LECTURE 1:
Systems Architecture

CIS 410
Hardware and Software Architecture
Winter 2011

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Learning Objectives

- Describe the activities of information systems professionals.
- Describe the general capabilities of a computer.
- Describe computer system components and their functions.

Outline

- Activities of information systems professionals
- Computer capabilities
- Computer system components
  - Hardware
    - CPU
    - Storage
    - Input/output devices
  - Software
- Computer system classes
- Computer networks

Technology and Knowledge

- Technical knowledge of computer hardware and systems software is required to develop information systems.
- Computers
  - Increasingly complex and powerful.
  - Easier to use.
- Why is technological knowledge important?

Typical Computer Ad

- Is the computer fast enough to run necessary programs?
- Is the computer cost-effective?

Acquiring and Configuring Technological Devices

- To purchase a computer, you must:
  - Know your hardware and software preferences.
  - Know your hardware and software requirements.
  - Have sufficient knowledge of the available alternatives.
  - Understand related technical terms.
- The knowledge required to purchase and configure technically complex devices is greater than the knowledge needed to use them.

Why Study Computer System Architecture?

- User
- Systems analyst
- Systems programmers
- Web designer
- Hardware personnel
- Systems managers

Why Study Computer System Architecture? (Cont.)

- User
  - Understand system capabilities and limitations.
  - Make informed decisions.
  - Improve communications with information technology professionals.
- Systems Analyst
  - Conduct surveys, determine feasibility and define and document user requirements.
  - Specify computer systems to meet application requirements.

Why Study Computer System Architecture? (cont.)

- Systems Programmers
  - Develop system software (operating systems, compilers, database management systems, network security monitors).
  - Create efficient application software for specific processing needs.
  - Perform hardware troubleshooting and software installation and configuration.
  - Need in-depth knowledge of system software, computer hardware, and networks
    - System software often directly controls computer hardware or interacts with networks.

Why Study Computer System Architecture? (cont.)

- Web Designer
  - Optimize customer accessibility to web services.
  - System administration of web servers.
  - Select appropriate data formats.
  - Design efficient web pages.
- Hardware Personnel
  - Design, install, and maintain hardware.
  - Require extensive knowledge of computer hardware (processing, data storage, input/output, and networking devices).

Why Study Computer System Architecture? (cont.)

- Systems managers
  - Install, configure, maintain, and upgrade computer systems
  - Maximize system availability
  - Optimize system performance
  - Ensure system security
- Common job titles of systems managers
  - Computer operations manager
  - Network administrator
  - Database administrator
  - Chief information officer

Systems Managers

- Computer operations manager
  - Oversees operation of a large information processing facility (scheduling, staffing, security, system backups, maintenance, upgrades)
  - Knowledge requirements
    - Broad base of technical knowledge to understand organization's information systems and infrastructure
    - Capability of understanding advice of technical staff

Systems Managers (Cont.)

- Network administrator
  - May be responsible for network infrastructure
    - Requires technical expertise in computer hardware, telecommunications, and system software
    - Emphasis on network and data communication technology
  - May be responsible for local area network (LAN)
    - Provides access to many resources
    - One of the most demanding positions

Systems Managers (Cont.)

- Network administrator responsible for LAN
  - Operates and maintains network
  - Installs and maintains end-user software
  - Installs and configures hardware
  - Trains users
  - Assists management in selecting and acquiring software and hardware

Systems Managers (Cont.)

- Database administrator
  - Responsible for management of large collections of data
  - Requires technical expertise and ability to help the organization exploit its data resources

Systems Managers (cont.)

- Responsibilities of a Chief Information Officer
  - Organization's computers, networks, software, and data
  - Strategic planning
  - Effective use of information/computing technology
  - Broad base of technical knowledge to interact effectively with all technical specialists
  - Vision of how technology is changing and how best to respond to changes to support organizational objectives

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Computer Capabilities

- **Computer** – a device that can accept numeric inputs, perform computational functions such as addition and subtraction, and communicate results.
- Computer Capabilities
  - Processing;
  - Storage capability to hold large number of instructions;
  - Flexible communication capability.

