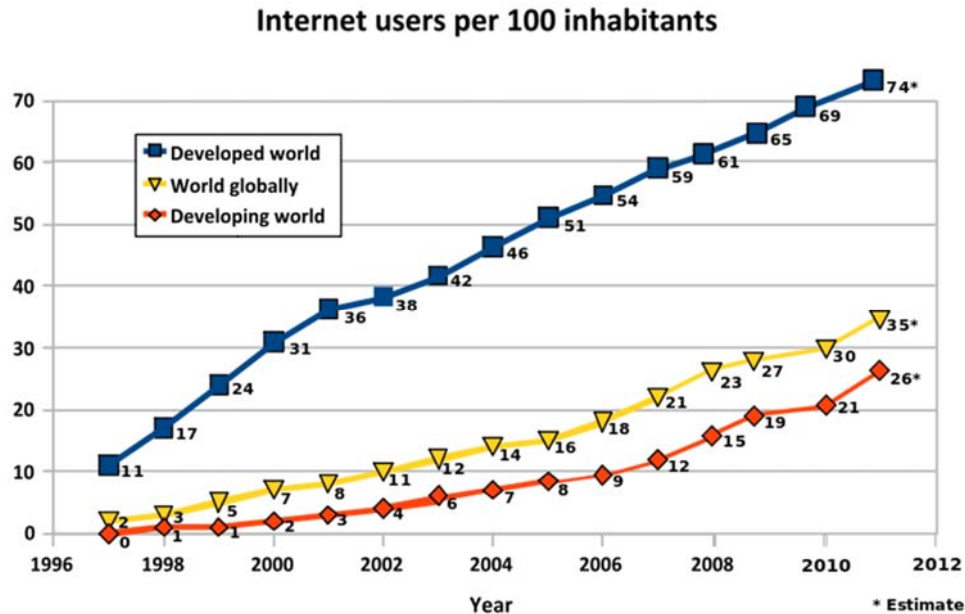
Example Networks

- Internet: Connection of ARPANET and NSFNET in 1983.
 - Millions of hosts, many more users
 - Size doubling every year
- Early important applications of internet: E-mail, FTP, Telnet, News
- Application that changed internet: Web Browsing (World Wide Web) developed in 1990 in CERN
- New Applications
 - Chat
 - VoIP
 - Multimedia streaming
 - E-commerce
 - Peer to Peer file sharing
 - Many more ...

