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
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  - 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

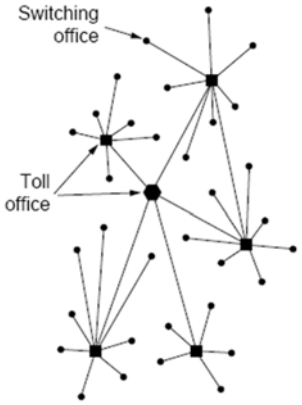
- Introduction.
- The Physical Layer.
- The Data Link Layer.
- Multiple Access Protocols.
- The Network Layer.
- The Transport Layer.
- The Application Layer.

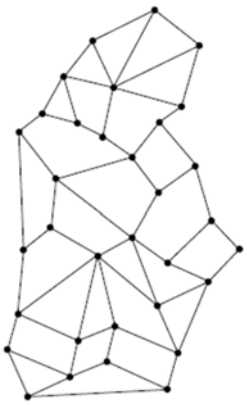
Course load

- 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

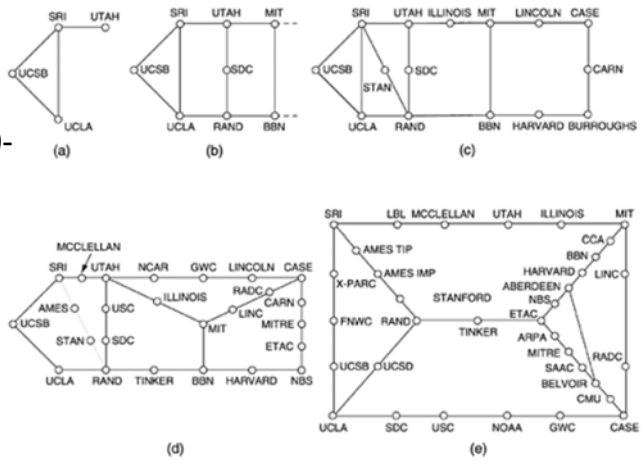
- 1961-1964 Idea of store and forward distributed communication in packet networks by L. Kleinrock, D. Watts and P. Baran
  - More suitable for computer communication
  - More resilient to node failure
- Creation of ARPANET in late 1960's
  - To build a network that withstands destruction of some of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





Example Networks

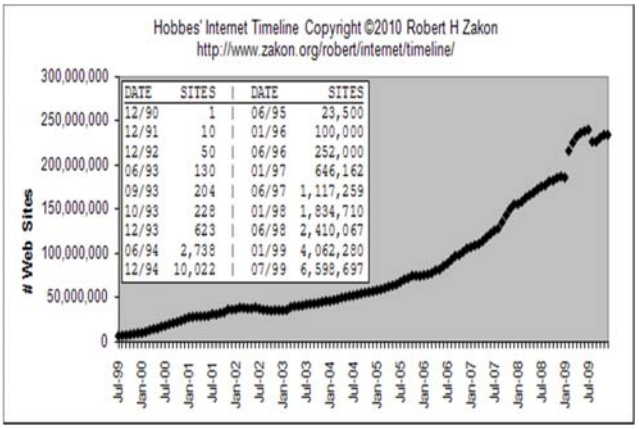
- Development of TCP/IP in 1970's (V. Cerf) and its full deployment over ARPANET in 1981-83
- Rapid expansion of ARPANET in 1970-1980's to include most key universities in USA and Europe
- NSFNET : U.S. National Science Foundation Network for Academia
  - First TCP/IP WAN early 1980s.
  - Three generations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

