

CS5310.001/002, Fall 2020
Computer Networks and Communication Systems
(08/26/2020)

Lecture 1: Introduction

Lecture Outline

1. Motivations and Histories
2. Data Communication Networks
3. Standards
4. The ISO's OSI Reference Model
5. The TCP/IP Reference Model
6. Example Networks

1. Motivations and Histories

(1) Motivations

- a. Disadvantages of centralized systems
- b. Resource sharing, load sharing
- c. Improving reliability
- d. Communication media (banking, airline reservation)

(2) Classification of computer systems

- a. Centralized systems
- b. Computer networks
 - (a) LANs
 - (b) WANs
 - (c) MANs
- c. Distributed systems
- d. Parallel computers
 - (a) Shared memory multiprocessor systems
 - (b) MIMD parallel computers
- e. Data flow machines

(3) Networks vs. distributed systems

- a. Common issues: various (middle to low level) protocols, resource management, concurrency control
 - b. Differences: transparent services
- (4) Computers and data communications (Fig.1)
- a. Layers of communications: applications talk with each other at the highest level
 - b. The computer-communication network part is called *data communication network*. Its composition is very diversified.

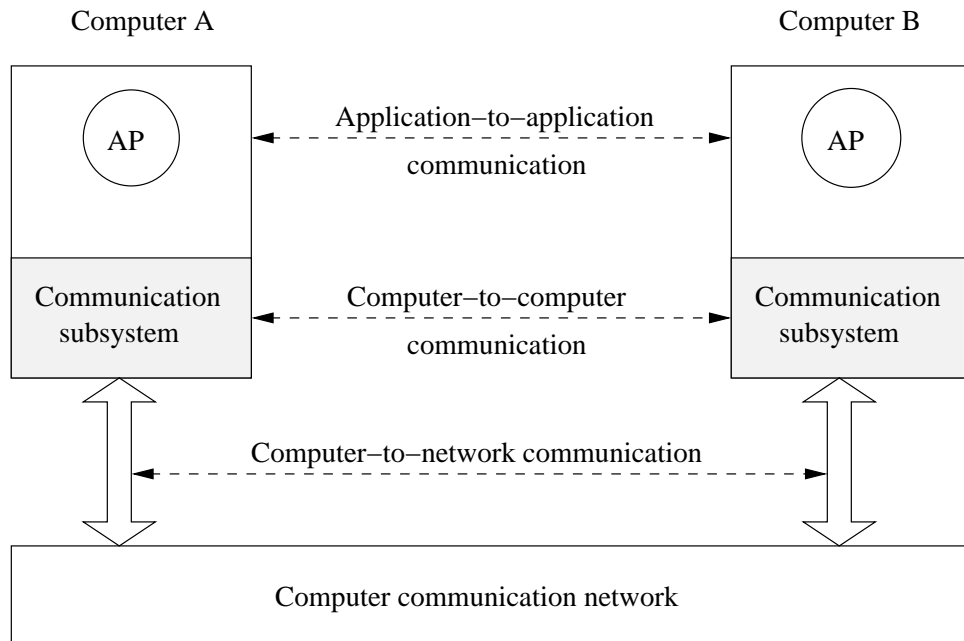
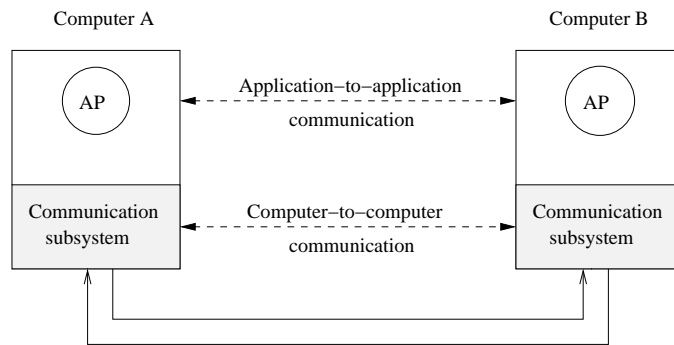


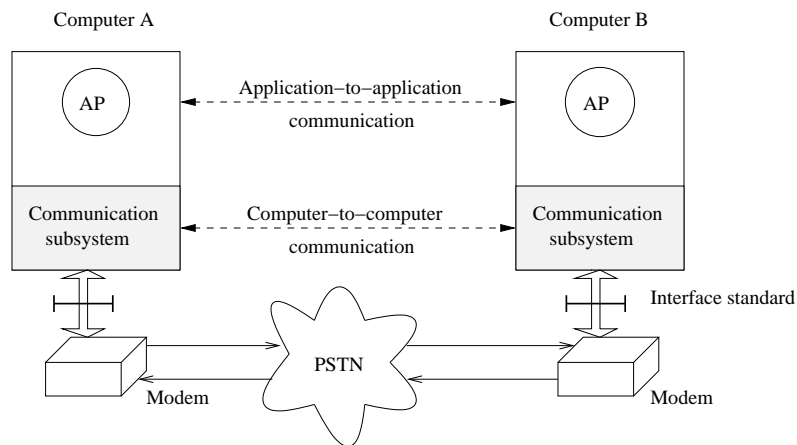
Figure 1: Computer communication schematic