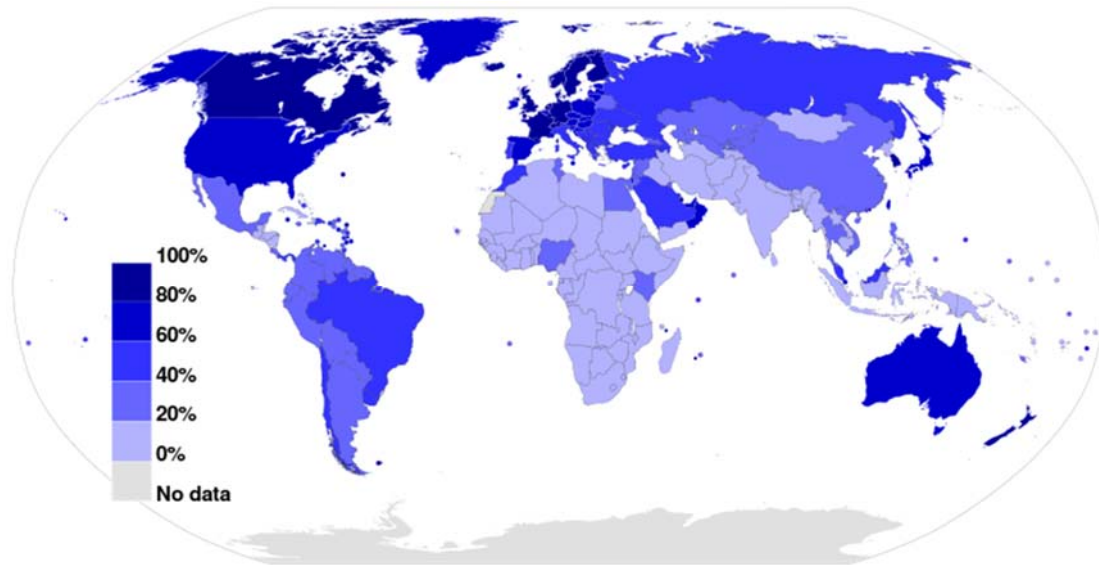
Network Expansion



Global Usage of Internet



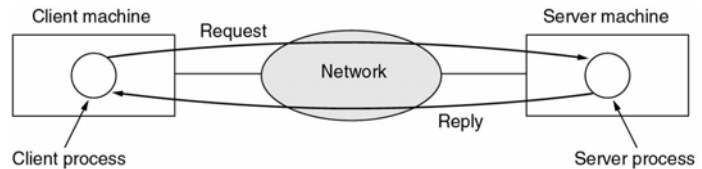
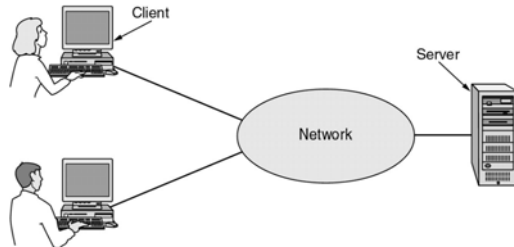
Global Usage of Internet



Source: International Telecommunication Union (2010)

Computer networks

- Old: Single powerful computer, many local terminals for interaction



- Now: Many autonomous computers interconnected to do the job

Applications of Computer Networks

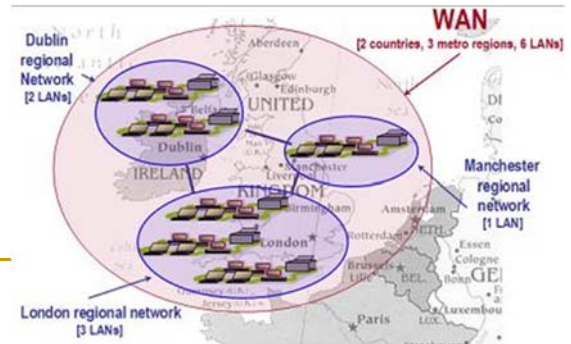
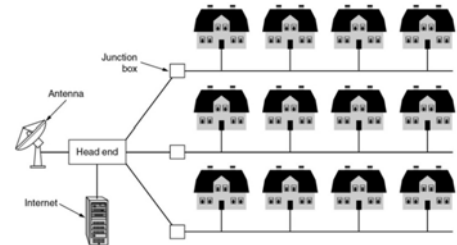
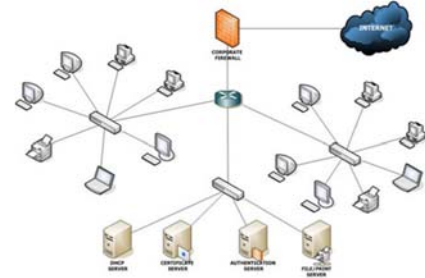
- Business Applications:
 - Resource sharing (Programs, equipment, information)
 - Communication medium (E-mail, Video-conference)
 - E-commerce (Business to Business, Business to Customer)
- Home Applications
 - Access to remote information
 - Person to person communication (E-mail, chat, peer to peer..)
 - Interactive Entertainment
 - E-commerce
- Mobile Applications:
 - Portable office (access to internet, E-mail, information, etc)
 - Access to information on the move
 - Navigation and maps

Networking Hardware

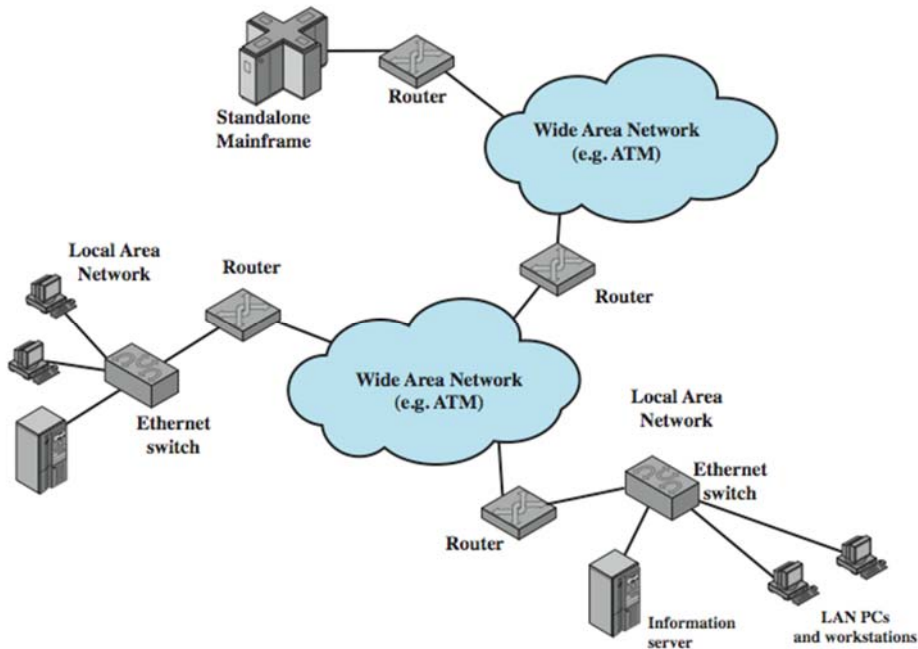
- **Broadcast**
 - ❑ Single channel shared by all parties
 - ❑ All receivers listen to each and every message and use the one intended for them
 - ❑ Used for smaller networks
- **Multicast**
 - ❑ Data sent by a source, received by some users
 - ❑ Application in video conferencing, collaboration, live video broadcast
- **Point to point**
 - ❑ Many connections between pairs
 - ❑ Multiple roots between source and destination
 - ❑ Used for larger networks

