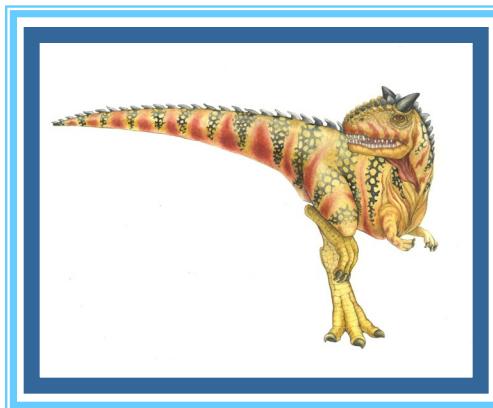


Chapter 1: Introduction (2)

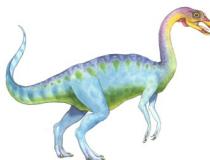




Process Management

- A process is a program in execution. It is a unit of work within the system. Program is a **passive entity**; process is an **active entity**.
- Process needs resources to accomplish its task
 - CPU, memory, I/O, files
 - Initialization data
- Process termination requires reclaim of any reusable resources
- Single-threaded process has one **program counter** specifying location of next instruction to execute
 - Process executes instructions sequentially, one at a time, until completion
- Multi-threaded process has one program counter per thread
- Typically system has many processes, some user, some operating system running concurrently on one or more CPUs
 - Concurrency by multiplexing the CPUs among the processes/threads





Process Management Activities

- The operating system is responsible for the following activities in connection with process management
 - Creating and deleting both user and system processes
 - Suspending and resuming processes
 - Providing mechanisms for process synchronization
 - Providing mechanisms for process communication
 - Providing mechanisms for deadlock handling





Memory Management

- To execute a program all (or part) of the instructions must be in memory
- All (or part) of the data that is needed by the program must be in memory
- Memory management determines what is in memory and when
 - Optimizing CPU utilization and computer response to users
- Memory management activities
 - Keeping track of which parts of memory are currently being used and by whom
 - Deciding which processes (or parts thereof) and data to move into and out of memory
 - Allocating and deallocating memory space as needed





Caching

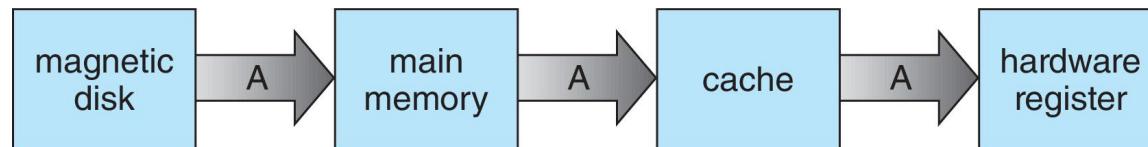
- Important principle, performed at many levels in a computer (in hardware, operating system, software)
- Information in use copied from slower to faster storage temporarily
- Faster storage (cache) checked first to determine if information is there
 - If it is, information used directly from the cache (fast)
 - If not, data copied to cache and used there
- Cache smaller than storage being cached
 - Cache management important design problem
 - Cache size and replacement policy





Migration of Data “A” from Disk to Register

- Multitasking environments must be careful to use most recent value, no matter where it is stored in the storage hierarchy



- Multiprocessor environment must provide **cache coherency** in hardware such that all CPUs have the most recent value in their cache
- Distributed environment situation even more complex
 - Several copies of a datum can exist
 - Various solutions covered in Chapter 19





File-System Management

- OS provides uniform, logical view of information storage
 - Abstracts physical properties to logical storage unit - **file**
 - Each medium is controlled by device (i.e., disk drive, tape drive)
 - ▶ Varying properties include access speed, capacity, data-transfer rate, access method (sequential or random)
- File-System management
 - Files usually organized into directories
 - Access control on most systems to determine who can access what
 - OS activities include
 - ▶ Creating and deleting files and directories
 - ▶ Primitives to manipulate files and directories
 - ▶ Mapping files onto secondary storage
 - ▶ Backup files onto stable (non-volatile) storage media





Mass-Storage Management

- Usually disks used to store data that does not fit in main memory or data that must be kept for a “long” period of time
- Proper management is of central importance
- Entire speed of computer operation hinges on disk subsystem and its algorithms
- OS activities
 - Mounting and unmounting
 - Free-space management
 - Storage allocation
 - Disk scheduling
 - Partitioning
 - Protection



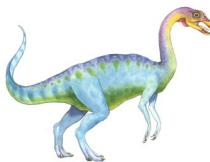


Characteristics of Various Types of Storage

Level	1	2	3	4	5
Name	registers	cache	main memory	solid-state disk	magnetic disk
Typical size	< 1 KB	< 16MB	< 64GB	< 1 TB	< 10 TB
Implementation technology	custom memory with multiple ports CMOS	on-chip or off-chip CMOS SRAM	CMOS SRAM	flash memory	magnetic disk
Access time (ns)	0.25-0.5	0.5-25	80-250	25,000-50,000	5,000,000
Bandwidth (MB/sec)	20,000-100,000	5,000-10,000	1,000-5,000	500	20-150
Managed by	compiler	hardware	operating system	operating system	operating system
Backed by	cache	main memory	disk	disk	disk or tape