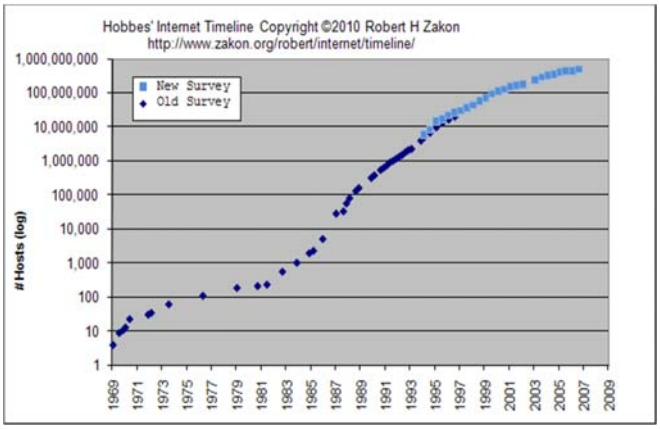


Example Networks

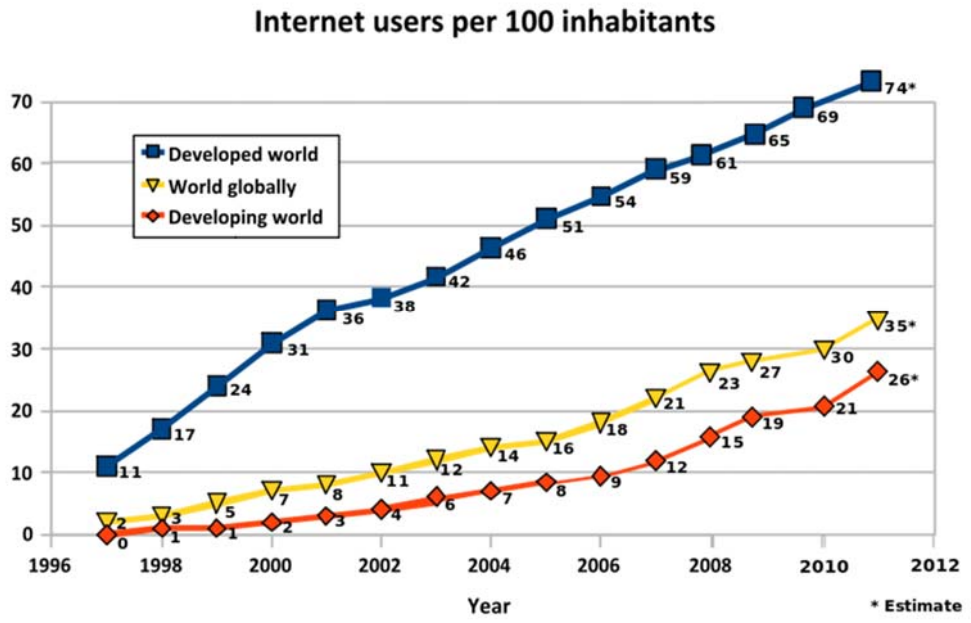
- Internet: Connection of ARPANET and NSFNET in 1983.
  - Millions of hosts, many more users
  - Size doubling every year
- Early important applications of internet: E-mail, FTP, Telnet, News
- Application that changed internet: Web Browsing (World Wide Web) developed in 1990 in CERN
- New Applications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