Network Hardware

- LAN (Local Area Network)
 - ❑ Network usually within a building
 - ❑ Restricted Size, delay
 - ❑ Rate: 10Mbps to 10Gbps
 - ❑ Topology: Bus, Ring or point to point
 - ❑ Channel allocation: Static or dynamic
 - ❑ Examples: Ethernet (IEEE 802.3),
- MAN (Metropolitan Area Network)
 - ❑ A network within a city
 - ❑ Examples: Cable TV network
- WAN (Wide Area Network)
 - ❑ A network with large area
 - ❑ Example: Backbone optical transmission network of a country



Typical Network Elements

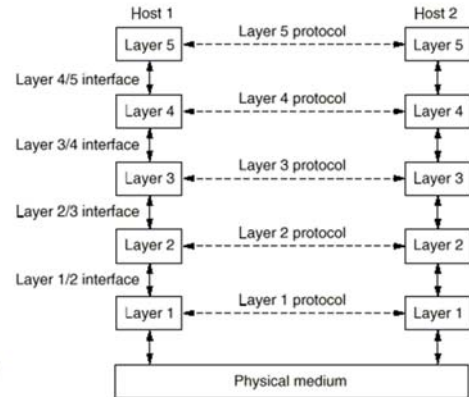
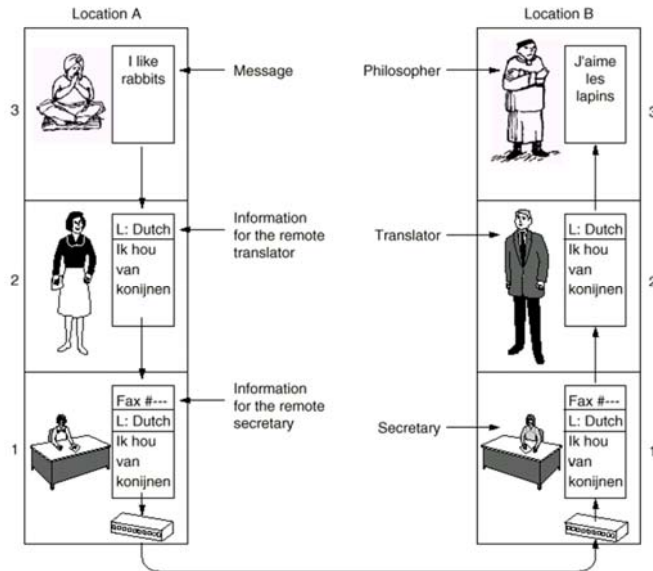


Network Hardware (By Technology)

- Wireless Networks
- Mobile Networks
- Satellite Networks
- Wireline Networks
- PSTN Networks
- Microwave Radio Networks
- Optical Networks
- Access Networks
- Home Networks
- P2P Networks
- Many more...

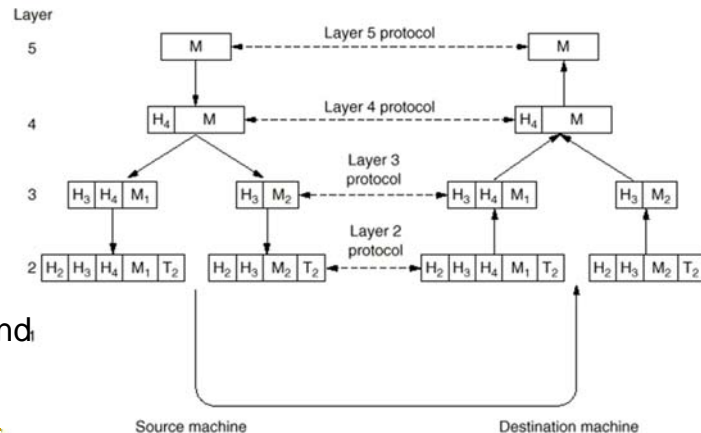
Network Operation Principles

- Functionality of most networks are organized as a series of layers
- Each layer is implemented by an entity
- Peers: two communicating entities (within the same layer)