Processing

- Implemented by the processor.
- A **processor** is a device that performs data manipulation and transformation functions including:
  - Computation (add, sub, mul, div).
  - Comparison (less than, greater than, equal to, not equal to).
  - Data movement among memory, mass storage, and input/output devices.
- Computer processors also can perform a more complex class of processing tasks called algorithms.

Storage Capability

- Types of information to be stored
  - Intermediate processing results
  - Data
  - Programs
- Characteristics of storage devices vary widely
  - Access speed
  - Reliability
  - Cost

Communication Capability

- Input/Output devices must encompass many communication modes
  - Sound, text, and graphics (for humans)
  - Electronic or optical communication (for other computers)

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Computer Basics

- Computer system: hardware + software
  - Hardware: the physical components
  - Software: the instructions that tell the hardware what to do
- A computer requires both hardware and software
- Each is essentially useless without the other

Architecture Components

- *Hardware*
  - Processes data by executing instructions
  - Provides input and output
- *Software*
  - Instructions executed by the system
- Data
  - Fundamental representation of facts and observations
- Communications
  - Sharing data and processing among different systems

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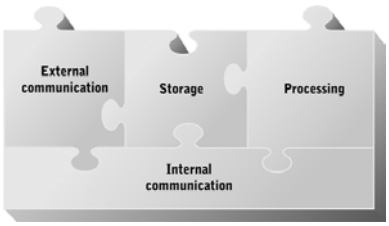
Computer Hardware System

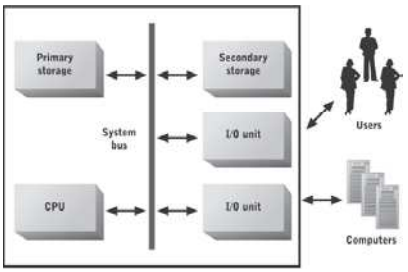
- All computer systems, no matter how complex, consists of the following hardware:
  - At least one CPU,
  - Memory,
  - I/O devices, and
  - Long-term storage.

Functions of Computer Hardware

Figure 2-6
The primary functions of computer hardware



Hardware Components of a Computer System



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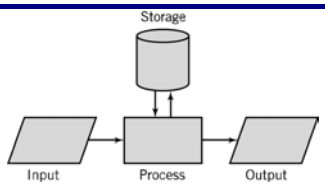
Standard Hardware Organization



- Input/Output: I/O devices facilitate user interaction.
- Processing: CPU executes the computer program.
- Storage: holds data and instructions, including main memory and secondary storage.

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Components of Computer System Hardware

- Central Processing Unit (CPU): executes program commands
- Storage devices: primary storage, secondary storage
- Input/Output devices
- System bus: bundle of wires that carry signals and power between different components.

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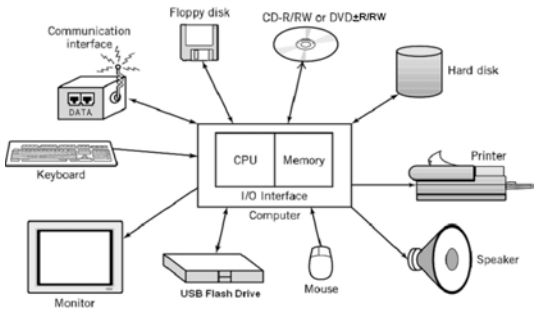
Typical Personal Computer System



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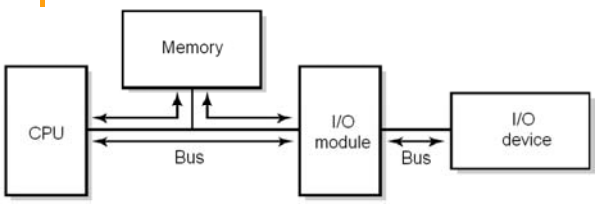
Basic CPU-Memory-I/O Pathway



Components in CPU-Memory-I/O Pathway

- Programs are loaded into memory before being executed.
- Except for a single pieces of input or output that can be transferred directly from a register of CPU, data from input or intended for output is normally stored at least temporarily in memory.
- Then the data can be accessed by the appropriate program.
- Hence, memory holds program instructions and data for currently executing programs.
- The I/O modules (I/O controllers) act as interfaces between the CPU/memory and I/O devices.