Network Expansion

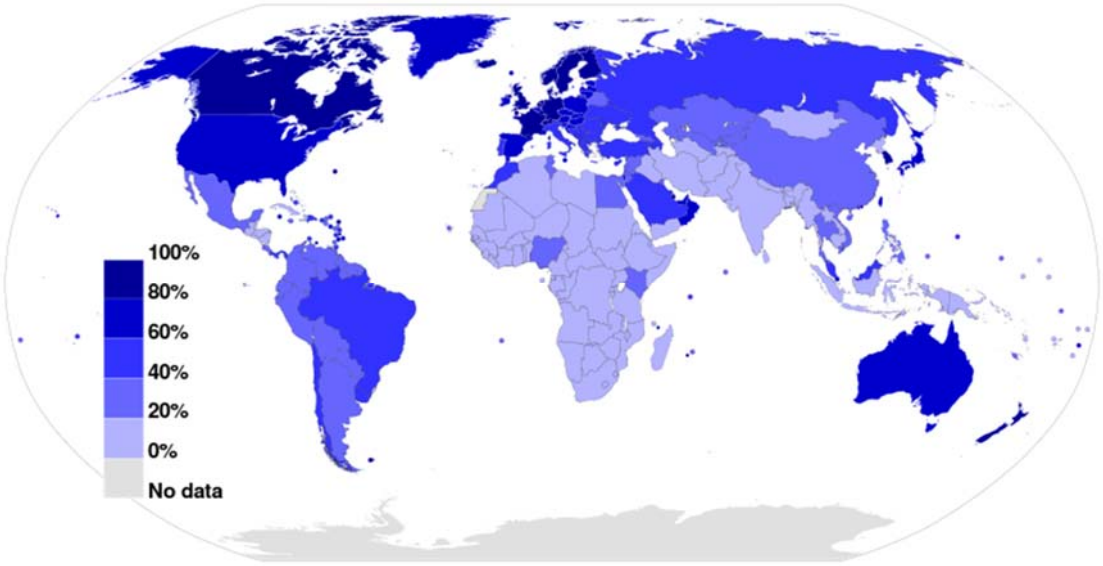




Global Usage of Internet



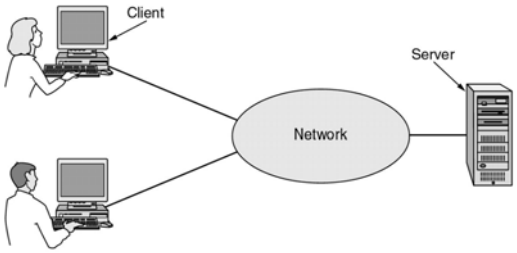
Global Usage of Internet

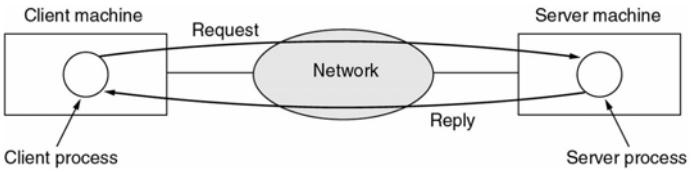


Source: International Telecommunication Union (2010)

Computer networks

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





- Now: Many autonomous computers interconnected to do the job

Applications of Computer Networks

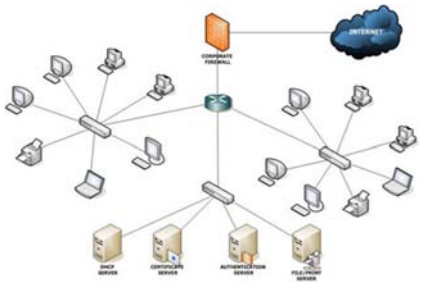
- Business Applications:
  - Resource sharing (Programs, equipment, information)
  - Communication medium (E-mail, Video-conference)
  - E-commerce (Business to Business, Business to Customer)
- Home Applications
  - Access to remote information
  - Person to person communication (E-mail, chat, peer 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