2. Data Communication Networks

- (1) Direct wire connection: Fig.2(a)
- (2) Connection through PSTN (Public Switched Telephone Network): Fig.2(b)
 - Modem is needed
 - Fig.2.4, p.101 illustrates more details
- (3) LANs: Fig.3



(a) Point-to-point two-wire links



(b) PSTN+Modem connection

Figure 2: Simple computer-to-computer alternatives: (a) point-to-point wire link (b) PSTN + modem link.

a. Diversified structure (topology)

b. Diversified transmission media

(4) Enterprise-wide private networks: Fig. 3.22, p.215

(5) ISDN (Integrated Services Digital Network): Fig.3.23(a), p.209

a. Many public carries have been trying to convert its PSTN into ISDN

b. ISDN can be thought as one form of DSL (digital subscriber line)

(6) WANs and internetworking: Fig. 1.1, p.2 and Fig.2.35, p.155

3. Standards

综合业务数字网
(Integrated Services
Digital Network,
ISDN) 是一个数字电话
网络国际标准, 是一种
典型的电路交换网络系
统 (circuit-switching
network)

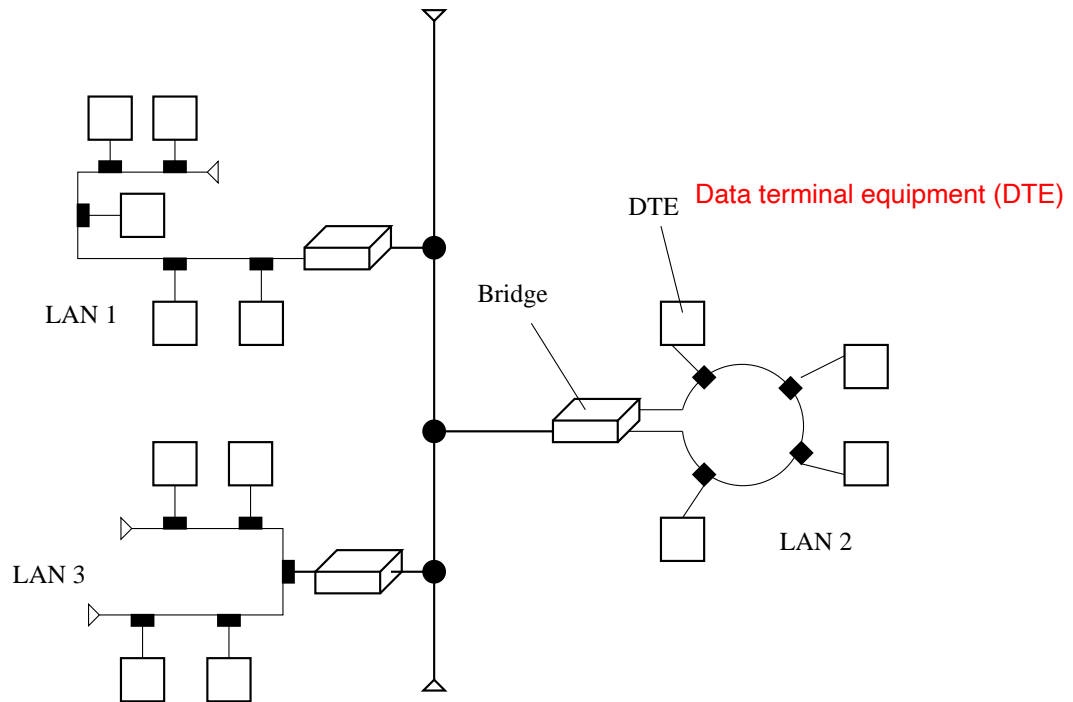


Figure 3: Illustration of LAN

(1) Closed systems and Open systems

- a. Early computers had complex, activity-driven hardware and software components for networking (called *communication subsystems*).
- b. Only machines of the same type, or from the same vendor, can communicate with each other (called *plug compatible systems*). such systems are called *closed systems*
- c. In contrast, open systems are those that allow communication from various machines of potentially different vendors.

(2) International Standards

- a. The need of standardization and and major standardization organizations
 - (a) Standardization leads higher productivity
 - (b) Major players: ISO, ITU (International Telecommunications Union), IEEE, CCITT
 - IEEE, ECMA (European Computer Manufactures Association), EIA (Electrical Industries Association): represent computer industry, mainly promote proprietary standards for closed systems.

- ITU-T (International Telecommunication Union Telecommunication Sector), CEPT (Conference European of Post and Telecommunications), ANSI (American National Standards Institute): represent telecommunication industry, promote interface standards and standards for multi-vendor systems.
- ISO and ITU-T: represent integrated computer and telecommunication industries, promote international standards and standards for open system interconnections.

b. Standardization of different parts

- * *V-series recommendations* for connection of equipment (normally referred as *data terminal equipment* (DTE)) to a modem or to the PSTN;
- * *X-series recommendations* for connecting DTEs to a public data network;
- * *I-series recommendations* for connecting DTEs to an ISDN.