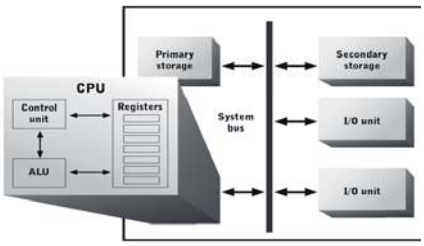
Outline

CPU: Central Processing Unit

- CPU is a general-purpose processor.
  - Executes all instructions (computation and comparison functions)
  - Directs all data movement
- Special-purpose processor:
  - designed to perform only one specific task in devices such as microwave ovens, DVD players, etc.

Components of CPU

Figure 2-8 Components of the central processing unit (CPU)



Primary Components of a CPU

- ALU: arithmetic/logic unit
  - Performs arithmetic and Boolean logical calculations.
- CU: control unit
  - Controls processing of instructions.
  - Controls movement of data within the CPU.
  - Accesses program instructions and issues appropriate commands to ALU.
- Registers:
  - Store data or instructions that are needed immediately or frequently.

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Comparison of Storage Types

Storage type	Implementation	Content	Typical quantity
CPU registers	High-speed electrical devices in the CPU	Currently executing instructions and associated data inputs and outputs	Several dozen to a few hundred instructions and data items
Primary storage	High-speed electrical devices (RAM) outside but close to the CPU	Currently running programs and data needed immediately (if they fit in primary storage)	1 to 8 billion data items per CPU
Secondary storage	Low-speed electromagnetic and optical devices	Programs not currently running and data not currently being accessed by programs	Billions (gigabytes), trillions (terabytes), or quadrillions (petabytes) of data items

Primary Storage (Main Memory)

- Holds program instructions and data for currently executing programs.
- Implemented with random access memory (RAM)
  - Provides access speed and allows CPU to read or write to specific memory locations
  - Volatile: loses its values when power is removed.
    - Does not provide permanent storage

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Memory

- Short-term storage for CPU calculations.
- Also known as *primary storage*, working storage, main memory, and *RAM (random access memory).*
- Consists of bits, each of which hold a value of either 0 or 1.
  - 8 bits = 1 byte
- Holds both instructions and data of a computer program (*stored program concept*).

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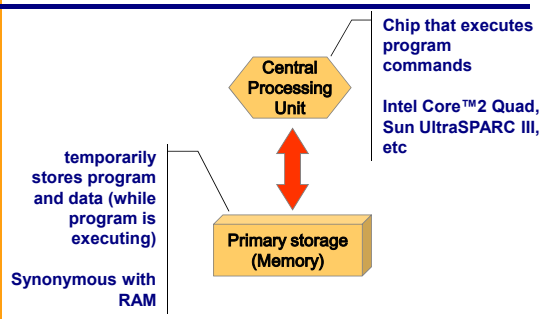
CPU and Memory



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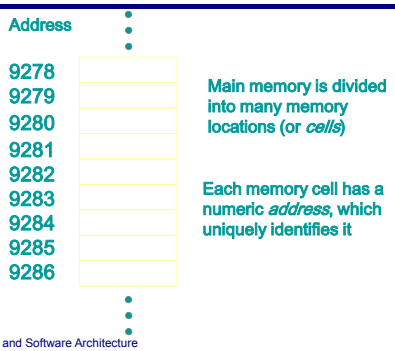
Memory Cell and Address



Main memory is divided into many memory locations (or *cells*)

Each memory cell has a numeric *address*, which uniquely identifies it

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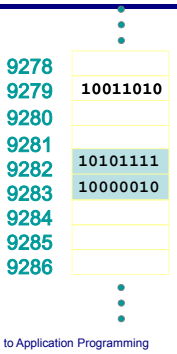
Storing Information in Memory



Each memory cell stores a set number of bits (usually 8 bits, or one *byte*)

Large values are stored in consecutive memory locations

In this example, 8-bit data **10011010** is stored in the memory location with address **9279.**
16-bit data **10101111 10000010** is stored in the memory locations with address **9282** and **9283.**

