Lecture 2

Operating System

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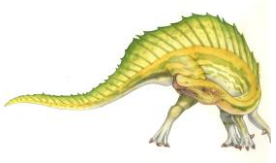
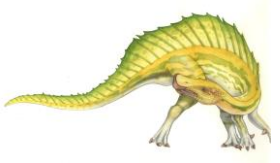


Operating-System Operations

- **Interrupt driven** (hardware and software)
  - Hardware interrupt by one of the devices
  - Software interrupt (**exception** or **trap):**
    - Software error (e.g., division by zero)
    - Request for operating system service
    - Other process problems include infinite loop, processes modifying each other or the operating system

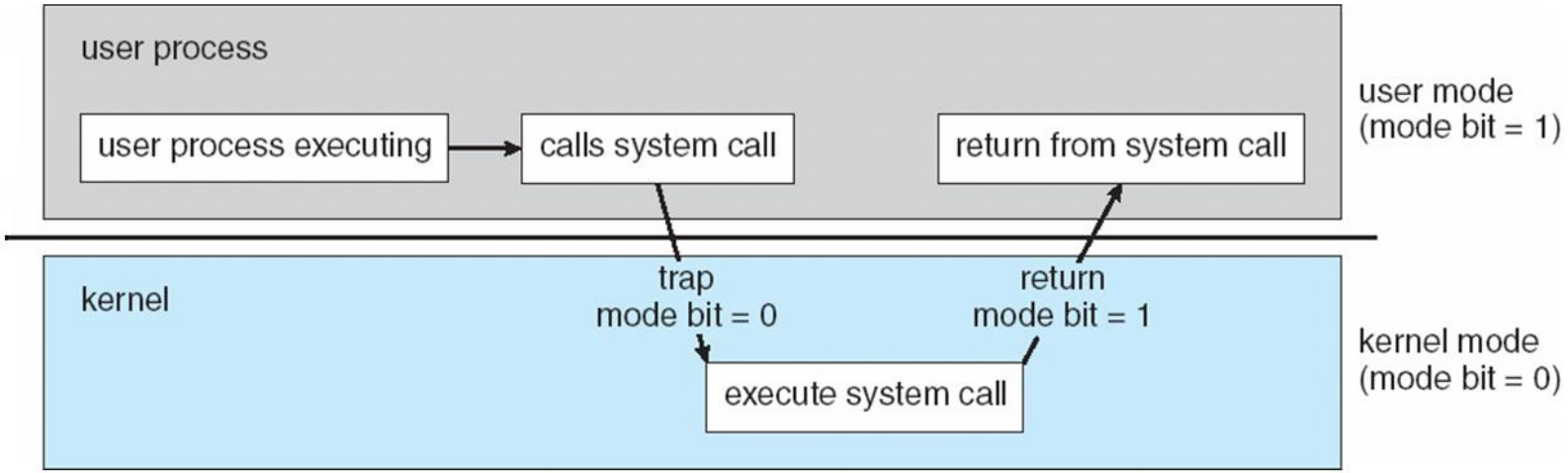


Operating-System Operations (cont.)

- **Dual-mode** we must be able to distinguish between the execution of operating-system code and user defined code.
- **User mode** and **kernel mode**
  - **Mode bit** provided by hardware
    - Provides ability to distinguish when system is running user code or kernel code
    - Some instructions designated as **privileged**, only executable in kernel mode
    - System call changes mode to kernel, return from call resets it to user
- Increasingly CPUs support multi-mode operations
  - i.e. **virtual machine manager** (**VMM**) mode for guest **VMs**

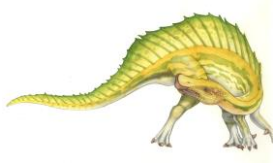
Transition from User to Kernel Mode

- Timer to prevent infinite loop / process hogging resources
  - **Timer** is set to interrupt the computer after some time period
  - Keep a **counter** that is decremented by the physical clock.
  - Operating system set the counter (privileged instruction)
  - When counter zero generate an interrupt
  - Set up before scheduling process to regain control or terminate program that exceeds allotted time



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



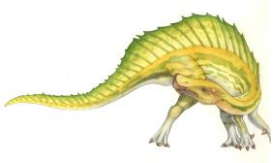
Process Management Activities

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

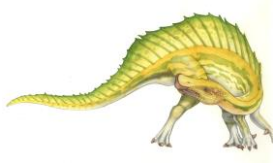
Memory Management

- 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



Storage 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
  - Free-space management
  - Storage allocation
  - Disk scheduling
- Some storage need not be fast
  - Tertiary storage includes optical storage, magnetic tape
  - Still must be managed – by OS or applications
  - Varies between WORM (write-once, read-many-times) and RW (read-write)