- c. Data transmissions are primary targets initially. More recently, exchange of electronic messages (Teletex), and access to public databases (Videotex). Formal syntax and control of the exchange of these various forms of information are needed. The resulting systems are called **open systems** (more completely as **open system interconnection environment (OSIE)**).

4. The ISO's OSI Reference Model

- (1) Layered structure: a strategy for dealing with complex problems: Fig.4

- a. Example: two philosophers want to converse. One of them can only speak English while the other can only speak French.
- (a) They have to engage translators. The translators rely on secretaries to carry out the real physical communication (phone calls, faxes, emails)
 - (b) Each sentence from a philosopher is first given to his/her translator through the layer 3 to 2 interface, who then passes it to his/her secretary through the layer 2 to 1 interface. Notice that the two translators must agree on a common language, and the secretaries must also agree on the communication method.
 - (c) The secretary then sends the translated sentence through some communication medium to the other secretary.
- b. Observation:

Teletext, or broadcast teletext, is a videotex standard for displaying text and rudimentary graphics on suitably equipped television sets.

Videotex (or interactive videotex) was one of the earliest implementations of an end-user information system

- (a) The philosophers rely on the services of the translators, who in turn rely on the secretaries. The philosophers can be completely unaware of the complex communication process involved.
- (b) The two translators can change their agreed language, so long as the philosophers can express their thinkings with the chosen.
- (c) The secretaries can choose the communication methods without affecting the whole process.

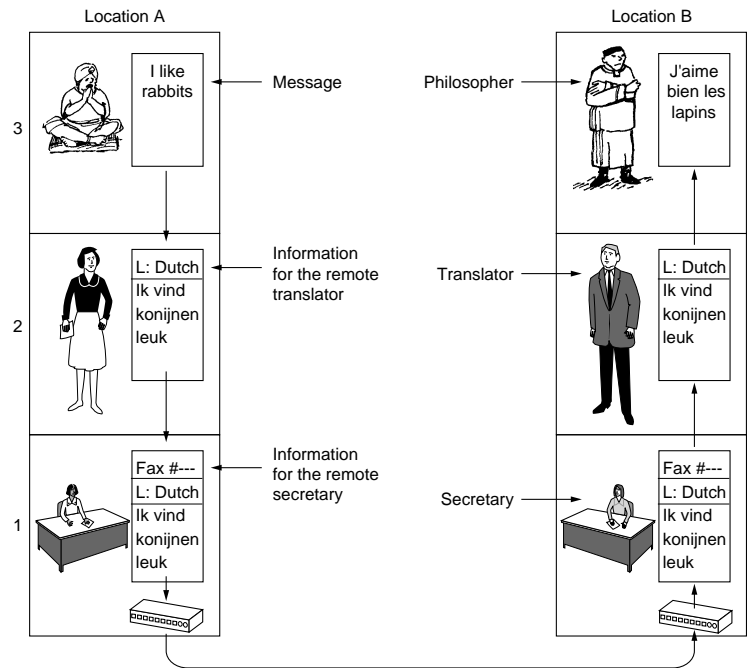


Figure 4: Layers in OSI model and Internet protocol suite

(2) Principles of OSI layers

- a. Layer creation criteria: level of abstraction;
- b. Each layer: perform a well-defined function;
- c. Layer function: easy to be standardized;
- d. Layer boundaries: minimize information flow between layers;
- e. Number of layers: reasonable.

(3) The Physical Layer

物理层，就是发了1bit，就收1bit

General Services: transmitting bits through physical channels

Design issues: (ensure that a bit 1 sent will be received as 1)
transmission media selection
signal (electrical, optical, electromagnetic) encoding
and decoding

(4) The Data Link Layer 保持无误

Gen. Services: providing error-free transmission services to its upper layer

Design issues: disassemble messages and reassemble messages
detecting loss of messages, retransmitting, detecting duplicates
flooding control, piggybacking

