

Overview

- What is an operating system, anyway?
- Operating systems history
- The zoo of modern operating systems
- Review of computer hardware
- Operating system concepts
- Operating system structure
 - User interface to the operating system
 - Anatomy of a system call

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Operating system timeline

- First generation: 1945 – 1955
 - Vacuum tubes
 - Plug boards
- Second generation: 1955 – 1965
 - Transistors
 - Batch systems
- Third generation: 1965 – 1980
 - Integrated circuits
 - Multiprogramming
- Fourth generation: 1980 – present
 - Large scale integration
 - Personal computers
- Fifth generation: ??? (maybe 2001–?)
 - Systems connected by high-speed networks?
 - Wide area resource management?
 - Peer-to-peer systems?

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What *is* an operating system?

- It's a program that runs on the “raw” hardware
 - Acts as an **intermediary** between computer and users
 - Standardizes the interface to the user across different types of hardware: extended machine
 - Hides the messy details which must be performed
 - Presents user with a virtual machine, easier to use
- It's a **resource manager**
 - Each program gets time with the resource
 - Each program gets space on the resource
- May have potentially conflicting goals:
 - Use hardware efficiently
 - Give maximum performance to each user

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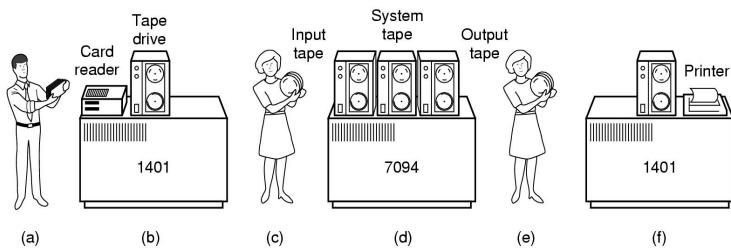
First generation: direct input

- Run one job at a time
 - Enter it into the computer (might require rewiring!)
 - Run it
 - Record the results
- Problem: lots of **wasted** computer time!
 - Computer was idle during first and last steps
 - Computers were **very expensive!**
- Goal: make better use of an expensive commodity: computer time

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Second generation: batch systems

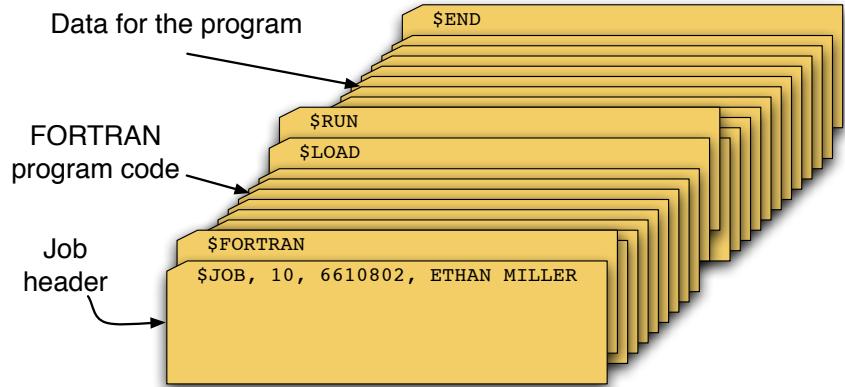


- Bring cards to 1401
- Read cards onto input tape
- Put input tape on 7094
- Perform the computation, writing results to output tape
- Put output tape on 1401, which prints output

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Structure of a typical 2nd generation job



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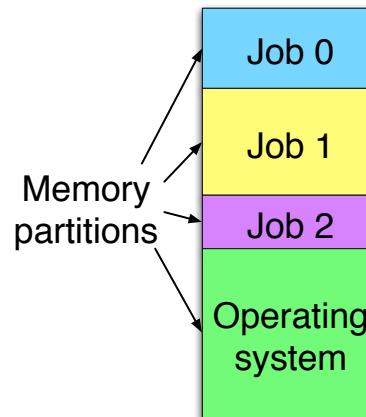
Spooling

- Original batch systems used tape drives
- Later batch systems used disks for buffering
 - Operator read cards onto disk attached to the computer
 - Computer read jobs from disk
 - Computer wrote job results to disk
 - Operator directed that job results be printed from disk
- Disks enabled simultaneous peripheral operation **online (spooling)**
 - Computer **overlapped** I/O of one job with execution of another
 - Better utilization of the expensive CPU
 - Still only **one job** active at any given time

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Third generation: multiprogramming



- Multiple jobs in memory
 - Protected from one another
- Operating system protected from each job as well
- Resources (time, hardware) split between jobs
- Still not interactive
 - User submits job
 - Computer runs it
 - User gets results minutes (hours, days) later