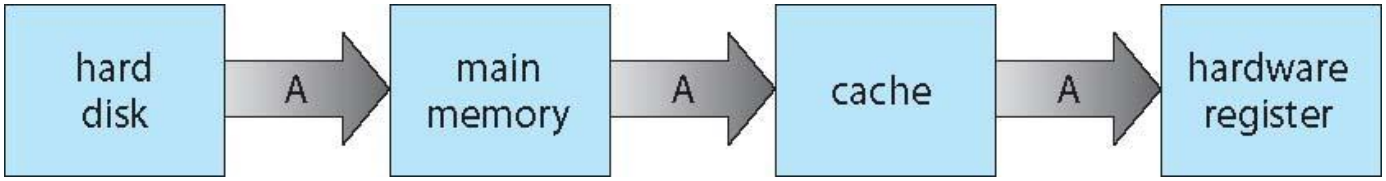
Performance of Various Levels of Storage

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

Migration of data “A” from Disk to Register

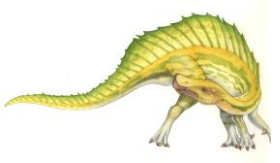
- Multitasking environments must be careful to use most **recent value**, no matter where it is stored in the storage hierarchy



- 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 17

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)
  - Drivers for specific hardware devices

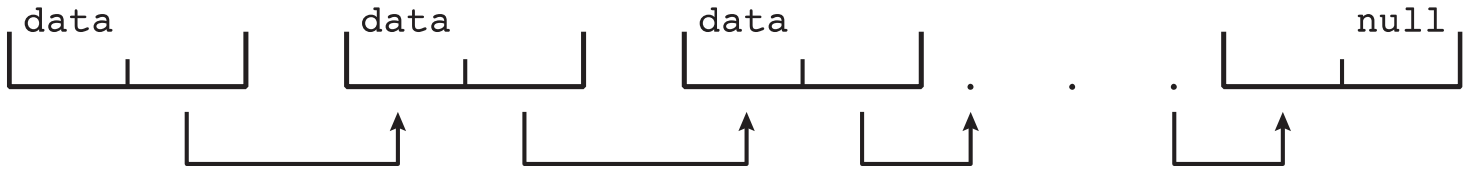


Protection and Security

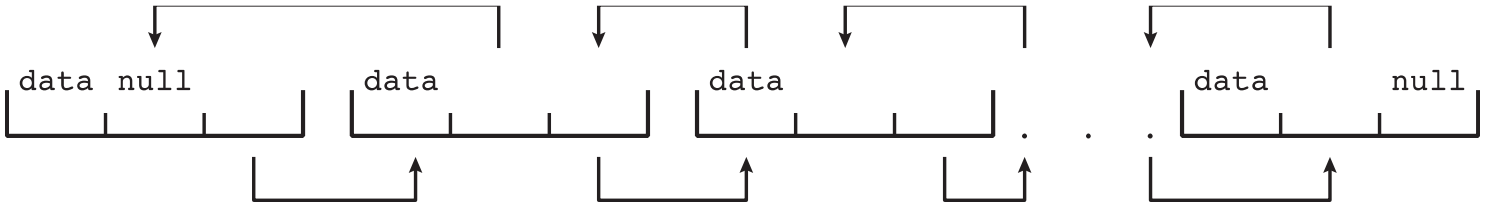
- **Protection** – any mechanism for controlling access of processes or users to resources defined by the OS
- **Security** – defense of the system against internal and external attacks
  - Huge range, including denial-of-service, worms, viruses, identity theft, theft of service
- Systems generally first 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