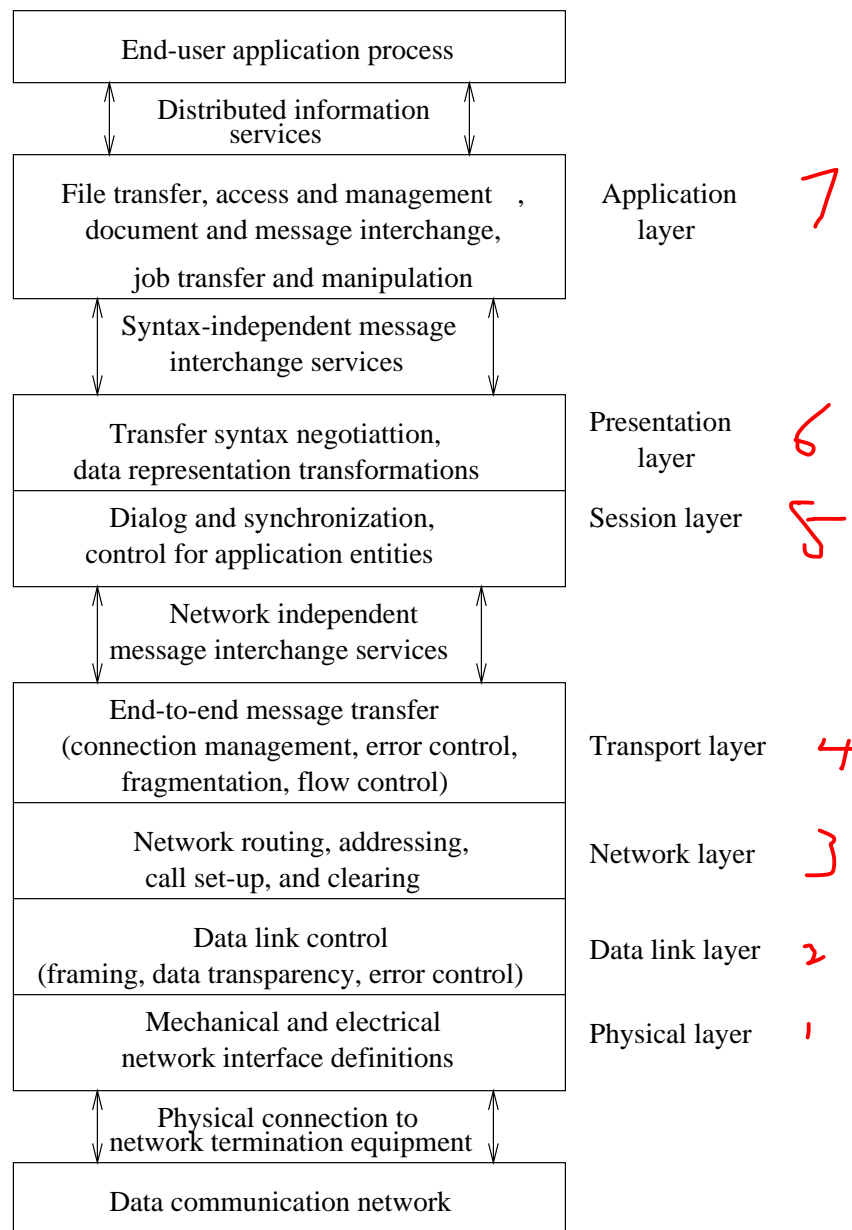


Figure 5: OSI reference model

(5) The Network Layer

Gen. Services: controlling the network operations

Design issues: routing: static, semi-dynamic, dynamic
 congestion control
 accounting
 internetworking