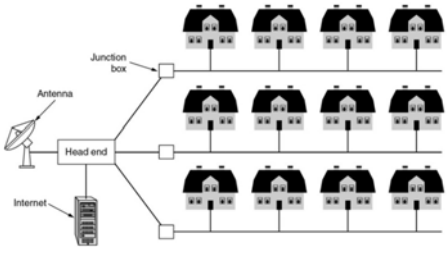
Networking Hardware

- 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

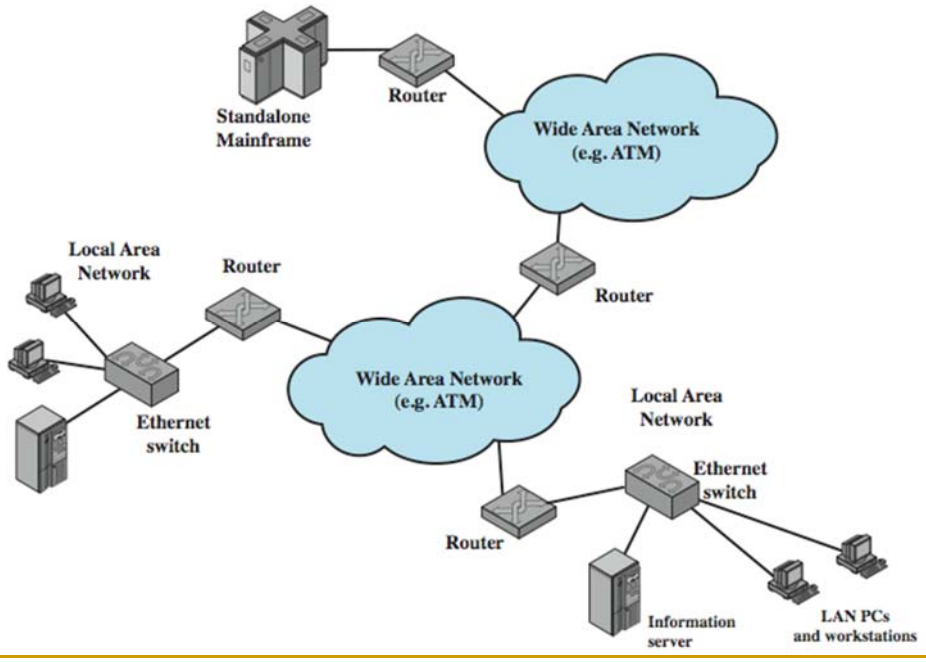
Network Hardware

- 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

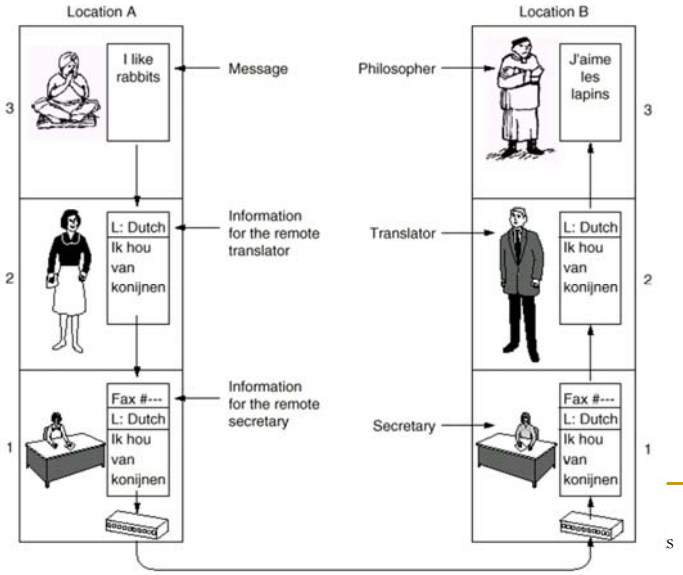


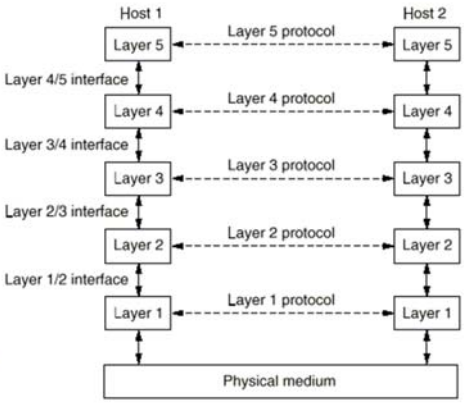
Network Hardware (By Technology)

- 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)





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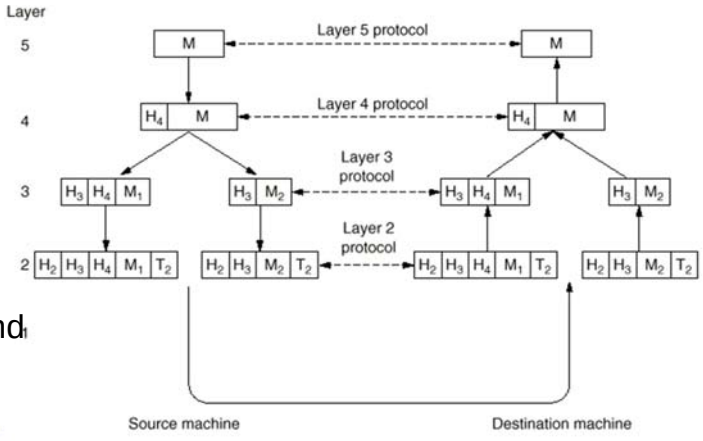
Network Software