Network Software

- Network architecture:
 - set of layers and protocols
- Protocol:
 - An agreement on rules and procedures between two communicating parties on how the communications is to proceed.
- Protocol stack:
 - list of protocols, one per layer
- Interface:
 - Primitive operations and services offered by the lower layers to the higher layers
- Having Layers => Much simpler, more manageable and more flexible implementation of the network architecture

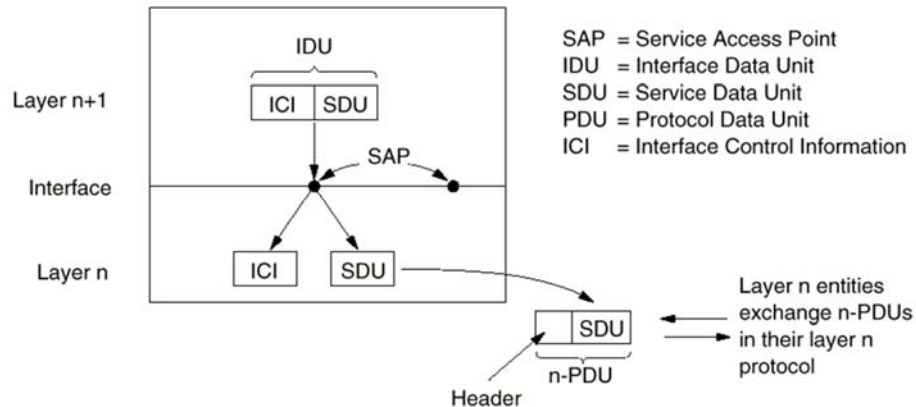


Examples of Layer Design Issues

- Addressing: specifying source and destination
- Data transfer rules
 - simplex / half-duplex / duplex
 - logical channels per connection
 - priorities, e.g. one normal and one urgent channel
- Error control
 - detection / correction / retransmission
- Packet order and sequencing
- Flow control
 - regulate traffic; avoid overflow
 - Message length: cannot be arbitrary long
 - (re)assembly needed !
 - Multiplexing
- Routing
 - multiple paths

Interfaces and Services

■ Relation between layers at an interface



Service Categories and Reliability

■ Service Categories:

- Connection oriented
 - Phone conversation
 - Telnet / remote login / FTP
- Connectionless
 - Postal system
 - Email

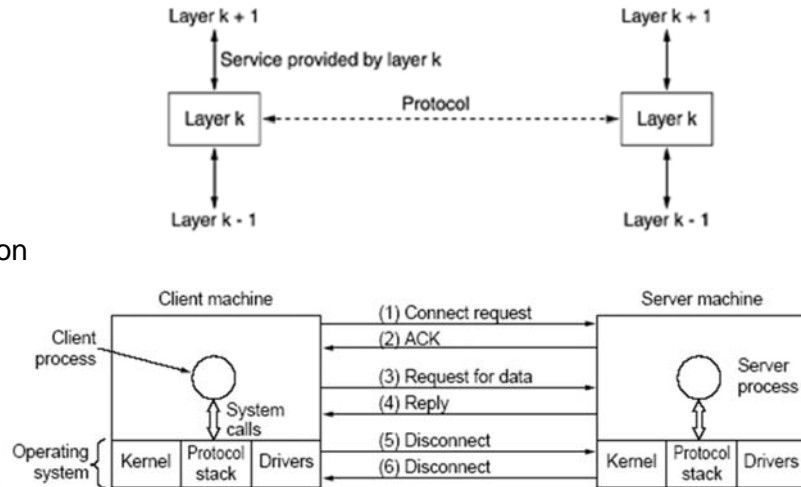
■ Service Reliability

- Reliable: never loose data
 - Acknowledgements / retransmission
- Unreliable: data may be lost
 - No acknowledgements
 - Datagram service

		Service	Example
Connection-oriented	{	Reliable message stream	Sequence of pages
		Reliable byte stream	Remote login
		Unreliable connection	Digitized voice
Connection-less	{	Unreliable datagram	Electronic junk mail
		Acknowledged datagram	Registered mail
		Request-reply	Database query