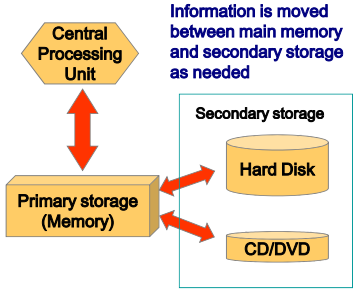
Secondary Storage

- Composed of high-capacity nonvolatile storage devices that hold:
  - Programs not currently being executed
  - Data not needed by currently executing programs
  - Data needed by currently executing programs that does not fit within available primary storage

Secondary Storage Devices

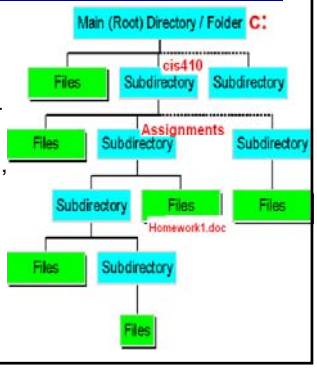
Secondary storage devices provide long-term storage to save program and results, including

Hard disks, Floppy disks, ZIP disks, CD/DVD, HD-DVD/Blu-ray Disc, USB flash drives, etc



Secondary Storage Organized as a Tree-and-Branch Structure

- Secondary storage (such as hard disk) organization graph looks like an upside-down **tree** with the root directory (C:, D:, etc) at the top and the leaves (files) at the bottom.



Storage Capacity

- Every storage device has a *storage capacity*, indicating the number of bytes it can hold
- Capacities are expressed in various units:

Unit	Symbol	Number of Bytes
kilobyte	KB	$1K = 2^{10} = 1024$
megabyte	MB	$1M = 2^{20}$ (over 1 million)
gigabyte	GB	$1G = 2^{30}$ (over 1 billion)
terabyte	TB	$1T = 2^{40}$ (over 1 trillion)

- For example, `512MB` memory holds $512*2^{20}$ bytes, or $512*2^{20}*8$ bits

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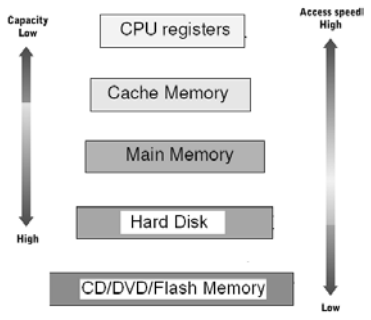
Storage Performance Hierarchy



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Input/Output Devices

- Implement external communication functions
  - Input devices accept input from a human and convert that input into something the computer can understand.
  - Output devices display information to the user and implement communication among computer systems.
- Human-oriented communication devices (e.g., keyboard, mouse, printer)
- Computer-oriented communication devices (e.g., modem, network interface unit)

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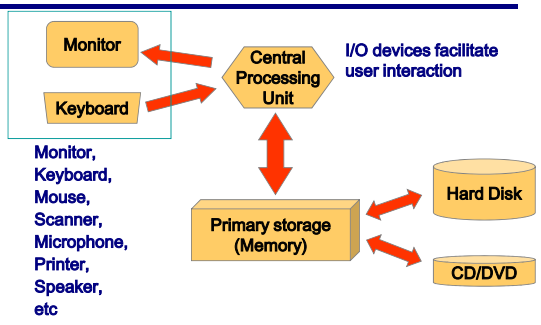
Input / Output Devices (Cont.)



System Bus

- Internal communication channel that connects all other hardware devices
- Main channel for moving data and instructions among hardware components
- Capacity is critical to performance, secondary storage, and I/O device performance

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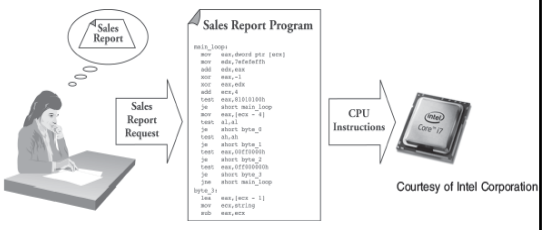
The Role of Software

- Translates user requests into machine instructions
- Performs complex translation process that bridges two gaps
  - Human language to machine language (binary)
  - High-level abstraction to low-level detail