Movement between levels of storage hierarchy can be explicit or implicit





I/O Subsystem

- One purpose of OS is to hide peculiarities of hardware devices from the user
- I/O subsystem responsible for
 - Memory management of I/O including buffering (storing data temporarily while it is being transferred), caching (storing parts of data in faster storage for performance), spooling (the overlapping of output of one job with input of other jobs)
 - General device-driver interface
 - Drivers for specific hardware devices





Protection and Security

- **Protection** – any mechanism for controlling access of processes or users to resources defined by the OS
- **Security** – defense of the system against internal and external attacks
 - Huge range, including denial-of-service, worms, viruses, identity theft, theft of service
- Systems generally first distinguish among users, to determine who can do what
 - User identities (**user IDs**, security IDs) include name and associated number, one per user
 - User ID then associated with all files, processes of that user to determine access control
 - Group identifier (**group ID**) allows set of users to be defined and controls managed, then also associated with each process, file
 - **Privilege escalation** allows user to change to effective ID with more rights





Virtualization (1)

- Allows operating systems to run applications within other OSes
 - Vast and growing industry
- **Emulation** used when source CPU type different from target type (i.e. PowerPC to Intel x86)
 - Generally slowest method
 - When computer language not compiled to native code – **Interpretation**
- **Virtualization** – OS natively compiled for CPU, running **guest** OSes also natively compiled
 - Consider VMware running WinXP guests, each running applications, all on native WinXP **host** OS
 - **VMM** (virtual machine Manager) provides virtualization services





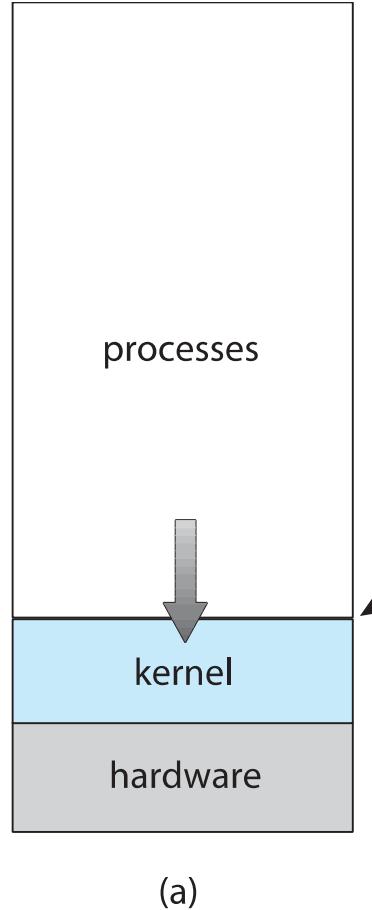
Virtualization (2)

- Use cases involve laptops and desktops running multiple OSes for exploration or compatibility
 - Apple laptop running Mac OS X host, Windows as a guest
 - Developing apps for multiple OSes without having multiple systems
 - Quality assurance testing applications without having multiple systems
 - Executing and managing compute environments within data centers
- VMM can run natively, in which case they are also the host
 - There is no general-purpose host then (VMware ESX and Citrix XenServer)





Computing Environments - Virtualization

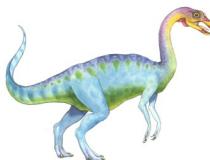




Distributed Systems

- Collection of separate, possibly heterogeneous, systems networked together
 - **Network** is a communications path, **TCP/IP** most common
 - ▶ **Local Area Network (LAN)**
 - ▶ **Wide Area Network (WAN)**
 - ▶ **Metropolitan Area Network (MAN)**
 - ▶ **Personal Area Network (PAN)**
- **Network Operating System** provides features between systems across network
 - Communication scheme allows systems to exchange messages
 - Illusion of a single system