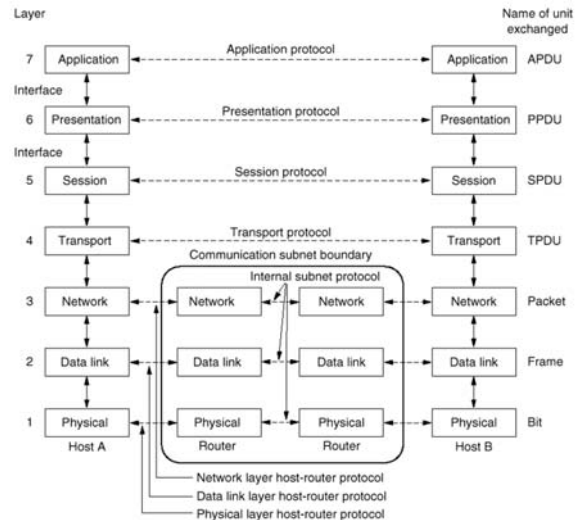
Services versus Protocols

- Service = set of primitives (operations) that a layer provides to the above layer
- Protocol = set of rules implementing a service Protocol concerns format, meaning of frames / packets / messages
- A protocol may be changed without changing the service
- Service primitives
 1. CONNECT. request
 2. CONNECT. indication
 3. CONNECT. response
 4. CONNECT. confirm
 5. DATA. request
 6. DATA. indication
 7. DISCONNECT. request
 8. DISCONNECT. Indication
- CONNECT:
 - confirmed service
 - response required
- DISCONNECT:
 - unconfirmed service



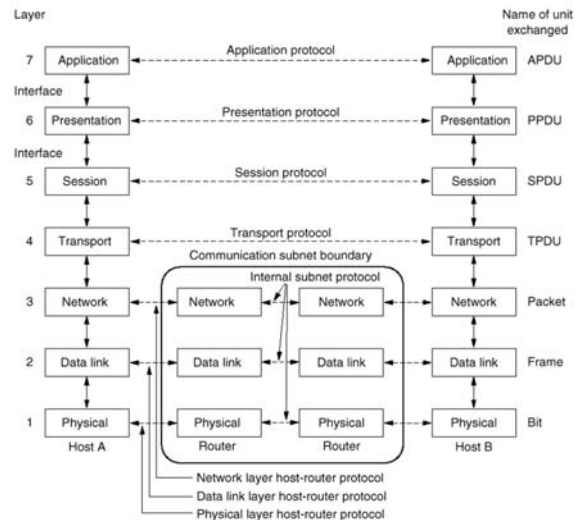
Open System Interconnect (OSI) Reference Model

- Model has 7 layers
 - A model which tells what each layer should do, not how it should be done!
- Physical layer
 - Transmission of raw bits (0/1 encoding)
 - Relevant aspects are: voltage, bit rate,
 - Channel characteristics (Electrical)



OSI Reference Model

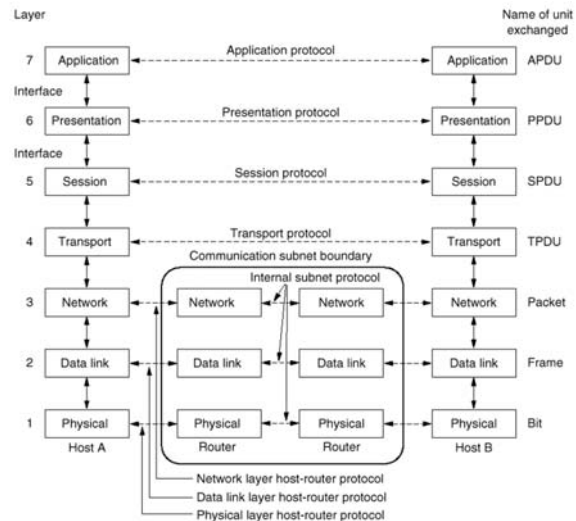
- Data link layer
 - ❑ Transport of frames (of bits)
 - ❑ Reliable transmission
 - ❑ Flow control
 - ❑ Broadcast networks: channel sharing (medium access sub-layer)
- Network layer
 - ❑ Transport of packets
 - ❑ Controlling the subnet
 - ❑ Routing: static or dynamic
 - ❑ Congestion control
 - ❑ Connect heterogeneous networks