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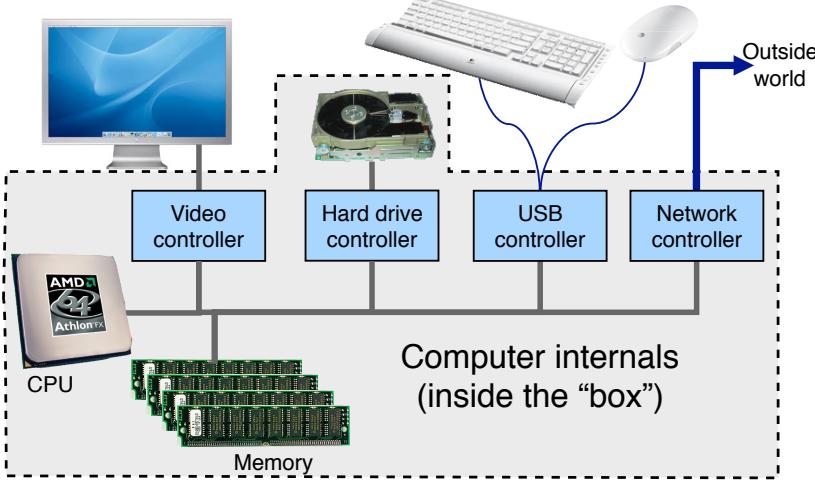
Timesharing

- Multiprogramming allowed several jobs to be active at one time
 - Initially used for batch systems
 - Cheaper hardware terminals ⇒ interactive use
- Computer use got much cheaper and easier
 - No more “priesthood”
 - Quick turnaround meant quick fixes for problems

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Components of a simple PC



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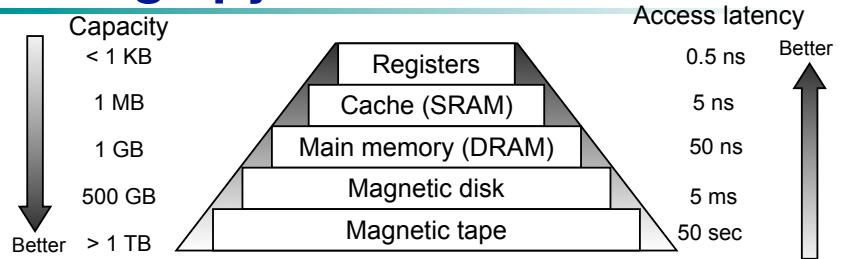
Types of modern operating systems

- Mainframe operating systems: MVS
 - Server operating systems: FreeBSD, Solaris, Linux
 - Multiprocessor operating systems: Cellular IRIX
 - Personal computer operating systems: MacOS X, Windows Vista, Linux
 - Real-time operating systems: VxWorks
 - Embedded operating systems
 - Smart card operating systems
- ⇒ Some operating systems can fit into more than one category

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Storage pyramid



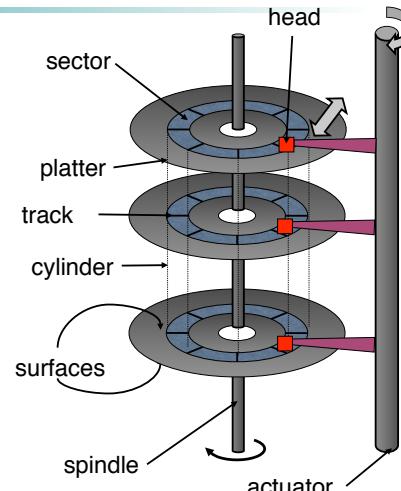
- Goal: really large memory with very low latency
 - Latencies are smaller at the top of the hierarchy
 - Capacities are larger at the bottom of the hierarchy
- Solution: move data between levels to create illusion of large memory with low latency

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Disk drive structure

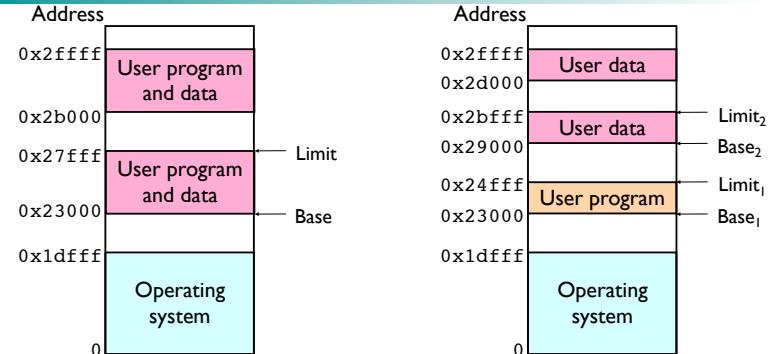
- Data stored on surfaces
 - Up to two surfaces per platter
 - One or more platters per disk
- Data in concentric tracks
 - Tracks broken into sectors
 - 256B–1KB per sector
 - Cylinder: corresponding tracks on all surfaces
- Data read and written by heads
 - Actuator moves heads
 - Heads move in unison