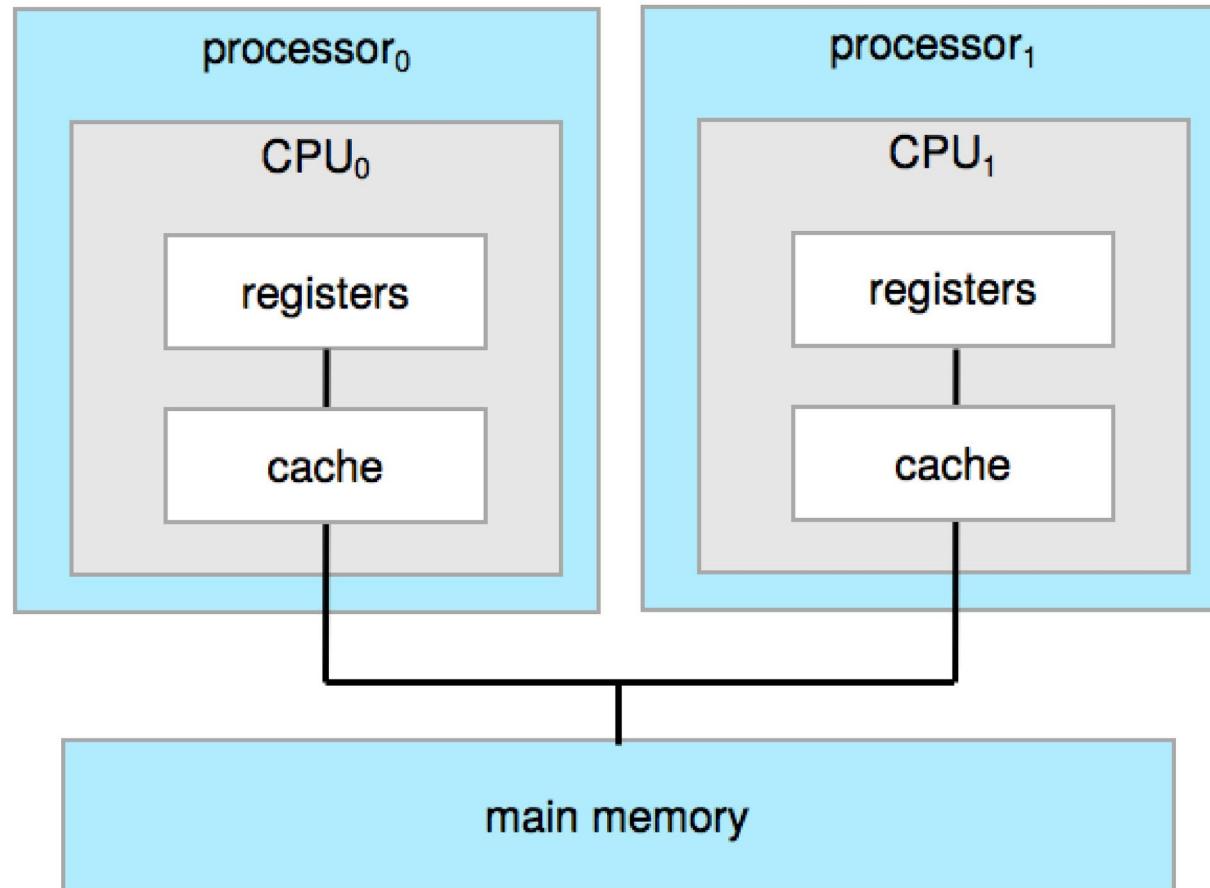
Computer-System Architecture

- Most systems use a single general-purpose processor
 - Most systems have special-purpose processors as well
- **Multiprocessors** systems growing in use and importance
 - Also known as **parallel systems, tightly-coupled systems**
 - Advantages include:
 1. **Increased throughput**
 2. **Economy of scale**
 3. **Increased reliability** – graceful degradation or fault tolerance
 - Two types:
 1. **Asymmetric Multiprocessing** – each processor is assigned a specific task.
 2. **Symmetric Multiprocessing** – each processor performs all tasks