OSI Reference Model

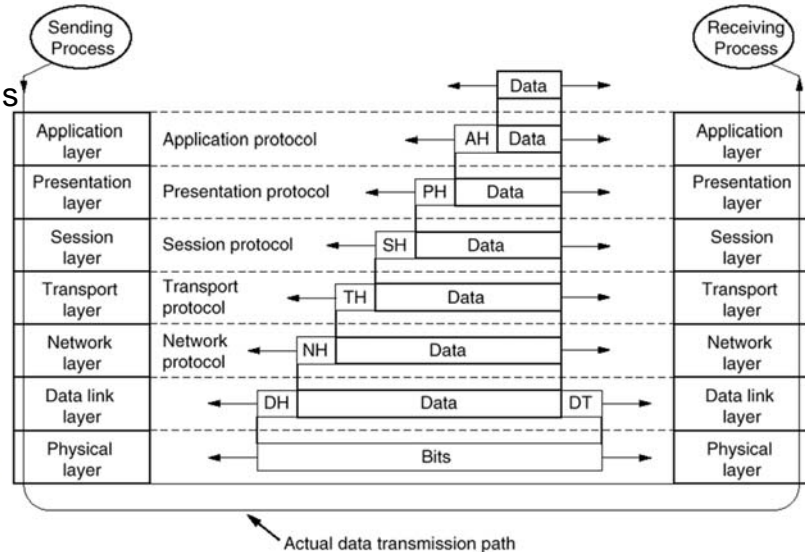
■ Transport layer

- ❑ Connection management
- ❑ End-to-end layer, from source to destination
- ❑ Split data stream in packets
- ❑ In-order delivery of packets (if network does not guarantee this)
- ❑ Establish and delete connections across the network
- ❑ Usually a unique connection is created for each required transport connection. However it may use 1-n or n-1 mappings
- ❑ Flow control



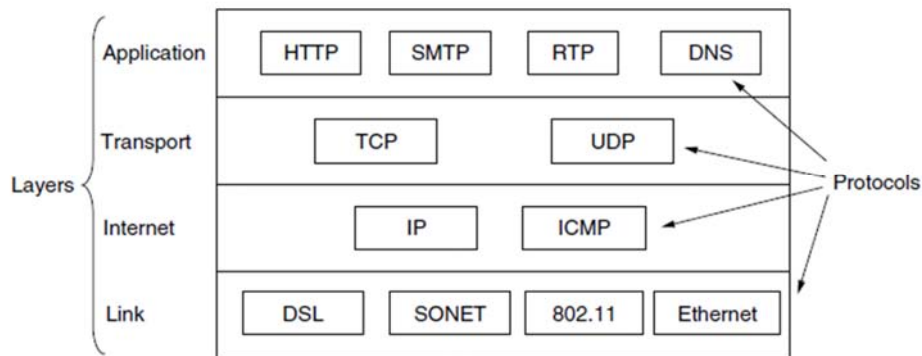
OSI Reference Model

- Session layer
 - Session management : dialogue control, synchronization after crash
- Presentation layer
 - Concerned with syntax and semantics of transmitted information
- Application layer
 - Commonly needed application protocols
 - Examples:
File transfer,
E-mail



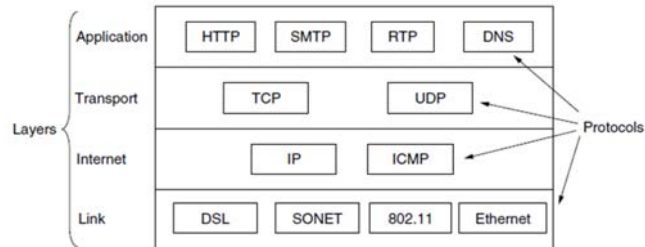
TCP/IP Reference Model

- Originated from ARPA NET
- Connecting many USA Universities and government institutes using leased telephone lines
- Internet layer is the most important layer
- IP: internet protocol
 - ❑ Connectionless
 - ❑ Packet-switching (Possible out-of-order delivery)



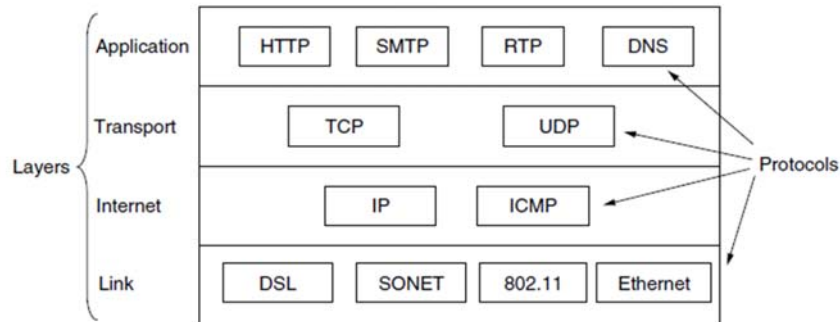
TCP/IP Reference Model

- Transport layer
 - End-to-end communication
 - TCP: transmission control protocol
 - Reliable
 - Connection-oriented
 - Flow control
 - Sequencing
 - Fragments byte stream into IP messages
 - UDP : user datagram protocol
 - Unreliable
 - Connectionless
 - No sequencing and flow control
 - often used for 'one shot' communication: e.g. booting