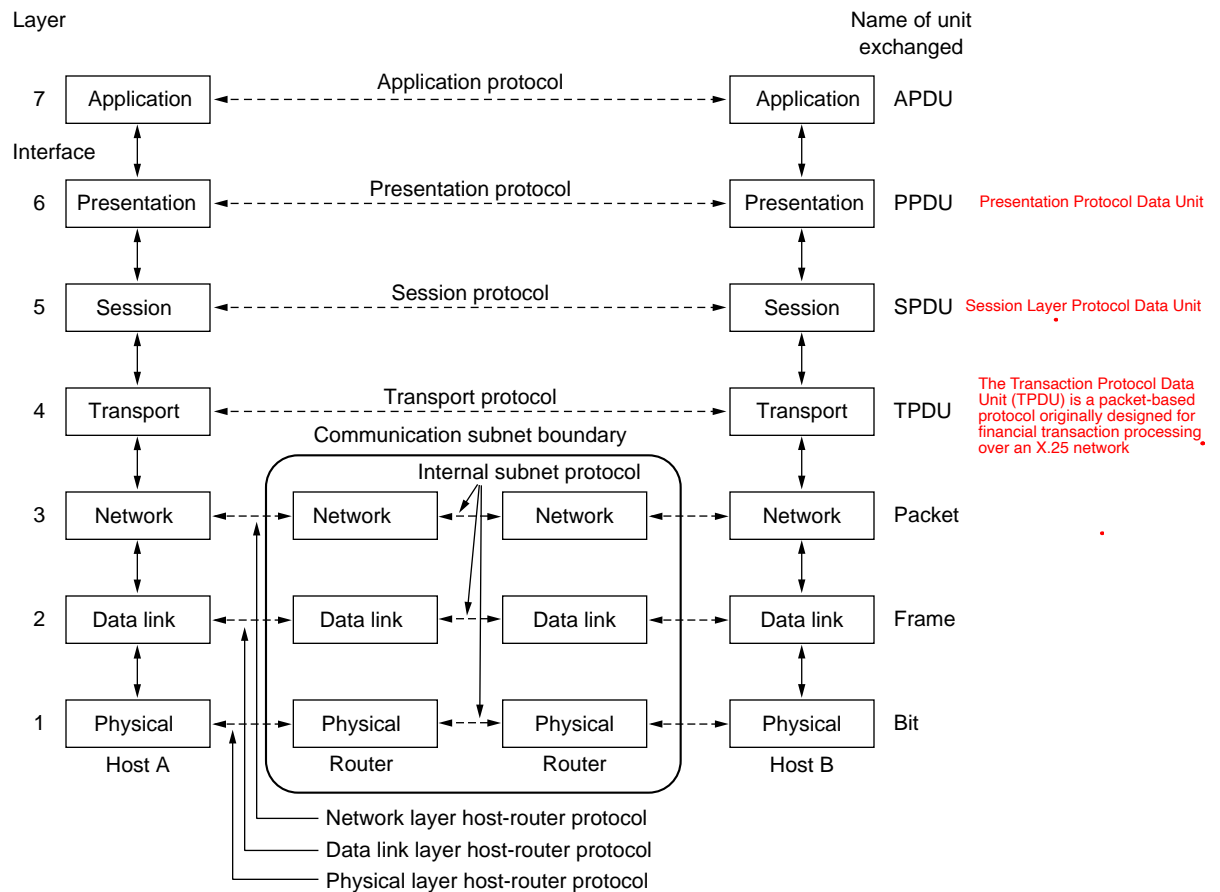


Figure 6: OSI reference model: another illustration

(6) The Transport Layer

Gen. Services: Accept and pass data
 Design issues: multiple and multiplex transport
 determine service types to session layer and network
 (error-free point-to-point FIFO channel, no guaranteed order)
 the first end-to-end layer
 connection management

(7) The Session Layer

Gen. Services: establish sessions between users
 data transport
 enhanced services: remote login, file transfer
 token management
 synchronization (checkpointing in long transmissions)

(8) The Presentation Layer 网页显示??

Gen. Services: ensure syntax and semantics of the information
coding and encoding of abstract data structures (eg bank records)
data compression, cryptography

(9) The Application Layer

Gen. Services: general and special user-support facilities

Examples: terminal mapping
file system mapping
electronic mails
HTTP services

(10) Comments:

- a. The OSI Reference Model is intended as a template for the structure of communication subsystems, not as a mandatory requirement.
- b. Standards for different protocols in the different layer of the OSI Reference Model have been proposed by ISO, IEEE, ITU, and DARPA.
- c. TCP/IP used by Internet has been used as the bases of ISO standards as the internetworking protocol.
- d. The service and functionalities of the top three layers are sometime overlapping and difficult to distinguish clearly. The TCP/IP model (to be discussed) next combine them into one layer.

(11) Protocol stacks: Section 1.5 of first textbook.

- a. Fig.1.38, p.84 illustrates the notion of protocol stacks
- b. The Internet protocol stack is to be discussed next.

5. The TCP/IP Reference Model

(1) The TCP/IP model: developed with the Arpanet.

- a. Goal of Arpanet: connecting different hosts and networks in the US military reliably.
- b. Packet switching (to be covered later) is the technique was employed by Arpanet. The layer that ensured reliability (keeping communications possible as long as the source and destination machines are still up) is the **internet layer**.

c. Structure of the TCP/IP model: Fig.7

- (a) The *presentation* and *session* layers are not present.
- (b) The *network* layer in the OSI model corresponds to the *internet* layer.
- (c) The *data link* and *physical* layers together correspond to the *host-to-network* layer. The TCP/IP model itself didn't say much about this layer. It is a combination of various hardware techniques and software (drivers) that provide support for host-to-host, network-to-network, and host-to-network communications using IP packets.

d. Protocols and networks in the initial TCP/IP model: Fig.8

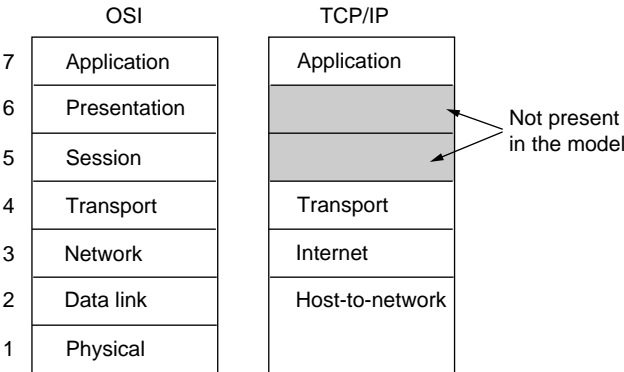


Figure 7: The TCP/IP reference model

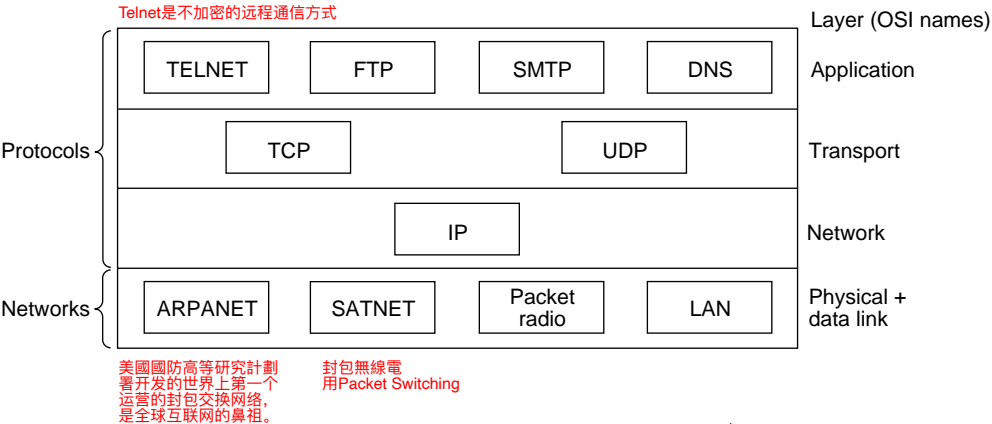


Figure 8: Protocols and networks in the initial TCP/IP reference model

6. Example Networks

- (1) ARPANET – created by ARPA, now DARPA (defense Advanced Research Projects Agency), in 1969