Kernel Data Structures

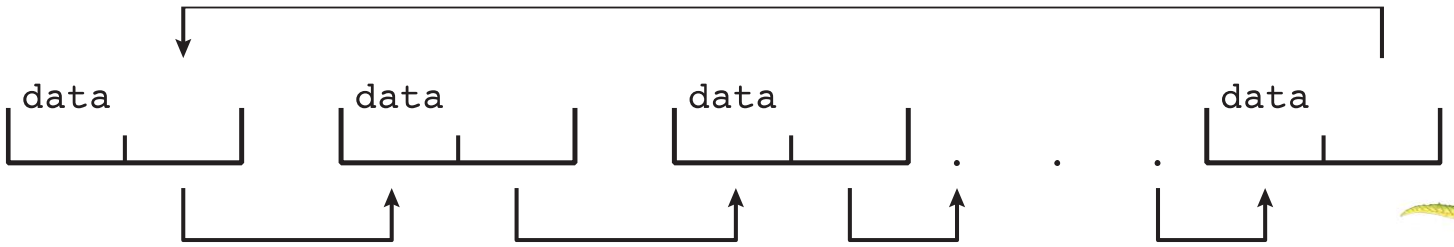
- **Lists, Stacks, and Queues**
- Many similar to standard programming data structures
- ***Singly linked list***



- ***Doubly linked list***

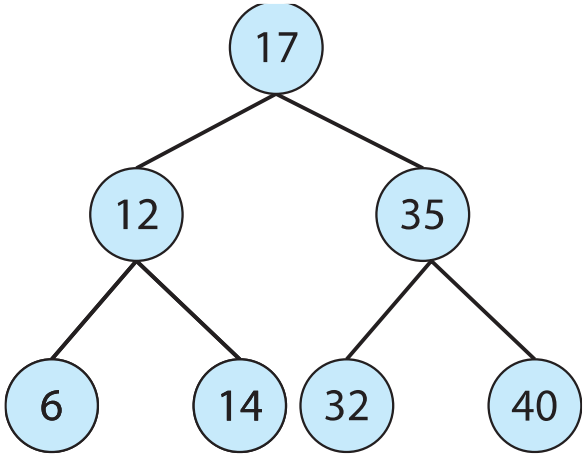


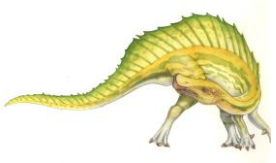
- ***Circular linked list***



Kernel Data Structures

- **Binary search tree**
  left <= right
  - Search performance is *O(n)*
  - **Balanced binary search tree** is *O(lg n)*