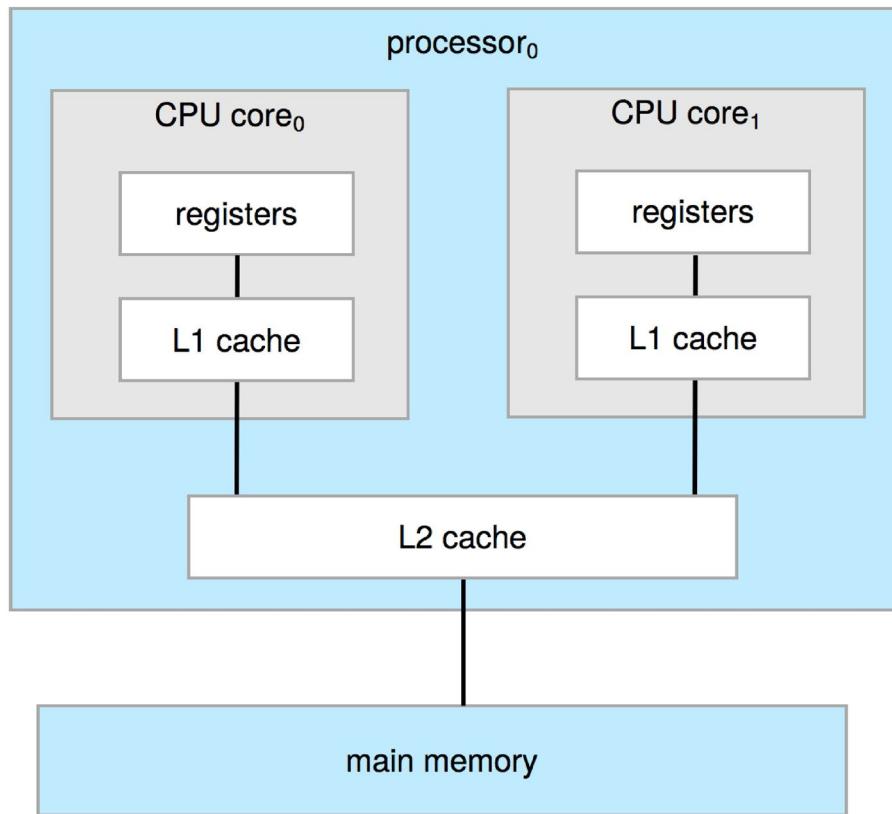
Symmetric Multiprocessing Architecture





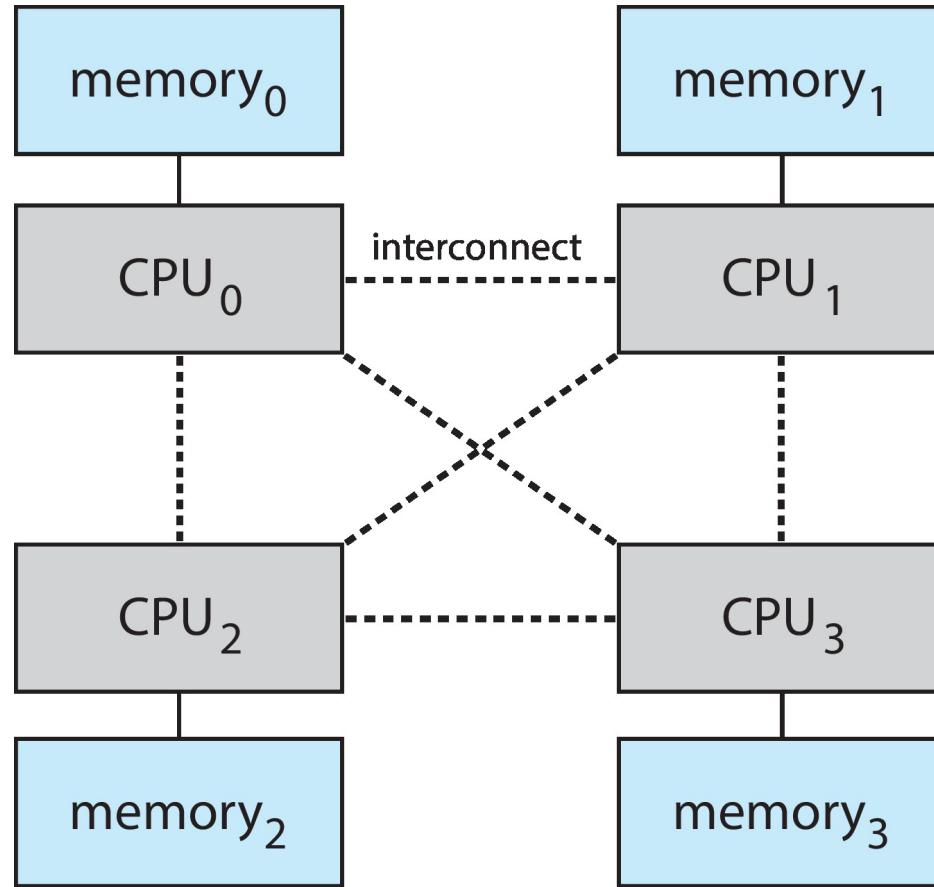
Dual-Core Design

- Multi-chip and **multicore**
- Systems containing all chips
 - Chassis containing multiple separate systems