- 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

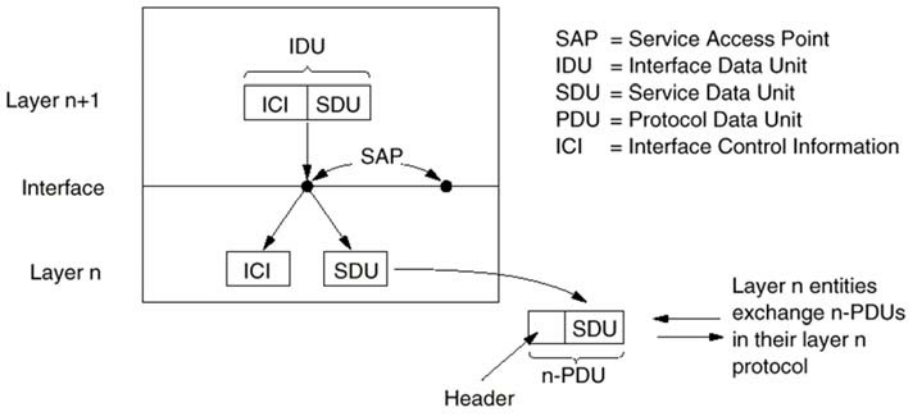


Examples of Layer Design Issues

- 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



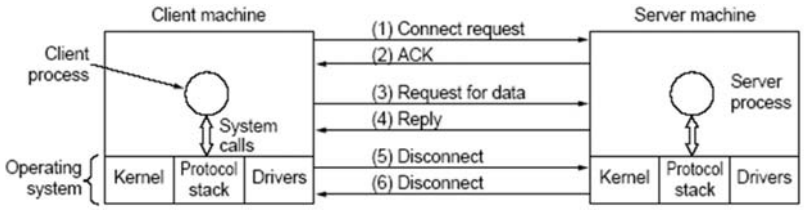
Service Categories and Reliability

- 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

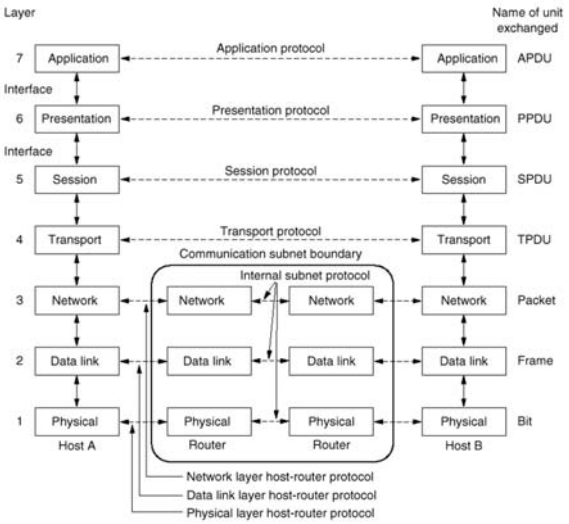
Services versus Protocols

- 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



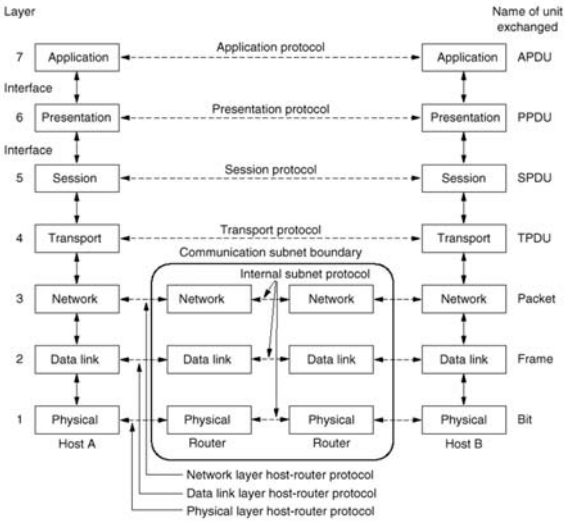
Open System Interconnect (OSI) Reference Model

- 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)