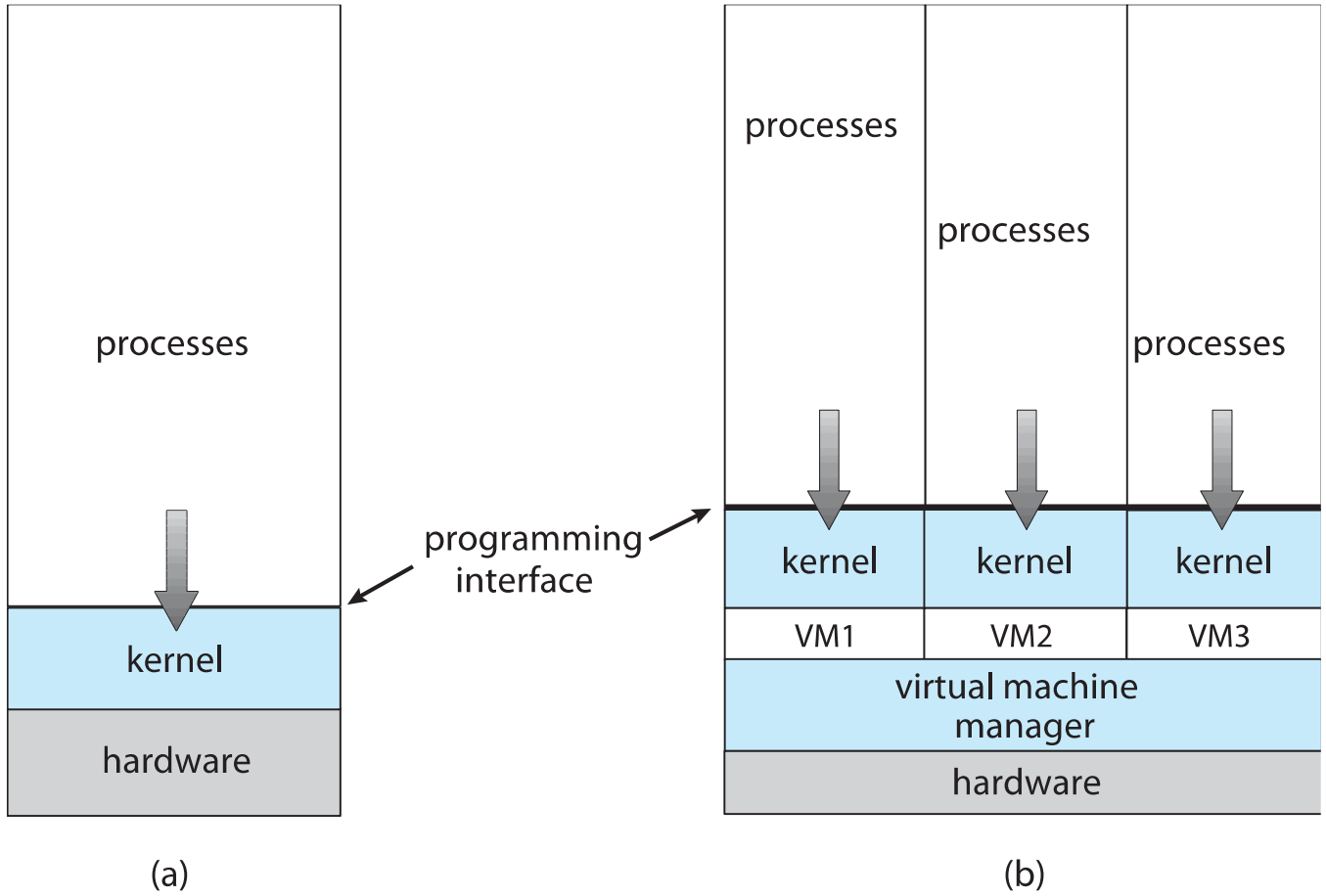




Computing Environments - Virtualization

- **Virtualization** –running **guest** OSes
  - **VMM** (virtual machine Manager) provides virtualization services
- 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

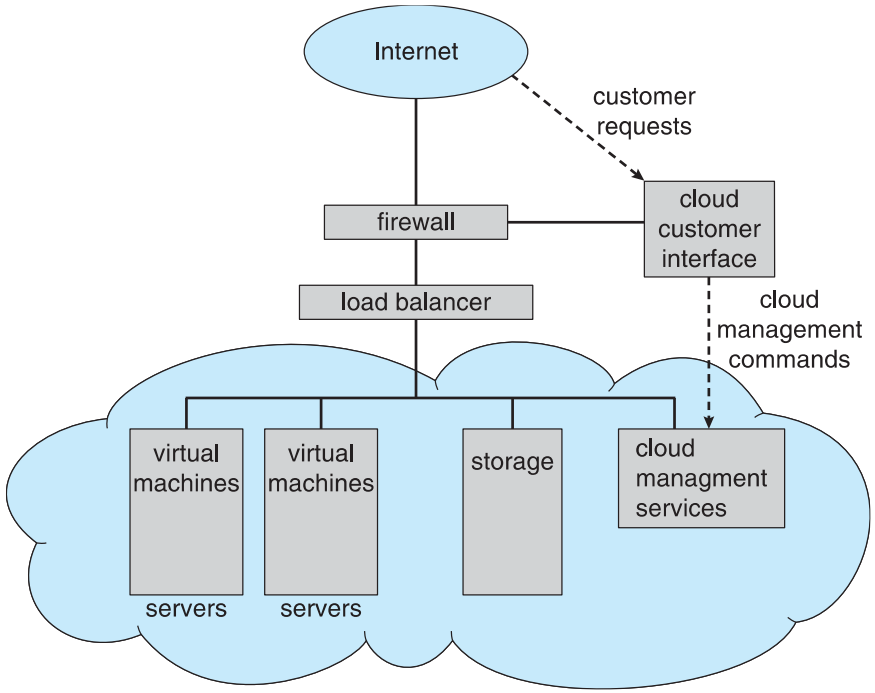


Computing Environments – Cloud Computing

- Delivers computing, storage, even apps as a service across a network
- Logical extension of virtualization because it uses virtualization as the base for it functionality.
  - Amazon **EC2** has thousands of servers, millions of virtual machines, petabytes of storage available across the Internet, pay based on usage
- 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,programming language)
  - Infrastructure as a Service (**IaaS**) – servers or storage available over Internet (i.e., storage available for backup use)

Computing Environments – Cloud Computing

- 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



Computing Environments – Real-Time Embedded Systems

- Real-time embedded systems most prevalent form of computers
  - Vary considerable, special purpose, limited purpose OS, **real-time OS**
- 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

Open-Source Operating Systems

- Operating systems made available in source-code format rather than just binary **closed-source**
- Counter to the **copy protection** and **Digital Rights Management (DRM)** movement
- Started by **Free Software Foundation (FSF)**, which has "copyleft" **GNU Public License (GPL)**
- 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