Non-Uniform Memory Access System

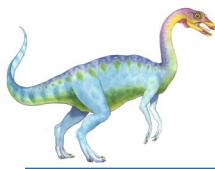




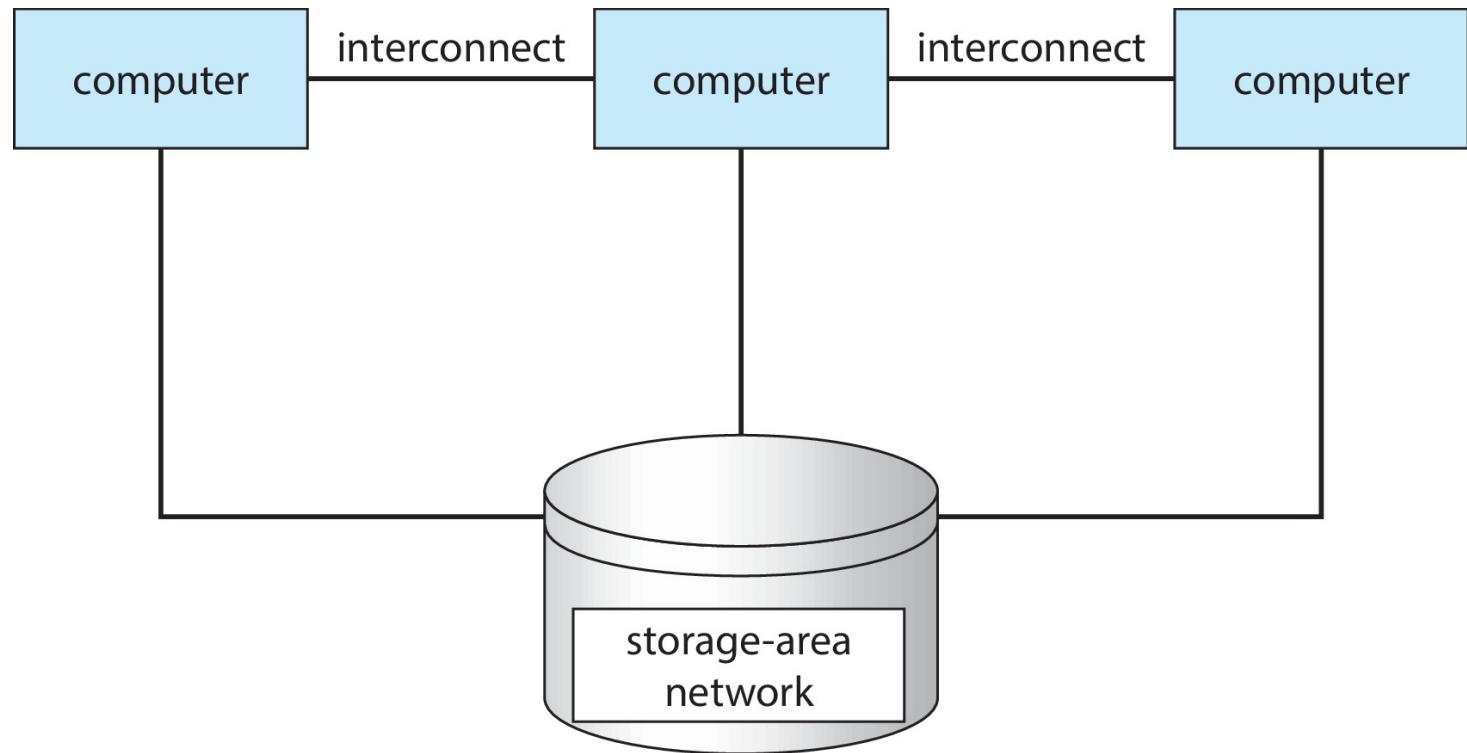
Clustered Systems

- Like multiprocessor systems, but multiple systems work together
 - Usually sharing storage via a **storage-area network (SAN)**
 - Provides a **high-availability** service which survives failures
 - ▶ **Asymmetric clustering** has one machine in hot-standby mode
 - ▶ **Symmetric clustering** has multiple nodes running applications, monitoring each other
 - Some clusters are for **high-performance computing (HPC)**
 - ▶ Applications must be written to use **parallelization**
 - Some have **distributed lock manager (DLM)** to avoid conflicting operations





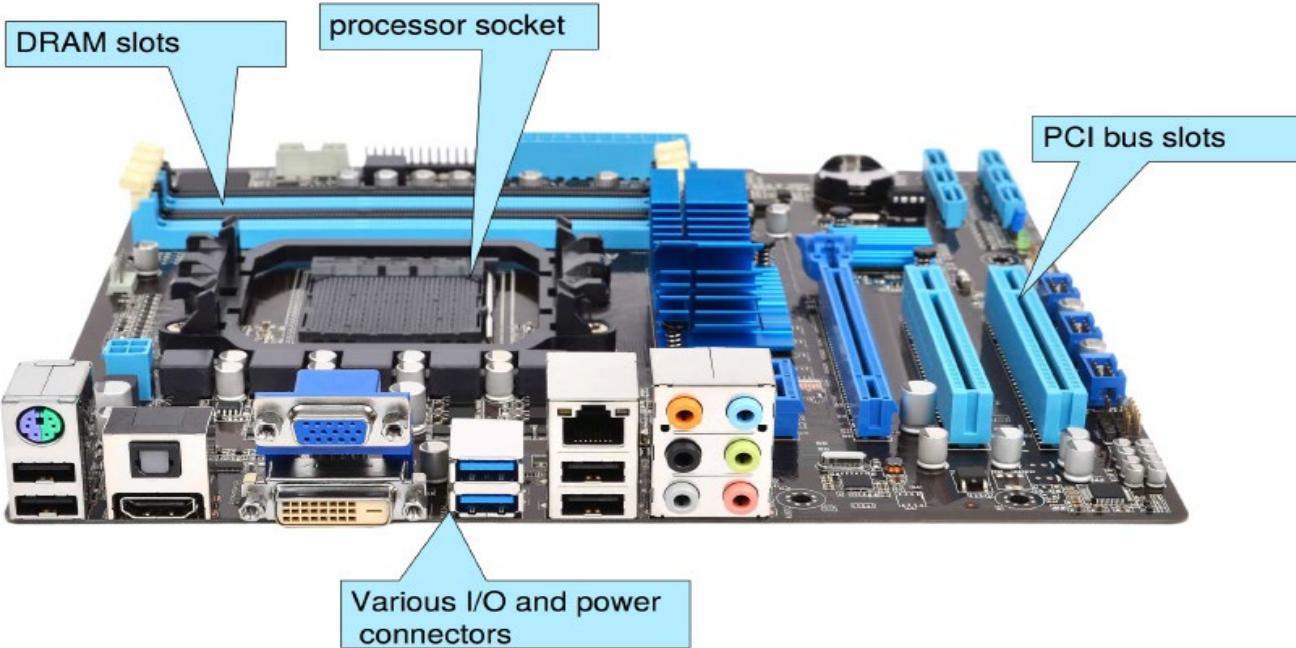
Clustered Systems





PC Motherboard

Consider the desktop PC motherboard with a processor socket shown below:



This board is a fully-functioning computer, once its slots are populated. It consists of a processor socket containing a CPU, DRAM sockets, PCIe bus slots, and I/O connectors of various types. Even the lowest-cost general-purpose CPU contains multiple cores. Some motherboards contain multiple processor sockets. More advanced computers allow more than one system board, creating NUMA systems.





