

Chapter 1: Introduction



What is an Operating System?

- What would you say an operating system is?
- A program that acts as an intermediary between a user of a computer and the computer hardware
- ?
- ?
- ?
- ?
- ?
- ?

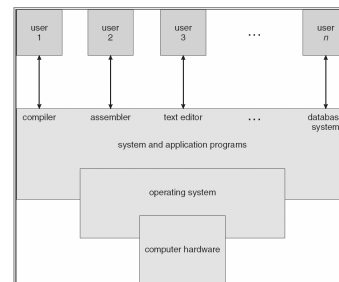


Operating System Definitions

- **Resource allocator** – manages and allocates resources
 - What resources?
- **Control program** – controls the execution of user programs and operations of all devices
 - We say it is an “interrupt driven” system
- **Kernel** – the one program running at all times
 - In contrast to application programs



Four Components of a Computer System



US v. Microsoft

- 1998 US Department of Justice (DOJ) joined by 20 States
- alleged that Microsoft abused monopoly power
- before US District Court Judge Thomas Penfield Jackson

- Microsoft submitted as evidence a (falsified) video showing that removing IE from Windows caused malfunctions.
- Microsoft submitted a second (falsified) video showing how easy it was for AOL users to install Netscape Navigator.

- 2001 Settlement: DOJ required Microsoft to share its API. http://en.wikipedia.org/wiki/Microsoft_antitrust_case



Goals of an Operating System

- **Simplicity:** convenient to use
 - Virtual machine abstraction--hide details
 - Morph to the problem domain of interest (semantics of that domain)
 - Modularity: changes easy
- **Efficiency**
 - Share resources, save costs
 - Pay attention to on-line user first
- **Control**
 - Fair to all users (people or processes)
 - Security: permission (rights mgt“)

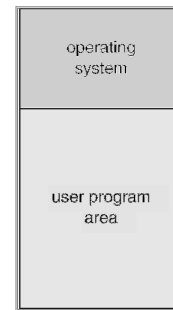


1950s: Mainframes

- Batch similar jobs
- Automatic transfers of control from one job to another.
- Resident monitor
 - Monitor, job, monitor, job, ...

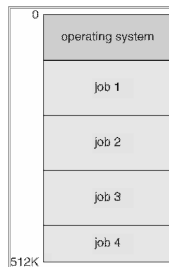


1950s: Batch System



1960s: Multiprogrammed Batch Systems

Several jobs are kept in main memory at the same time, and the CPU is multiplexed among them



1970s: Time-Sharing Systems

- CPU multiplexed among several jobs in memory and disk (CPU allocated to the job in memory)
- Jobs swapped in and out
- Multiple users interact from keyboard
 - After each command, the OS gets next command from user



1980s: Desktop Systems

- *Personal computers (PC)*– dedicated to single user
- I/O devices – keyboard, mouse, display screens (“glass TTY”), small printers
- Adopt technology originally developed for larger operating systems:
 - **Multiprocessing**
 - **Multiprocessors**
 - **Virtual machines**



1990s: Distributed Systems

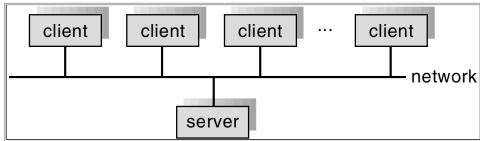
- *Loosely coupled system* – each processor has local memory; processors communicate across network
- Advantages of distributed systems
 - Resources are shared.
 - Faster – computation is shared.
 - More reliable
 - Communicate among users

Sun Microsystems' Scott McNeay: “The network is the computer.”

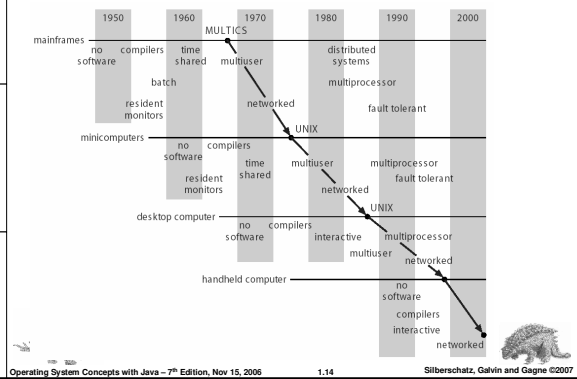


1990s: Distributed Systems (cont)

- Local area networks (LAN) or Wide area networks (WAN)
- *Client-server* or *peer-to-peer*
- General structure of client-server:



Migration of Operating-System Concepts and Features

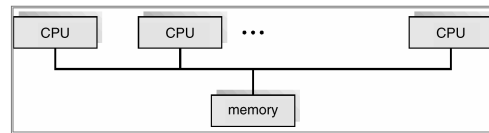


Multiprocessing: WinXP & Linux

- Advantages of multiple processors in parallel:
 - Increased *throughput*
 - Increased economy
 - Increased reliability
 - “graceful degradation” or fail-soft
- **Symmetric Multiprocessing (SMP)**
 - Multiple CPUs
 - *Tightly coupled*: share memory, bus, & clock
 - Each processor runs the same operating system
- **Asymmetric multiprocessing**
 - Master/slave processors
 - Examples
 - Graphics processing units (GPU) on PCs
 - Communication concentrators on mainframes



Symmetric Multiprocessing



Clustered Systems

- Shared storage
- High reliability
- *Asymmetric clustering*: one server runs the application or applications while other servers standby
- *Symmetric clustering*: all N hosts are running the application or applications

When would a system responding in “real time” be good?



Read to p. 28 for Wed. quiz
Read Ch. 10-11 for Mon.



End of Day 1



Real-Time Systems

- Scientific experiments, medical imaging, industrial control systems, and some graphical display
- Well-defined fixed-time constraints
- Real-Time systems may be either *hard* or *soft* real-time
- Known upper bound vs. upper bound
- Dedicated processor vs. WinXP/Linux



2000s: Handheld Systems

- Personal Digital Assistants (PDAs)
- Cellular phones
- Issues:
 - Power: Limited memory and slow processors
 - Usability: small display screens



Computer Startup

- **bootstrap program** is loaded at power-up or reboot
 - Typically stored in ROM or EPROM, generally known as **firmware**
 - Initializes all aspects of system
 - Loads operating system kernel and starts execution



Computer-System Operation

- I/O devices and the CPU can execute concurrently.
- Each device controller is in charge of a particular device type.
- Each device controller has a local buffer.
- CPU moves data from/to main memory to/from local buffers
- I/O is from the device to local buffer of controller.
- Device controller informs CPU that it has finished its operation by causing an *interrupt*.



Common Functions of Interrupts

- Interrupt transfers control to the interrupt service routine generally, through the *interrupt vector*, which contains the addresses of all the service routines.
- Interrupt architecture must save the address of the interrupted instruction.
- Incoming interrupts are *disabled* while another interrupt is being processed to prevent a *lost interrupt*.
- A *trap* is a software-generated interrupt caused either by an error or a user request.
- An operating system is *interrupt driven*.

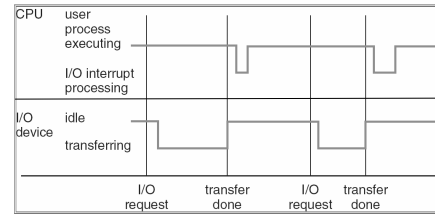


Interrupt Handling

- ❑ The operating system preserves the state of the CPU by storing registers and the program counter.
- ❑ Determines which type of interrupt has occurred:
 - *polling*
 - *vectored* interrupt system
- ❑ Separate segments of code determine what action should be taken for each type of interrupt



Interrupt Timeline

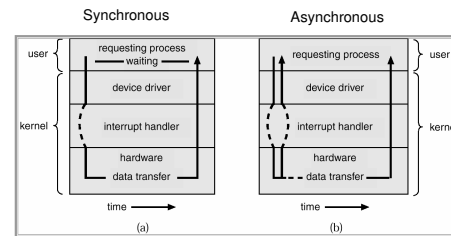


I/O Structure

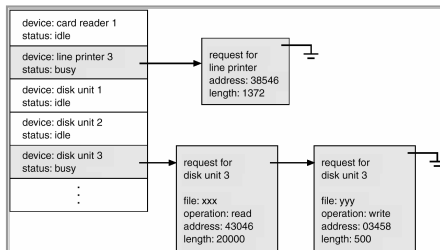
- ❑ After I/O starts, control returns to user program only upon I/O completion.
 - Wait instruction idles the CPU until the next interrupt
 - Wait loop (contention for memory access).
 - At most one I/O request is outstanding at a time, no simultaneous I/O processing.
- ❑ After I/O starts, control returns to user program without waiting for I/O completion.
 - *System call* – request to the operating system to allow user to wait for I/O completion.
 - *Device-status table* contains entry for each I/O device indicating its type, address, and state.
 - Operating system indexes into I/O device table to determine device status and to modify table entry to include interrupt.