a. Background

United States Department of Defense

(a) DoD funded many CS depts for computer network researches.

(b) MILNET was derived from ARPANET.

军事网 military network

b. Original Arpanet design: Fig.9

The Interface Message Processor (IMP) was the packet switching node used to interconnect participant networks to the ARPANET from the late 1960s to 1989.

(a) IMP (interface message processor). The Arpanet began as a group of IMPs connected with 56Kbps transmission lines.

(b) Software: IMP-to-IMP protocol; IMP-to-Host protocol; Host-to-host protocol.

c. Growth of the Arpanet (from Dec. 1969 to Sept. 1972): Fig.10.

(a) It eventually grew to a network with thousands of sites and more than 100,000 users.

(b) The use of TCP/IP protocol suite demonstrated its viability to growth.

d. Main contributions:

(a) TCP and IP. TCP (transfer control protocol), IP (internet protocol) were developed to connect multiple subnetworks.

(b) Very influential, besides TCP and IP, many network protocol, such as FTP (file transfer protocol), SMTP (simple mail transfer protocol), TELNET (remote login).

(c) It played the role of the direct predecessor of today's Internet

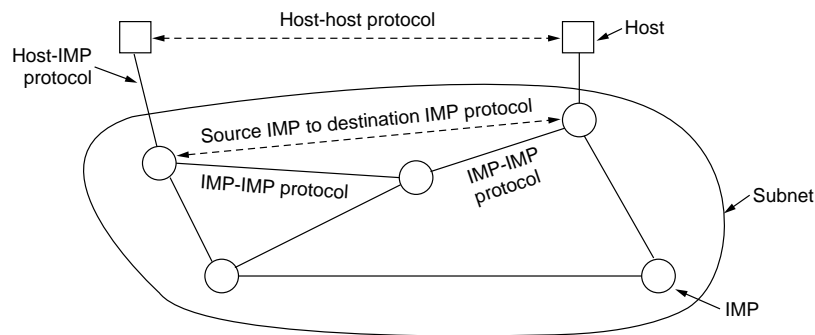


Figure 9: The original Arpanet design

(2) CSNET – funded by NSF in 1980, to connect CS depts in US.

A network of networks.

a. Not a real network like ARPANET. It is a *metanetwork*, using transmission facilities provided by other networks and adding a uniform protocol on top to make it look like a single logical network to users.

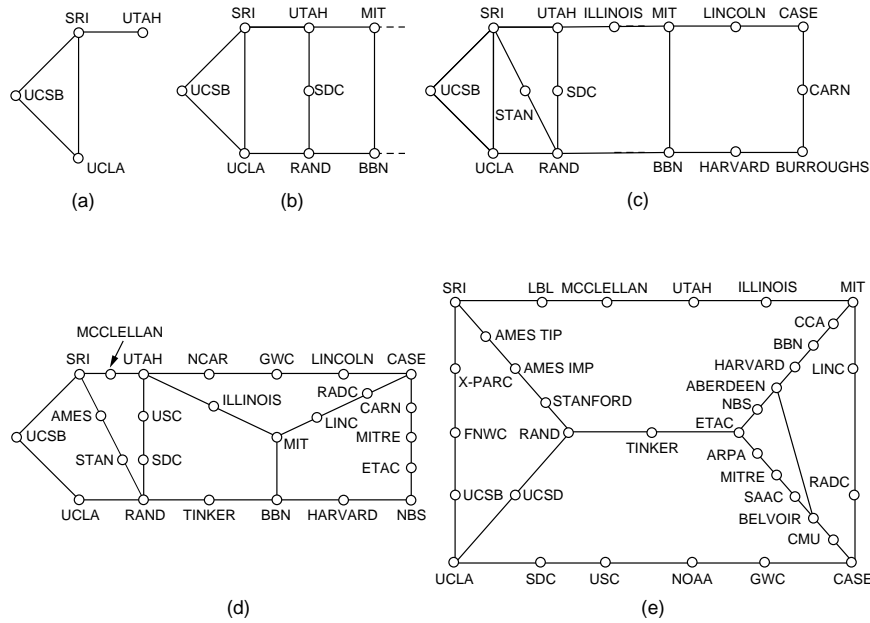


Figure 10: Growth of the Arpanet. (a) December 1969. (b) July 1970. (c) March 1971. (d) April 1972. (e) September 1972.