Computing Environments

- Traditional
- Mobile
- Client Server
- Peer-to-Peer
- Cloud computing
- Real-time Embedded





Traditional

- Stand-alone general-purpose machines
- But blurred as most systems interconnect with others (i.e., the Internet)
- **Portals** provide web access to internal systems
- **Network computers (thin clients)** are like Web terminals
- Mobile computers interconnect via **wireless networks**
- Networking becoming ubiquitous – even home systems use **firewalls** to protect home computers from Internet attacks





Mobile

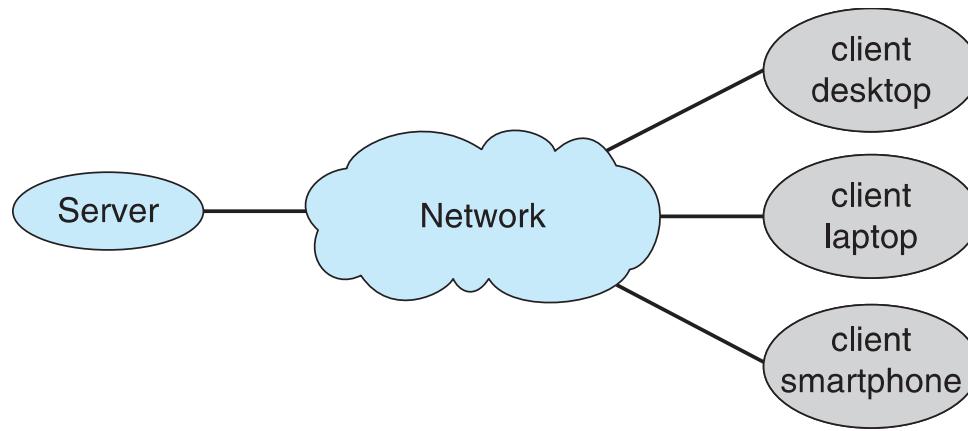
- Handheld smartphones, tablets, etc.
- What is the functional difference between them and a “traditional” laptop?
- Extra feature – more OS features (GPS, gyroscope)
- Allows new types of apps like ***augmented reality***
- Use IEEE 802.11 wireless, or cellular data networks for connectivity
- Leaders are **Apple iOS** and **Google Android**





Client Server

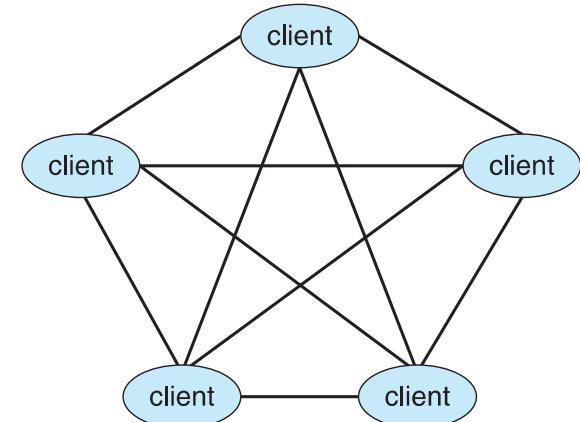
- Client-Server Computing
 - Dumb terminals supplanted by smart PCs
 - Many systems now **servers**, responding to requests generated by **clients**
 - ▶ **Compute-server system** provides an interface to client to request services (i.e., database)
 - ▶ **File-server system** provides interface for clients to store and retrieve files





Peer-to-Peer

- Another model of distributed system
- P2P does not distinguish clients and servers
 - Instead all nodes are considered peers
 - May each act as client, server or both
 - Node must join P2P network
 - ▶ Registers its service with central lookup service on network, or
 - ▶ Broadcast request for service and respond to requests for service via ***discovery protocol***
 - Examples include Napster and Gnutella, **Voice over IP (VoIP)** such as Skype





Cloud Computing

- Delivers computing, storage, even apps as a service across a network
- Logical extension of virtualization because it uses virtualization as the base for its functionality.
 - Amazon **EC2** has thousands of servers, millions of virtual machines, petabytes of storage available across the Internet, pay based on usage





Cloud Computing (Cont.)

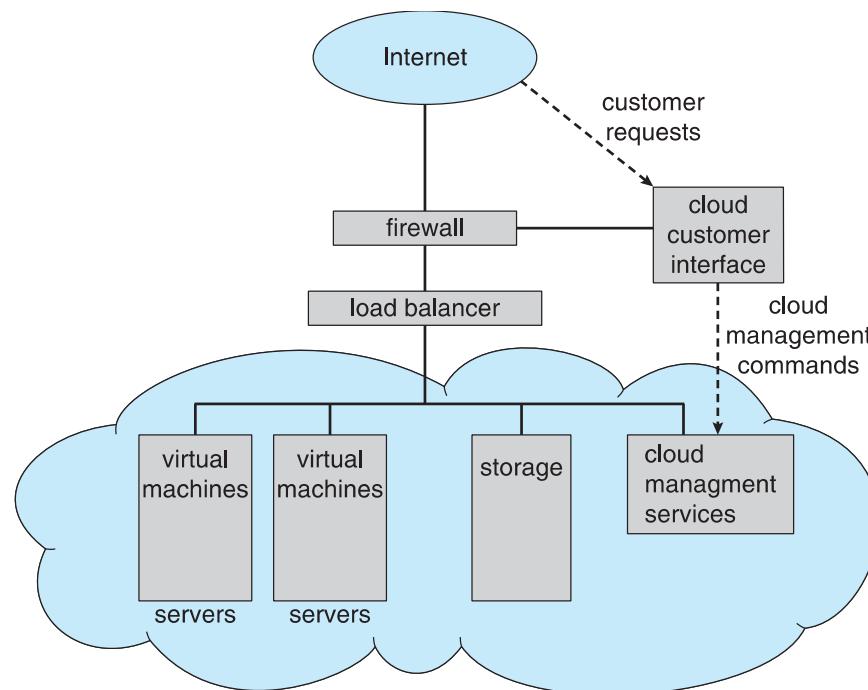
- Many types
 - **Public cloud** – available via Internet to anyone willing to pay
 - **Private cloud** – run by a company for the company's own use
 - **Hybrid cloud** – includes both public and private cloud components
 - Software as a Service (**SaaS**) – one or more applications available via the Internet (i.e., word processor)
 - Platform as a Service (**PaaS**) – software stack ready for application use via the Internet (i.e., a database server)
 - Infrastructure as a Service (**IaaS**) – servers or storage available over Internet (i.e., storage available for backup use)