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Memory

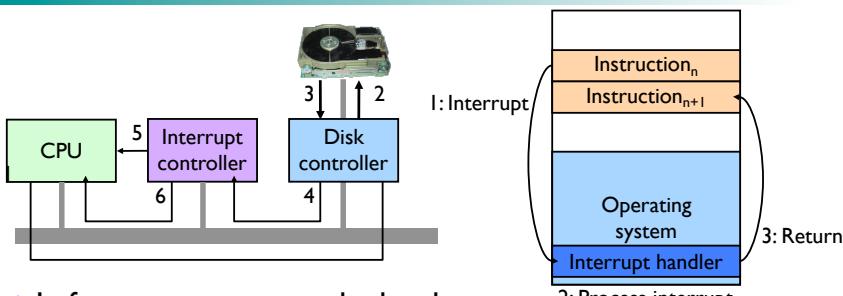


- Single base/limit pair: set for each process
- Two base/limit registers: one for program, one for data

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Anatomy of a device request



- Left: sequence as seen by hardware
 - Request sent to controller, then to disk
 - Disk responds, signals disk controller which tells interrupt controller
 - Interrupt controller notifies CPU
- Right: interrupt handling (software point of view)

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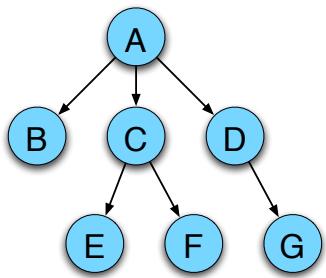
Operating systems concepts

- Many of these should be familiar to Unix users...
- Processes (and trees of processes)
- Deadlock
- File systems & directory trees
- Pipes
- We'll cover all of these in more depth later on, but it's useful to have some basic definitions now

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Processes

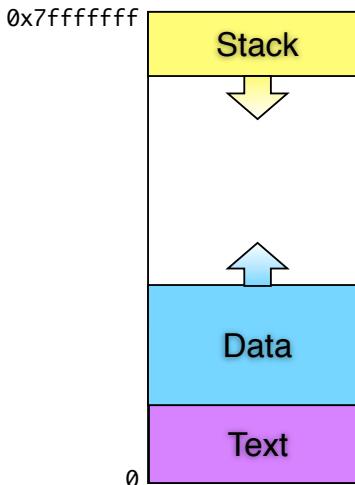


- Process: program in execution
 - Address space (memory) the program can use
 - State (registers, including program counter & stack pointer)
- OS keeps track of all processes in a process table
- Processes can create other processes
 - Process tree tracks these relationships
 - A is the root of the tree
 - A created three child processes: B, C, and D
 - C created two child processes: E and F
 - D created one child process: G

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Inside a (Unix) process

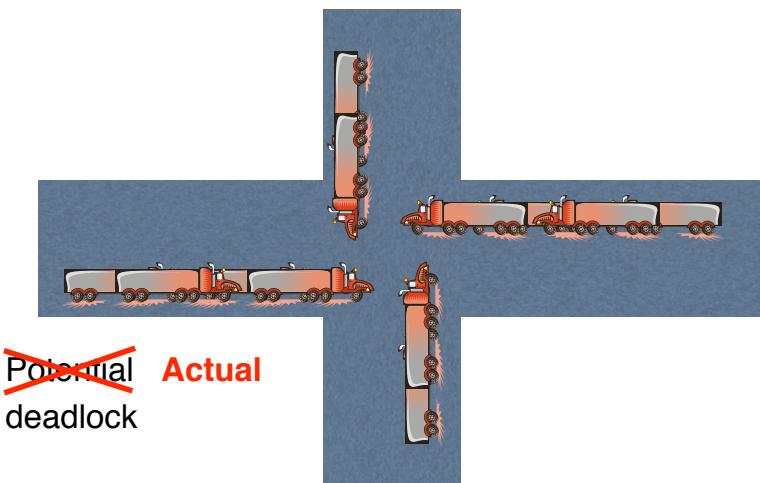


- Processes have three segments
 - Text: program code
 - Data: program data
 - Statically declared variables
 - Areas allocated by malloc() or new
 - Stack
 - Automatic variables
 - Procedure call information
- Address space growth
 - Text: doesn't grow
 - Data: grows "up"
 - Stack: grows "down"