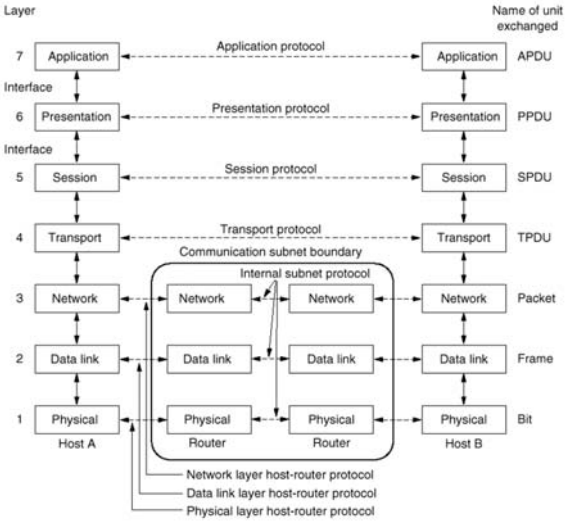
OSI Reference Model

- 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



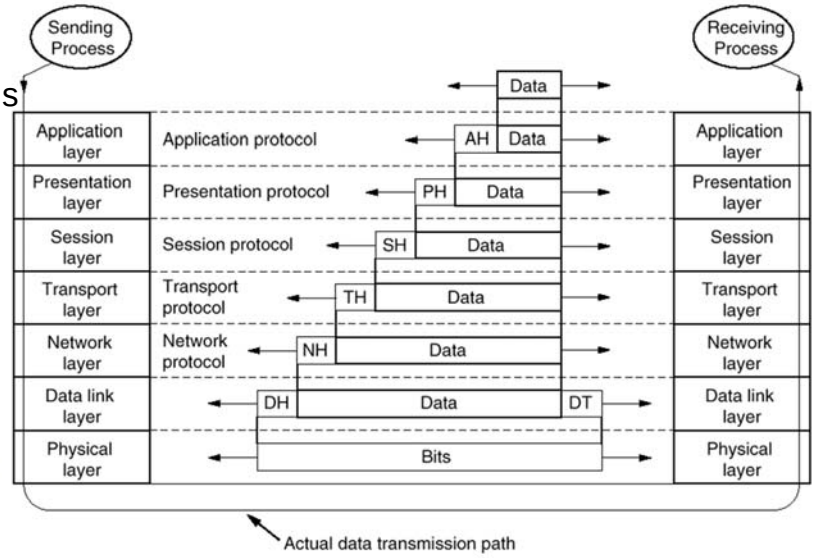
OSI Reference Model

- 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



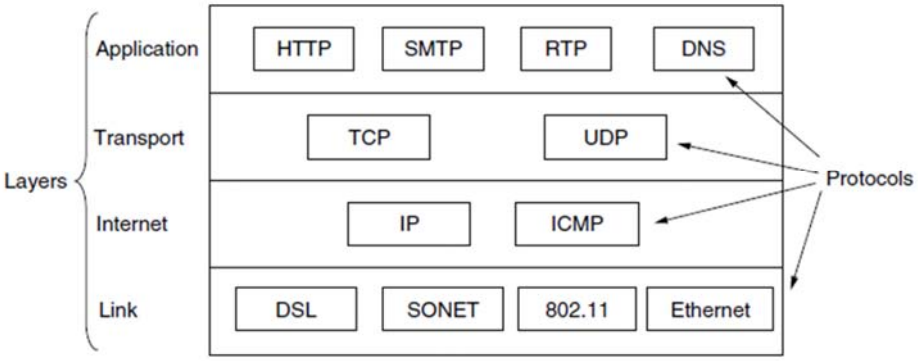
OSI Reference Model

- 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



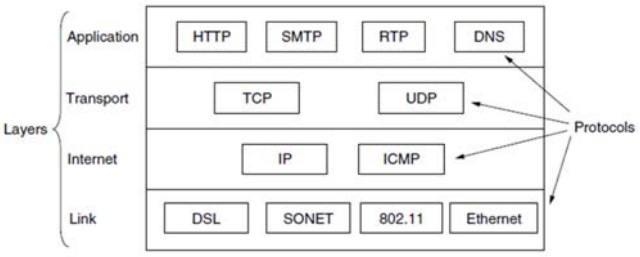
TCP/IP Reference Model

- 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)