Cloud Computing (cont.)

- Cloud computing environments composed of traditional OSes, plus VMMS, plus cloud management tools
 - Internet connectivity requires security like firewalls
 - Load balancers spread traffic across multiple applications





Real-Time Embedded Systems

- Real-time embedded systems most prevalent form of computers
 - Vary considerable, special purpose, limited purpose OS, **real-time OS**
 - Use expanding
- Many other special computing environments as well
 - Some have OSes, some perform tasks without an OS
- Real-time OS has well-defined fixed time constraints
 - Processing **must** be done within constraint
 - Correct operation only if constraints met





Free and Open-Source Operating Systems

- Operating systems made available in source-code format rather than just binary **closed-source** and **proprietary**
- Counter to the **copy protection** and **Digital Rights Management (DRM)** movement
- Started by **Free Software Foundation (FSF)**, which has “copyleft” **GNU Public License (GPL)**
 - Free software and open-source software are two different ideas championed by different groups of people
 - ▶ <https://www.gnu.org/philosophy/open-source-misses-the-point.en.html>
- Examples include **GNU/Linux** and **BSD UNIX** (including core of **Mac OS X**), and many more
- Can use VMM like VMware Player (Free on Windows), Virtualbox (open source and free on many platforms - <http://www.virtualbox.com>)
 - Use to run guest operating systems for exploration





The Study of Operating Systems

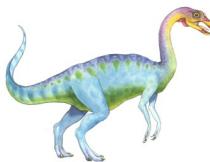
There has never been a more interesting time to study operating systems, and it has never been easier. The open-source movement has overtaken operating systems, causing many of them to be made available in both source and binary (executable) format. The list of operating systems available in both formats includes Linux, BSD UNIX, Solaris, and part of macOS. The availability of source code allows us to study operating systems from the inside out. Questions that we could once answer only by looking at documentation or the behavior of an operating system we can now answer by examining the code itself.

Operating systems that are no longer commercially viable have been open-sourced as well, enabling us to study how systems operated in a time of fewer CPU, memory, and storage resources. An extensive but incomplete list of open-source operating-system projects is available from https://curlie.org/Computers/Software/Operating_Systems/Open_Source/

In addition, the rise of virtualization as a mainstream (and frequently free) computer function makes it possible to run many operating systems on top of one core system. For example, VMware (<http://www.vmware.com>) provides a free “player” for Windows on which hundreds of free “virtual appliances” can run. Virtualbox (<http://www.virtualbox.com>) provides a free, open-source virtual machine manager on many operating systems. Using such tools, students can try out hundreds of operating systems without dedicated hardware.

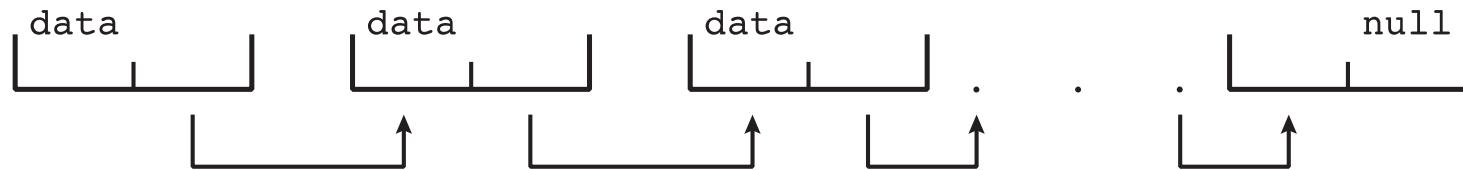
The advent of open-source operating systems has also made it easier to make the move from student to operating-system developer. With some knowledge, some effort, and an Internet connection, a student can even create a new operating-system distribution. Just a few years ago, it was difficult or impossible to get access to source code. Now, such access is limited only by how much interest, time, and disk space a student has.