- b. Four components, tied together by a machine called CSNET-RELAY (run by a company called BBN, in Cambridge, Mass.) ARPANET, public X.25 networks (Telenet and Uninet), PHONENET (calling up CSNET-RELAY through phones), CYPRESS (use leased lines and Microvax).
 - c. Basic services: emails. Remote login possible except PHONENET.
 - d. Extended to NSFNET, use 1.5Mbps microwave links for long distance transmission.
National Science Foundation Network 微波通讯
- (3) NSFNET – funded by NSF in 1980, as a version of the successful Arpanet to connect research groups in all academic institutions
- a. Backbone network (Fig.11): NSF already had six supercomputers located in San Diego, Boulder, Champaign, Pittsburgh, Ithaca, and Princeton. NSF funded the building of a backbone network that connects them.
 - (a) Each supercomputer was associated with a microcomputer called fuzzball, which were connected with 56kbps leased lines to form the subnet (within the city). The fuzzball used TCP/IP from the beginning (hence NSFNET is the first TCP/IP based WAN).
 - (b) The backbone supported 1.5Mbps data rate

- b. NSF funded about additional 20 subnets connecting to the backbone.
- c. To further its growth through commercialization, in 1990 NSF established (with MERIT, MCI, and IBM) a non-profit organization ANS (advanced networks and services) to manage NSFNET.
 - (a) ANS upgraded NSFNET to 45Mbps and NSFNET was renamed to ANSNET.
 - (b) ANSNET was sold to AOL around 1995.

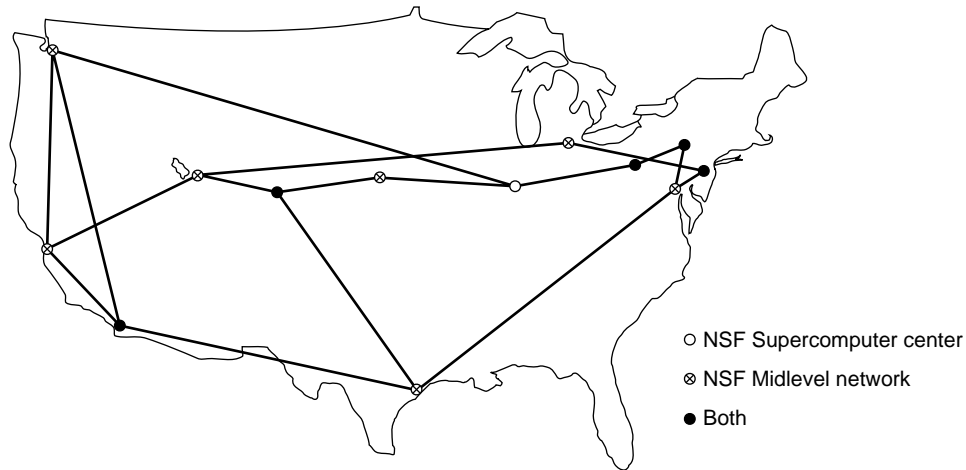


Figure 11: The NSFNET backbone in 1988

Systems Network Architecture (SNA)

- (4) SNA, by IBM, in 1974.

就是为了整合各种通信方式

- a. Intended to unify communication methods among IBM machines. Before SNA, hundreds of comm. products, three dozens access methods, more than one dozen data link protocols.
 - b. Featured by layered architectures. OSI reference model is strongly influenced by SNA
 - c. Important concepts: routing, flow control.
- (5) BITNET (Because It's Time to NETwork), started in 1981 at CUNY and Yale.
 - a. With ideas same as CSNET, except for all departments, not just the CS depts. In late of 1990's it had more than 500 sites around the world.
 - b. Similar to CYPRESS, using leased lines
 - c. Transmission protocols, donated by IBM, not compatible with TCP/IP and OSI (based on ideas of transmitting 80-column punched cards).

- d. Financial policy: leased line. Must agree to be connected by other sites.
- e. Basic services: file transfers and emails, very limited remote logins.

(6) Internet

- a. A direct descendant of ARPANET
- b. Standard communication protocols: TCP/IP
- c. Enormous number of applications due to its open communication standards
- d. Overview of the Internet: Fig.12