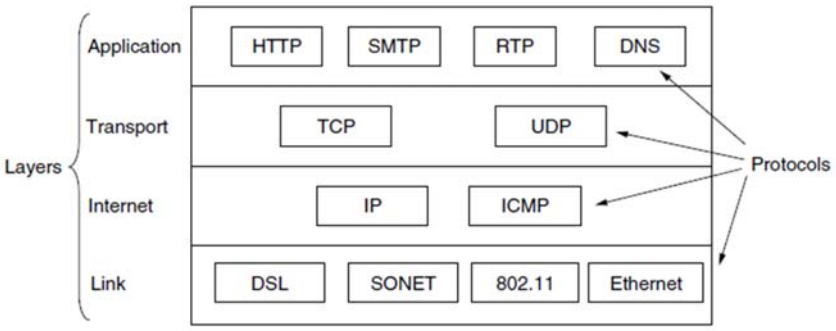
TCP/IP Reference Model

- 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



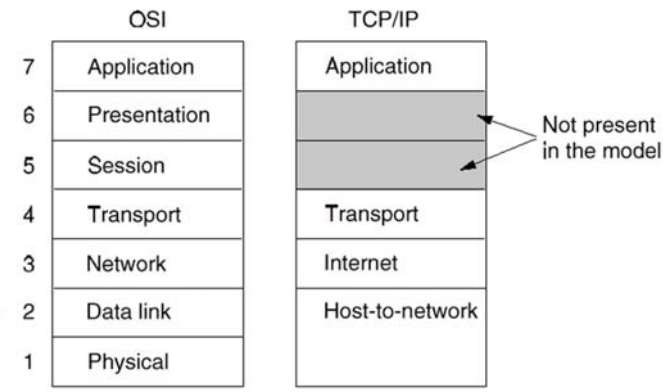
TCP/IP Reference Model

- 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

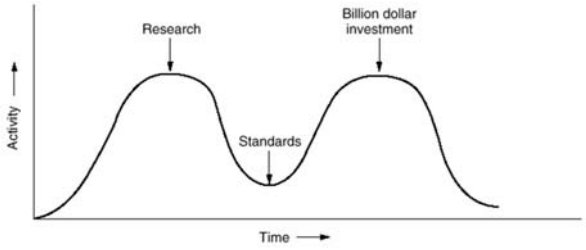


Comparing OSI and TCP/IP

- 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

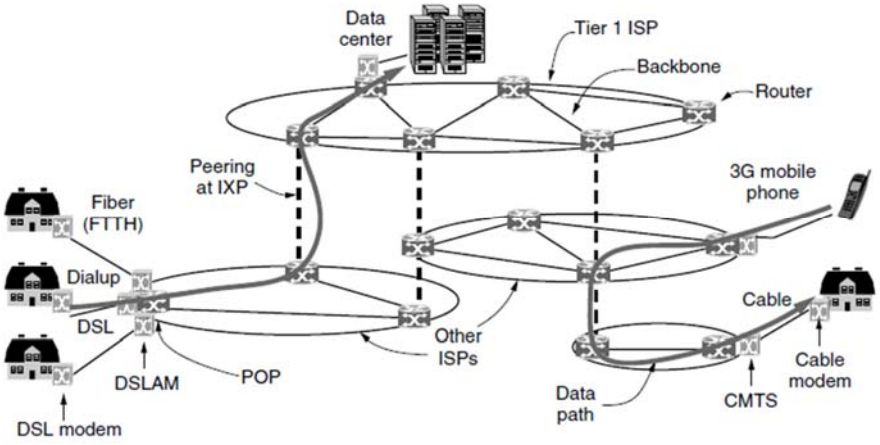
Model of Choice

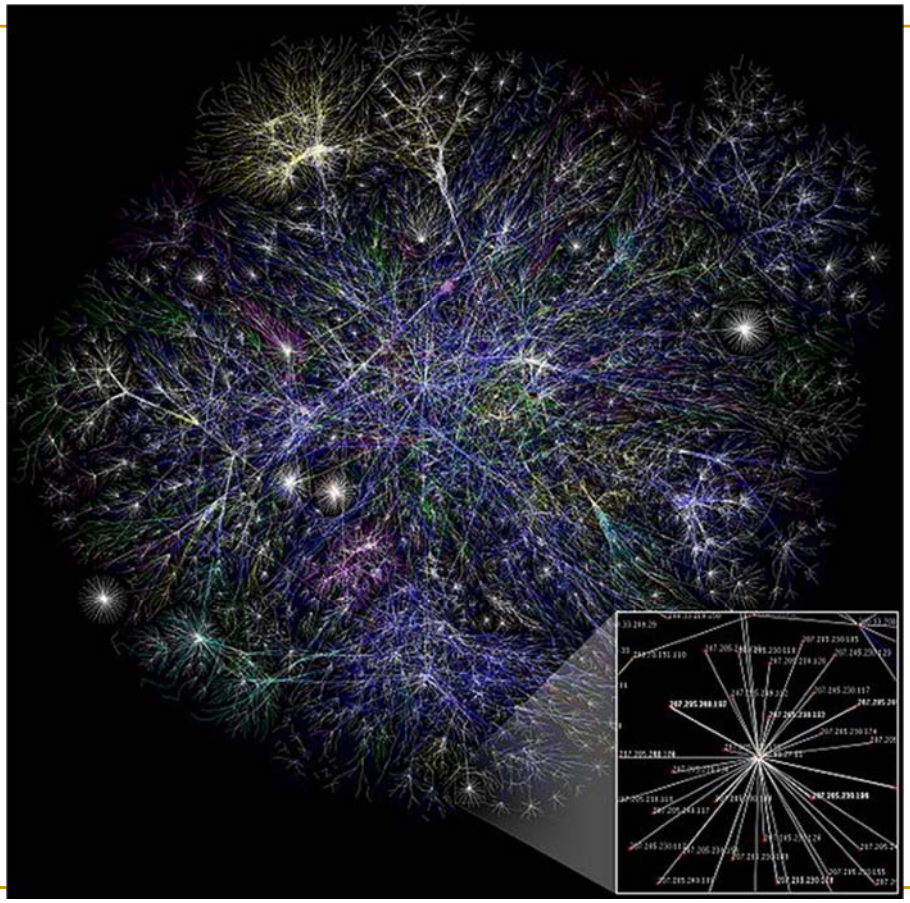
- We will follow a hybrid, 5-layer model in this course
- Data Link Layer includes Multiple Access Control (MAC) functionalities, but noting the importance of MAC, we will devote a special section to it.