TCP/IP Reference Model

- Application layer
 - ❑ TELNET: virtual terminal
 - ❑ FTP: file transfer protocol
 - ❑ SMTP: simple mail transfer protocol
 - ❑ DNS: domain name service
 - ❑ NNTP: network news transfer protocol
 - ❑ HTTP: hypertext transfer protocol
 - ❑ SNMP: simple network management protocol



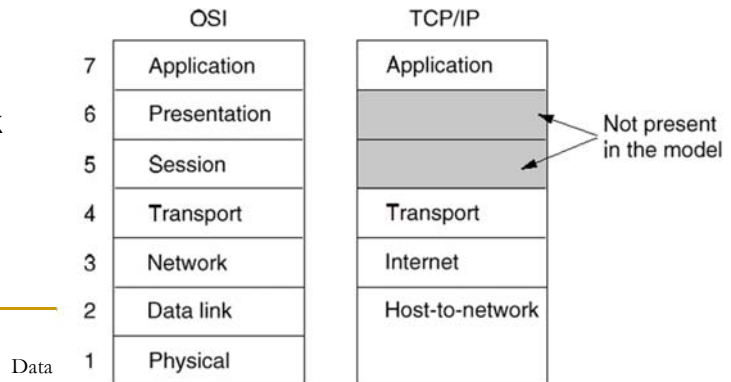
Comparing OSI and TCP/IP

■ OSI:

- ❑ Top-down design methodology
- ❑ The concepts clearly distinguishes
 - Services (specification)
 - Interfaces
 - Protocols (implementation)
- ❑ Network layer supports both connectionless and connection-oriented communication
- ❑ Transport layer supports only connection-oriented service !!

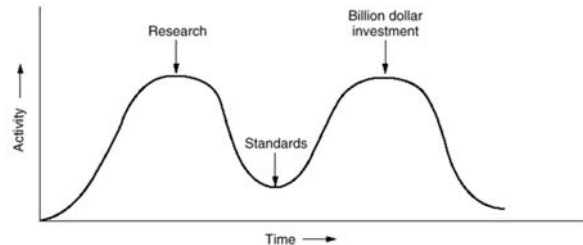
■ TCP / IP

- ❑ Bottom-up approach; grew out of practice
- ❑ Not a general protocol stack
- ❑ Host-to-network layer is actually an interface description



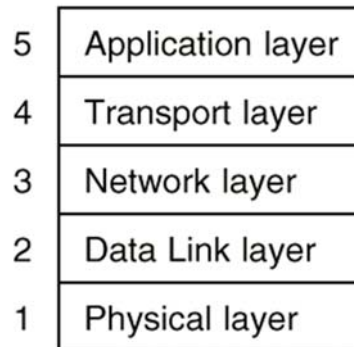
Critics on OSI model

- Bad timing.
- Bad technology.
 - ❑ Too many layers (Competition with 7 layer IBM SNA! stack)
 - ❑ Overloaded (L2, L1) and empty (L5, L6) layers
 - ❑ Too difficult to understand and implement
 - ❑ Initially ignored connectionless protocols
- Bad implementations.
 - ❑ Early implementations were huge, unwieldy, and slow.
- Bad politics
 - ❑ TCP/IP as part of UNIX, widely available, useful and open
 - ❑ OSI as a creature of telecom ministers/big telecom companies



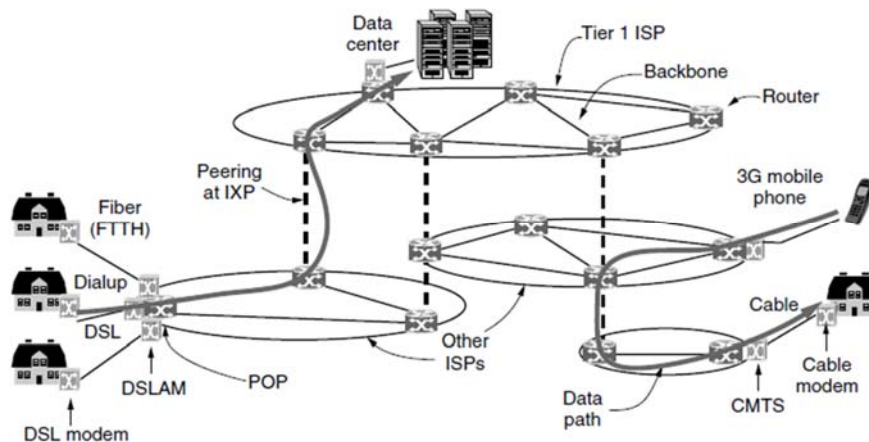
Model of Choice

- We will follow a hybrid, 5-layer model in this course
- Data Link Layer includes Multiple Access Control (MAC) functionalities, but noting the importance of MAC, we will devote a special section to it.