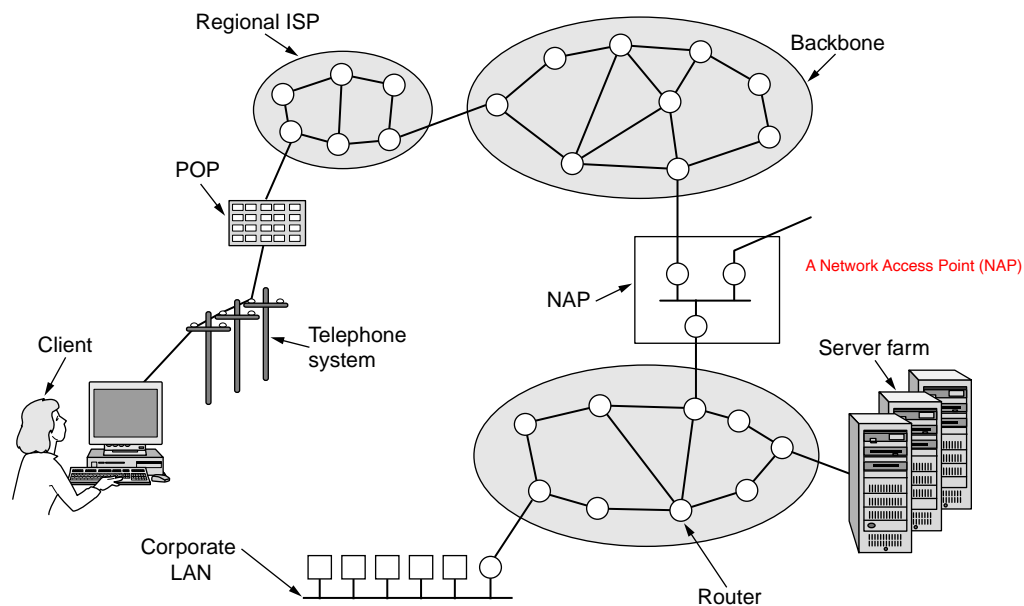
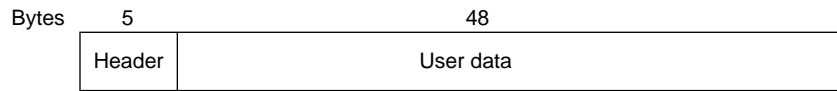


Figure 12: Overview of the Internet

Asynchronous Transfer Mode)

(7) ATM networks

- a. Motivations: as a new technique to provide unified transmission services to all Internet applications (files, audio, video, and etc)
- b. ATM cells and ATM virtual circuits
 - (a) ATM cells: Fig.13. Motivation: to accommodate various types of applications. Each cell is of 53 bytes, with a 5-byte header and 48-byte payload.
 - (b) ATM virtual circuits: each ATM communication session must establish an ATM virtual circuit first. Each virtual circuit will be assigned a unique connection identifier (Fig.14).



ATM is a connection-oriented technology.

Figure 13: An ATM cell

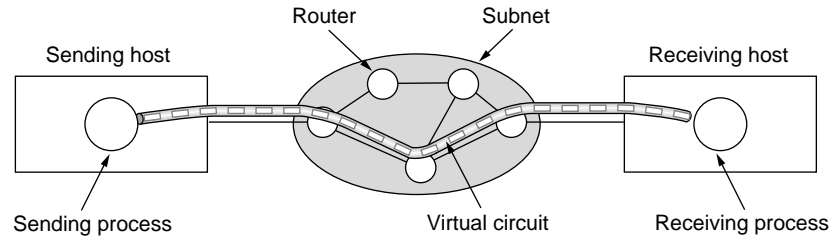
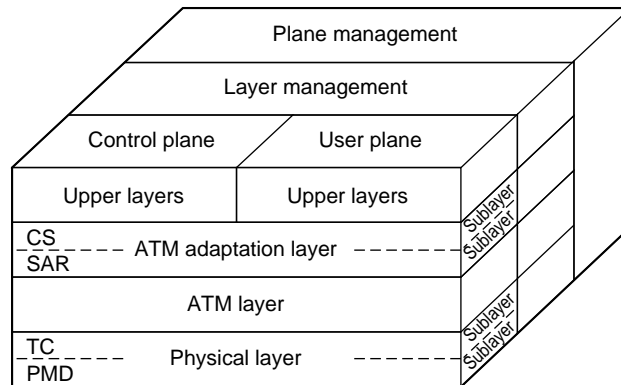


Figure 14: An ATM virtual circuit

c. ATM links: 155Mbps or 622Mbps

- (a) The 155Mbps is chosen to accommodate HDTV. The exact number is chosen for compability with IBM's SONET
- (b) The value 622Mbps is 155×4 for better multiplexing.

d. The ATM reference model: Fig.15 and Fig.16



异步传输模式 (英語: Asynchronous Transfer Mode, ATM)

CS: Convergence sublayer
SAR: Segmentation and reassembly sublayer
TC: Transmission convergence sublayer
PMD: Physical medium dependent sublayer

hysical Medium Dependent sublayers or PMDs further help to define the physical layer of computer network protocols.

Figure 15: The ATM reference model

e. Future of ATM

- (a) As a relatively new technology, ATM has been accepted well and has become an integrated part of today's PSTN and Internet.
- (b) Due to the emergence of all optical networks and increasingly importance of wireless communications and networks, ATM's further development is limited.

OSI layer	ATM layer	ATM sublayer	Functionality
3/4	AAL	CS	Providing the standard interface (convergence)
		SAR	Segmentation and reassembly
2/3	ATM		Flow control Cell header generation/extraction Virtual circuit/path management Cell multiplexing/demultiplexing
2	Physical	TC	Cell rate decoupling Header checksum generation and verification Cell generation Packing/unpacking cells from the enclosing envelope Frame generation
1		PMD	Bit timing Physical network access

Figure 16: The ATM layers and sublayers, and their functions