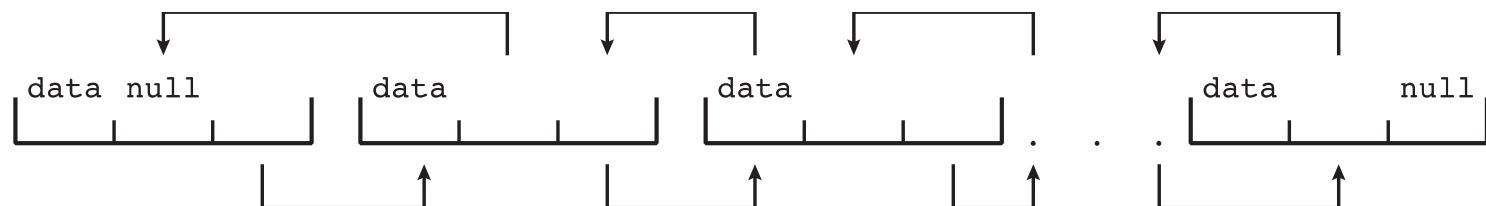


Kernel Data Structures

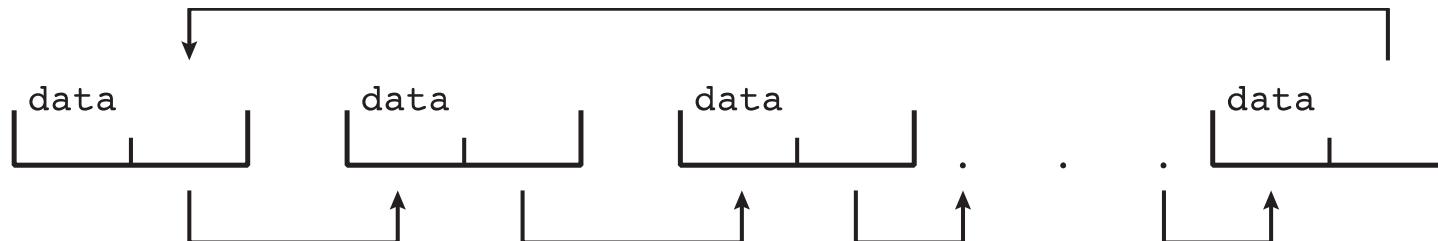
- Many similar to standard programming data structures
- ***Singly linked list***



- ***Doubly linked list***



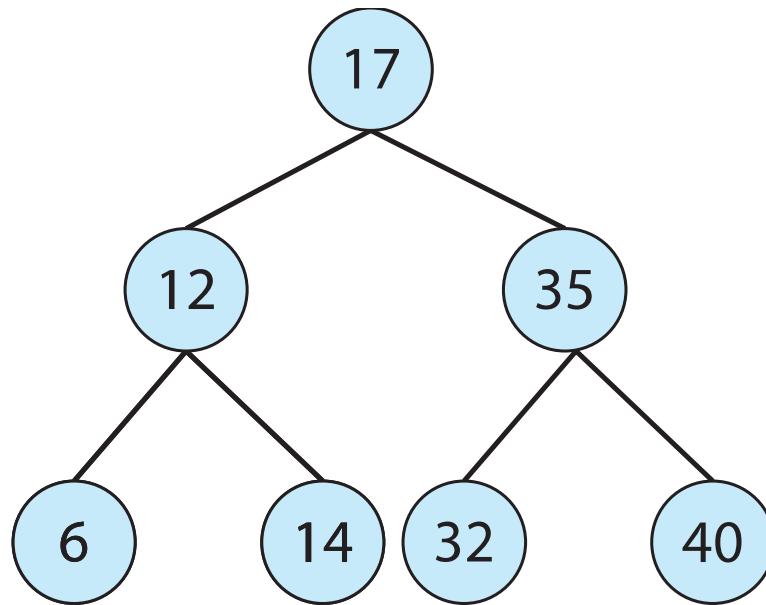
- ***Circular linked list***





Kernel Data Structures (Con'd)

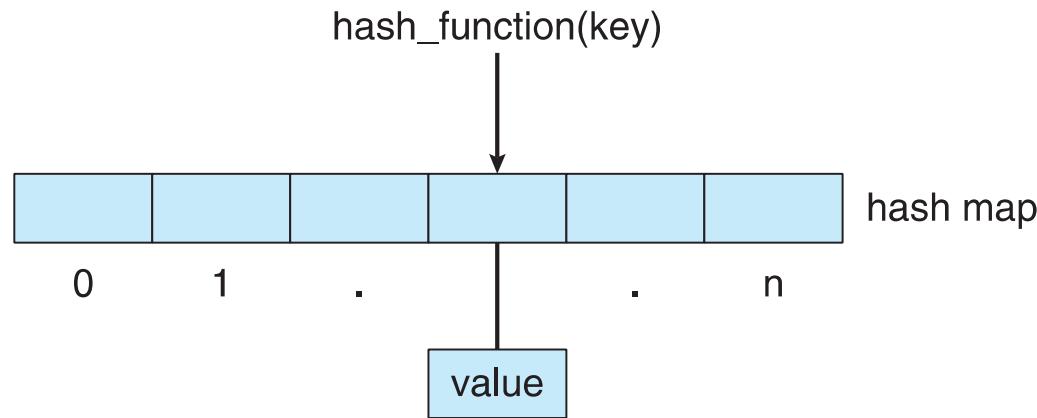
- **Binary search tree** left \leq right
 - Search performance is $O(n)$
 - **Balanced binary search tree** is $O(\log n)$





Kernel Data Structures (Con'd)

- **Hash function** can create a **hash map**



- **Bitmap** – string of n binary digits representing the status of n items
- Linux data structures defined in **include** files `<linux/list.h>`, `<linux/kfifo.h>`, `<linux/rbtree.h>`



End of Chapter 1