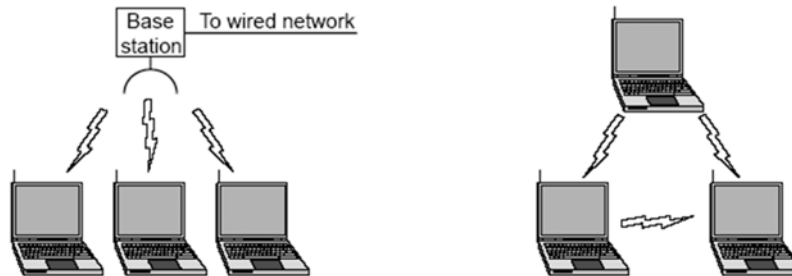
Internet Architecture

- ISP: Provide Connectivity (DSL, Dialup, Cable, FTTH, 3G, etc)
- ISP Routes data internally (Its own backbone) or through its interconnection with other ISPs (Peering at IXP) to the Data Centers that Host the desired services



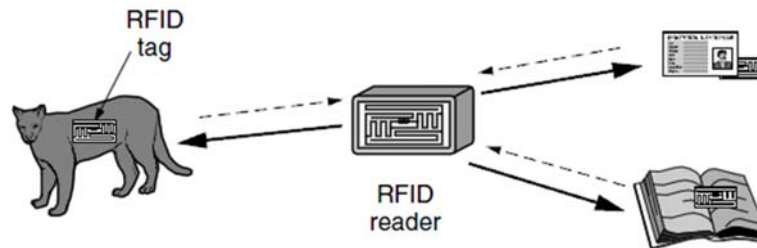
Local Area Networks: Wireless LAN

- Idea: Allow wireless communication for
 - Access to backbone networks
 - Ad Hoc peer to peer communication
- Most famous standard: IEEE 802.11 series
- First developments in 1997 with 1Mbps or 2Mbps speed
- Newer generation: 802.11g working at 54 Mbps and 802.11n working at up to 450 Mbps



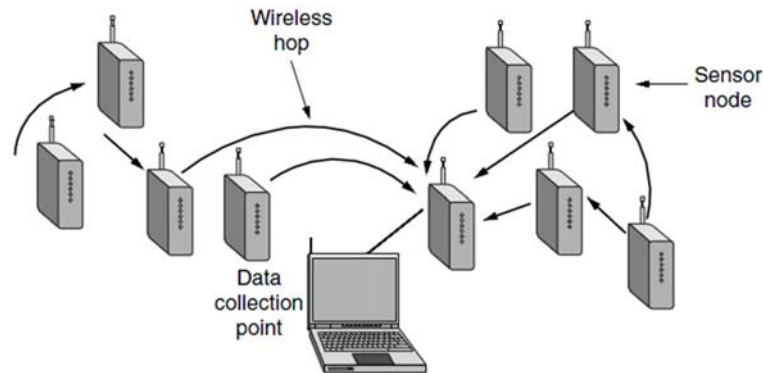
Radio Frequency Identification (RFID)

- Objects that can be used for many purposes such as identification and tracking
- RFID Reader interacts with RFID tags to send data to them and read data from them using radio waves
- RFID can be passive or active
- Networking issues such as addressing and multiple access control should be considered



Sensor Networks

- Many nodes that sense environmental conditions (temperature, sound, movement, etc) and report the data back to a central location
- Nodes should collaborate with each other to route the data properly
- Many key networking issues such as multiple access control and routing should be properly considered



Standardization: Who's Who

- Telecommunication world
 - ITU: International Telecommunication Union
- International standards
 - ISO: Int. Organization for Standardization (1946)
 - ANSI: American National Standards Institute
 - IEEE: Inst. of Electrical and Electronic Engineers
- Internet
 - IAB: Internet Activities Board
 - IETF: Internet Engineering Task Force
 - IRTF: Internet Research Task Force

Local Area Networks: Ethernet

- Ethernet:
 - ❑ Originally Developed by Metcalfe in 1976 at Xerox to connect computers
 - ❑ Initial standard by Xerox, Intel and DEC in 1978; standardized by IEEE as 802.3 in 1983
 - ❑ Evolved from original 3 Mbps to 100 Gbps
 - ❑ Dominant LAN technology, moving to MAN applications

Figure 1-34. Architecture of the original Ethernet.