Two I/O Methods



Device-Status Table



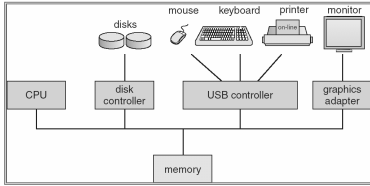
Direct Memory Access Structure

- ❑ Used for high-speed I/O devices able to transmit information at close to memory speeds.
- ❑ Device controller transfers blocks of data from buffer storage directly to main memory without CPU intervention.
- ❑ Only one interrupt is generated per block, rather than the one interrupt per byte.



Computer System Organization

- Computer-system operation
 - One or more CPUs, device controllers connect through common bus providing access to shared memory
 - Concurrent execution of CPUs and devices competing for memory cycles



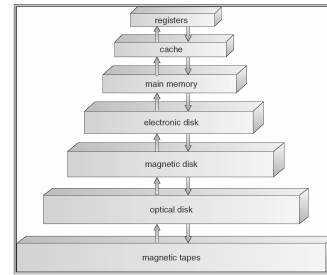
Storage Structure

- Main memory – only large storage media that the CPU can access directly.
- Secondary storage – extension of main memory that provides large nonvolatile storage capacity.
- Magnetic disks – rigid metal or glass platters covered with magnetic recording material
 - Disk surface is logically divided into *tracks*, which are subdivided into *sectors*.
 - The *disk controller* determines the logical interaction between the device and the computer.

Storage Hierarchy

- Storage systems organized in hierarchy.
 - Speed
 - Cost
 - Volatility
- *Caching* – copying information into faster storage system; main memory can be viewed as a last *cache* for secondary storage.

Storage-Device Hierarchy



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

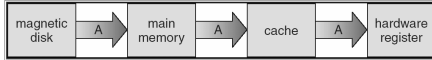
Performance of Various Levels of Storage

- Movement between levels of storage hierarchy can be explicit or implicit

Level	1	2	3	4
Name	registers	cache	main memory	disk storage
Typical size	< 1 KB	> 16 MB	> 16 GB	> 100 GB
Implementation technology	custom memory with multiple ports, CMOS	on-chip or off-chip CMOS SRAM	CMOS DRAM	magnetic disk
Access time (ns)	0.25 – 0.5	0.5 – 25	80 – 250	5,000,000
Bandwidth (MB/sec)	20,000 – 100,000	5000 – 10,000	1000 – 5000	20 – 150
Managed by	compiler	hardware	operating system	operating system
Backed by	cache	main memory	disk	CD or tape

Migration of Integer 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



Operating System Structure

- **Multiprogramming** needed for efficiency
 - Single user cannot keep CPU and I/O devices busy at all times
 - Multiprogramming organizes jobs (code and data) so CPU always has one to execute
 - A subset of total jobs in system is kept in memory
 - One job selected and run via **job scheduling**
 - When it has to wait (for I/O for example), OS switches to another job



Operating System Structure (Cont.)

- **Timesharing (multitasking)** is logical extension in which CPU switches jobs so frequently that users can interact with each job while it is running, creating **interactive** computing
 - **Response time** should be < 1 second
 - Each user has at least one program executing in memory ⇒ **process**
 - If several jobs ready to run at the same time ⇒ **CPU scheduling**
 - If processes don't fit in memory, **swapping** moves them in and out to run
 - **Virtual memory** allows execution of processes not completely in memory



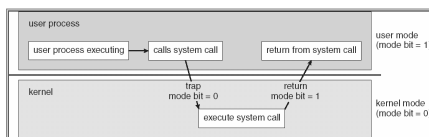
Operating-System Operations

- Interrupt driven by hardware
- Software error or request creates **exception** or **trap**
 - Division by zero, request for operating system service
- Other process problems include infinite loop, processes modifying each other or the operating system
- **Dual-mode** operation allows OS to protect itself and other system components
 - **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



Transition from User to Kernel Mode

- Timer to prevent infinite loop / process hogging resources
 - Set interrupt after specific period
 - Operating system decrements counter
 - 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

- All data in memory before and after processing
- All instructions in memory in order to execute
- Memory management determines what is in memory 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 dirs
 - 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
 - Varies between WORM (write-once, read-many-times) and RW (read-write)



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



Trends: 1 Embedded computing

□ Embedded

- *Most* computers (auto engine controllers, microwaves)
- Very limited operating system features, dedicated to one task
- Little or no user interface, need for remote access
- May be involved in life-critical applications (heart monitor, air navigation)
- "Wearable computers"



Trends: 2 Peer-to-Peer

- Another model of distributed system
- Does not distinguish clients and servers
 - All nodes are peers
 - Each is 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: *Napster*, *Gnutella*, *BitTorrent*



End of Chapter 1