5	Application layer
4	Transport layer
3	Network layer
2	Data Link layer
1	Physical layer

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

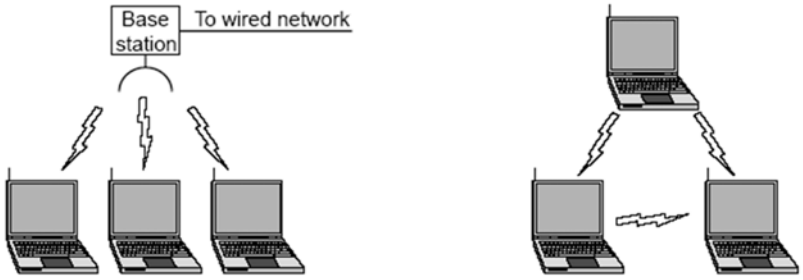




- A partial map of the Internet, rendered based on ping delay and colored based on Top Level Domains
- Source: http://en.wikipedia.org/wiki/File:Internet_map_1024.jpg

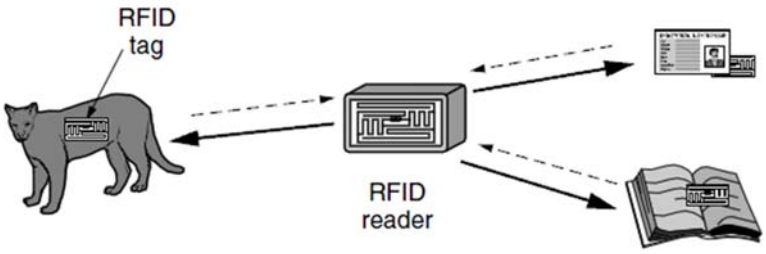
Local Area Networks: Wireless LAN

- 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



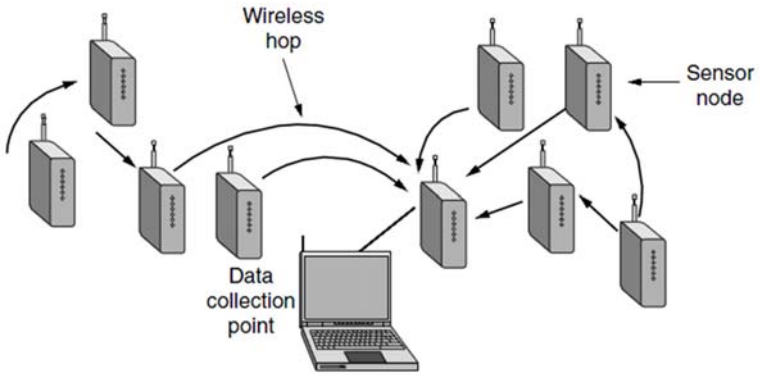
Radio Frequency Identification (RFID)

- 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.