Software

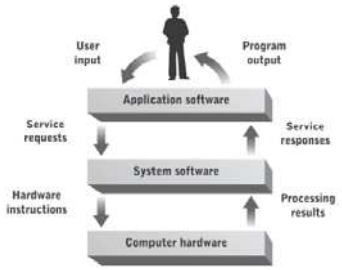


Courtesy of Intel Corporation

Software Types

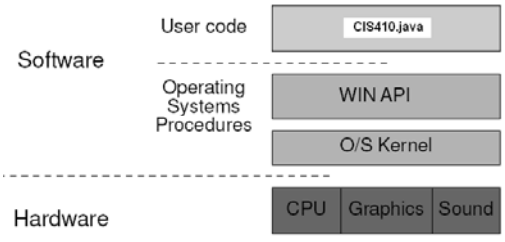
Application program	▪ Stored set of instructions for responding to a specific request ▪ Used directly by end users
Utility program	▪ Contains instructions for performing general-purpose tasks ▪ Usually operates invisibly in the background
System software	▪ Implements utility functions needed by many application programs ▪ Allocates computer resources to application programs ▪ Manages computer resources ▪ Acts as an interface between the user and the system

Layered Approach to Software Construction and Operation



The interaction between the user, application software, system software, and computer hardware

Layered Hierarchy of Software on a Hardware Bed



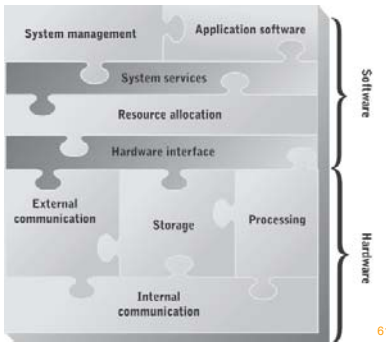
- **WIN API: Windows Application Programming Interface**

System Software Layer Functions

- System management: manage and control computer resources
- System services: perform common functions
- Resource allocation: allocate hardware and other resources among multiple users and programs
- Hardware interface: control and interact with individual hardware devices

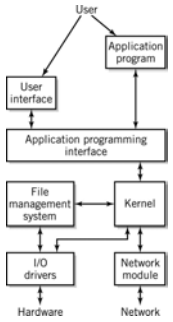
Software and Hardware

Fig 2.14 Software layers and their relationship to hardware



Software Component

- Applications
- *Operating system*
  - API: application program interface
  - File management
  - I/O
  - Kernel
    - Memory management
    - Resource scheduling
    - Program communication
    - Security
  - Network module



Operating Systems

- Most important system software component
- Collection of utility programs that provides:
  - Support for users and application programs
  - Allocation of resources to multiple users and application programs
  - Controlling access to hardware
- Examples of OS: Windows XP/Vista/7, Unix, Linux, Mac OS X

Operating System Functions

- Program storage, loading and execution
- File manipulation and access
- Secondary storage management
- Network and interactive user interfaces

Application Development Software

- Programs used to develop other programs
- Types
  - Program translators
  - Program editors
  - Debugging tools
  - System development tools
- Example: compilers, interpreters, and integrated software development packages such as Java, C++, VB, MS Visual Studio, Jcreator, IBM WebSphere, and Oracle JDeveloper.

Outline

Activities of information systems professionals

Computer capabilities

Computer system components

- Hardware
  - CPU
  - Storage
  - Input/output devices
- Software

⇨ Computer system classes

Computer networks

Computer System Classes

Microcomputer	§ Meets information processing needs of single user § Examples: PCs, network computers
Portable	§ Meets information processing needs of a single user at a variety of levels § Examples: laptop, network, PDA
Midrange computer	§ Supports many programs and users simultaneously
Mainframe	§ Handles information processing needs of large number of users and applications § Large amounts of data storage and access
Supercomputer	§ Designed for rapid mathematical computation

Class	Typical product	Typical specifications	Approximate cost	CPUs
Portable	Dell Latitude E6400	4 billion main memory cells 250 billion disk storage cells Rewritable DVD drive 14-inch display	$1150	2
Microcomputer	Dell Optiplex 760	4 billion main memory cells 500 billion disk storage cells Rewritable DVD drive	$1000	2
Workstation	Dell Precision T7500	12 billion main memory cells 1.5 trillion disk storage cells Rewritable high-capacity DVD drive Dual high-speed 3D graphics processors	$8350	8
Midrange	Dell PowerEdge T610	16 billion main memory cells 4 trillion high-speed disk storage cells High-speed fault-tolerant storage subsystem Tape backup	$15,050	8
Mainframe	IBM Z10 E64	512 billion main memory cells 100 trillion high-speed disk storage cells High-capacity tape archive system Four high-speed network interfaces	$500,000	64
Supercomputer	IBM Blue Gene/P	2 trillion main memory cells No internal disk storage	$1,300,000	4096

Table 2.2 Representative products in various computer classes (2009)

Multicomputer Configurations

- Any organization of multiple computers to support a specific set of services or applications
- Common configurations
  - Cluster
  - Blade
  - Grid
  - Could

Cluster

- Group of similar or identical computers that cooperate to provide services or execute a common application
  - Connected by high-speed network
  - Typically located close to one another
- Advantages: scalability and fault tolerance
- Disadvantages: complex configuration and administration

Blade

- Circuit board that contains most of a server
- Same advantages and disadvantages as a cluster, but also:
  - Concentrate more computing power in less space
  - Are simpler to modify

Grid

- Group of dissimilar computer systems, connected by high-speed network, that cooperate to provide services or execute a common application
- Computers may be in separate rooms, buildings, or continents
- Computers work cooperatively at some times, independently at others

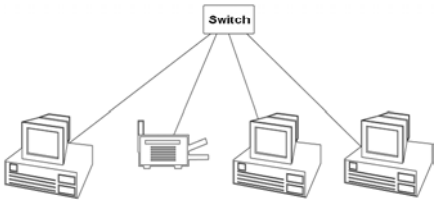
Cloud

- Set of computing resources with two components:
  - Front-end interfaces
  - Back-end resources
- Specific way of organizing computing resources for maximum availability and accessibility
- Minimum complexity in the user or service interface

Outline

Computer Networks

- A **computer network** is a set of hardware and software components that enable multiple users and computer systems to share information, software, and hardware resources.



Communication Components of Networks

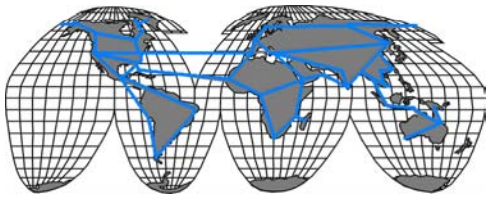
- Hardware
  - Communication *channels*
    - Physical connections between computer systems
    - Examples: wire cable, phone lines, fiber optic cable, infrared light, radio waves
  - Interface hardware
    - Handles communication between the computer and the communication channel
    - Examples: *Modem* or *network interface card (NIC)*
- Software
  - Network protocols: HTTP, HTTPS, FTP, TCP/IP

Protocols

- Common ground rules of communication between computers, I/O devices, and many software programs
- Examples
  - HTTP/HTTPS: between Web servers and Web browsers
  - TCP/IP: between computers on the Internet and local area networks

The Internet

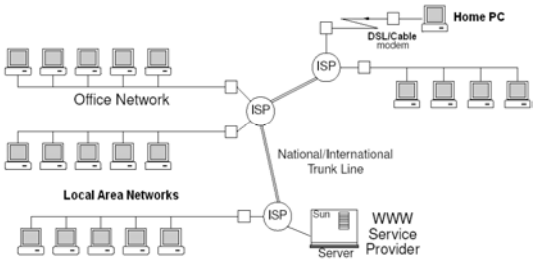
- The *Internet* is a WAN (Wide Area Network) and spans the entire planet.
- The software which manages Internet communication follows a suite of protocols called *TCP/IP.*



TCP/IP Protocol

- The *Internet Protocol* (IP) determines the format of the information as it is transferred
- The *Transmission Control Protocol* (TCP) dictates how messages are reassembled and handles lost information

ISP: Internet Service Provider



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IP and Internet Addresses

- Each computer on the Internet has a unique *IP address*, such as the address of CSULA web server:
  `130.182.3.1`
- Most computers also have a unique Internet name, which also is referred to as an *Internet address*:
  `www.calstatela.edu` (CSULA web server)
  `mars.calstatela.edu` (CSULA file server)
  `www.yahoo.com`
- The first part indicates a particular computer (`mars`)
- The rest is the *domain name*, indicating the organization (`calstatela.edu`)

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Digital Transmission Speed

- Bit rate (or called *data rate*)
  - Speed of transmission is usually shown in bits per second (bps)

Unit	Symbol	Number of Bits
Kilobits per second	kbps	$1k = 10^3 = 1000$
Megabits per second	Mbps	$1M = 10^6$ (1 million)
Gigabits per second	Gbps	$1G = 10^9$ (1 billion)

- Usually, 'b' stands for 'bit' and 'B' stands for 'byte'.

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Home/Small Office Wireless LAN Solution

- LAN: Local Area Network
- Wireless access routers can also assign IP address to your PCs using DHCP services.

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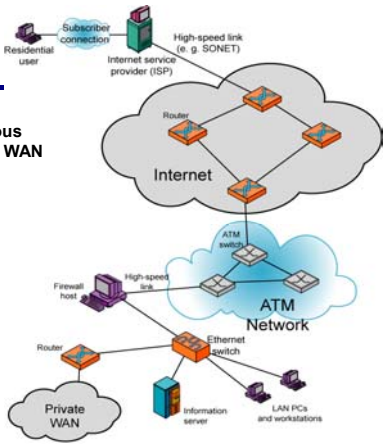
Networks System

ATM (Asynchronous Transfer Mode): a WAN system



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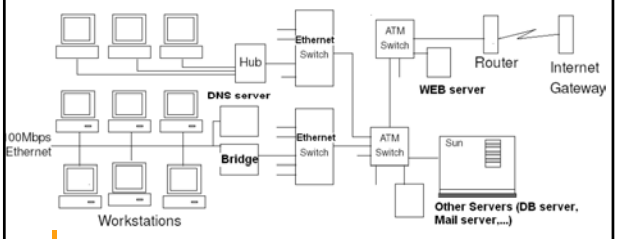
Campus Networks



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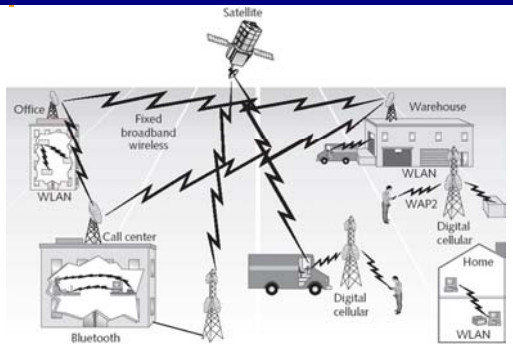
The Wireless Landscape



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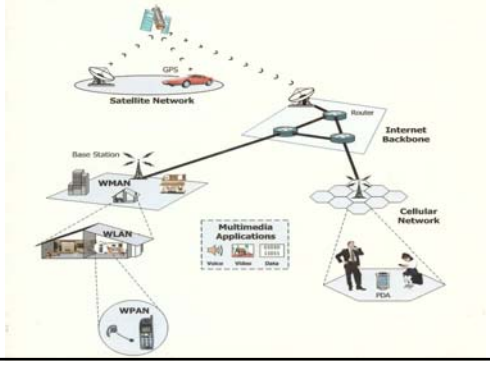
Wireless Communication Systems



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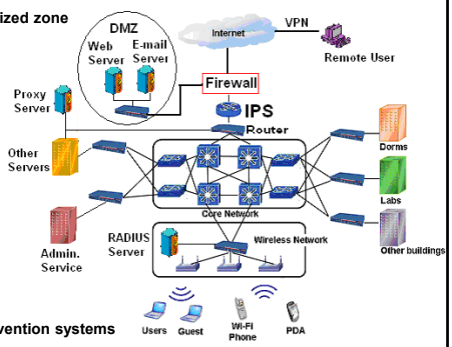
Campus Computer Network Protection

DMZ: demilitarized zone



IPS: intrusion prevention systems

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Summary

- Basic elements of computer system architecture
  - Hardware
  - Software
  - Networks
- Importance of knowing how all components of a computer system interrelate as well as their internal workings