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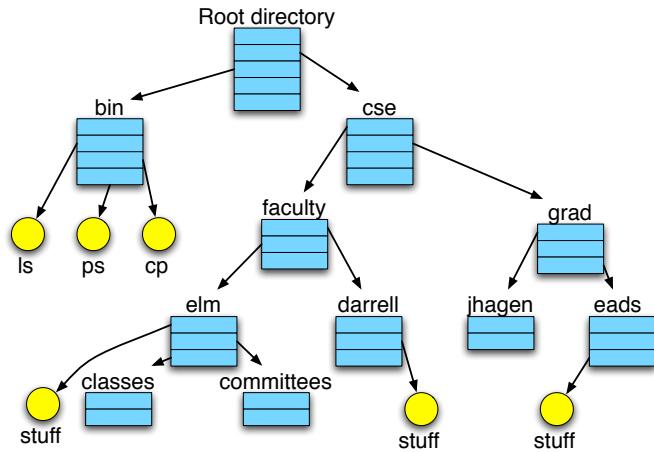
Deadlock



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Hierarchical file systems



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Interprocess communication

- Processes want to exchange information with each other
- Many ways to do this, including
 - Network
 - Pipe (special file): A writes into pipe, and B reads from it



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System calls

- OS runs in **privileged mode**
 - Some operations are permitted only in privileged (also called supervisor or system) mode
 - Example: access a device like a disk or network card
 - Example: change allocation of memory to processes
 - User programs run in user mode and can't do the operations
- Programs want the OS to perform a service
 - Access a file
 - Create a process
 - Others...
- Accomplished by system call

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How system calls work

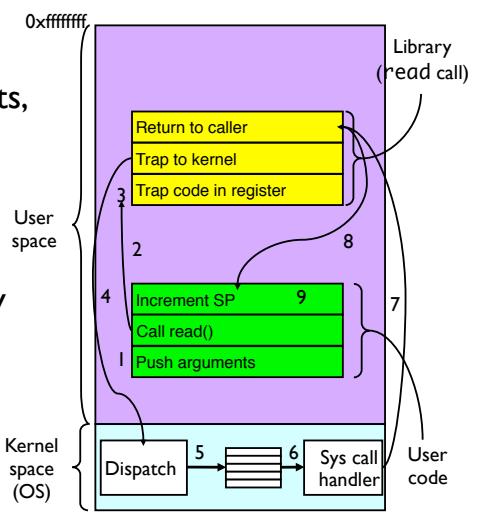
- User program enters supervisor mode
 - Must enter via well-defined entry point
- Program passes relevant information to OS
- OS performs the service if
 - The OS is able to do so
 - The service is permitted for this program at this time
- OS checks information passed to make sure it's OK
 - Don't want programs reading data into other programs' memory!
- OS needs to be paranoid!
 - Users do the darnedest things....

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Making a system call

- System call:
read(fd,buffer,length)
- Program pushes arguments, calls library
- Library sets up trap, calls OS
- OS handles system call
- Control returns to library
- Library returns to user program



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System calls for files & directories

Call	Description
<code>fd = open(name, how)</code>	Open a file for reading and/or writing
<code>s = close(fd)</code>	Close an open file
<code>n = read(fd,buffer,size)</code>	Read data from a file into a buffer
<code>n = write(fd,buffer,size)</code>	Write data from a buffer into a file
<code>s = lseek(fd,offset,whence)</code>	Move the “current” pointer for a file
<code>s = stat(name,&buffer)</code>	Get a file’s status information (in <i>buffer</i>)
<code>s = mkdir(name,mode)</code>	Create a new directory
<code>s = rmdir(name)</code>	Remove a directory (must be empty)
<code>s = link(name1,name2)</code>	Create a new entry (<i>name2</i>) that points to the same object as <i>name1</i>
<code>s = unlink(name)</code>	Remove <i>name</i> as a link to an object (deletes the object if <i>name</i> was the only link to it)

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A simple shell

```
while (TRUE) {          /* repeat forever */
    print_prompt();      /* display prompt */
    read_command(command, parameters);/* input from terminal */

    if (fork() != 0) {    /* fork off child process */
        /* Parent code */
        waitpid(-1, &status, 0); /* wait for child to exit */
    } else {
        /* Child code */
        execve(command, parameters, 0); /* execute command */
    }
}
```

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More system calls

Call	Description
<code>pid = fork()</code>	Create a child process identical to the parent
<code>pid=waitpid(pid,&statloc,options)</code>	Wait for a child to terminate
<code>s = execve(name,argv,environp)</code>	Replace a process’ core image
<code>exit(status)</code>	Terminate process execution and return status
<code>s = chdir(dirname)</code>	Change the working directory
<code>s = chmod(name,mode)</code>	Change a file’s protection bits
<code>s = kill(pid,signal)</code>	Send a signal to a process
<code>seconds = time(&seconds)</code>	Get the current time

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Operating system structure

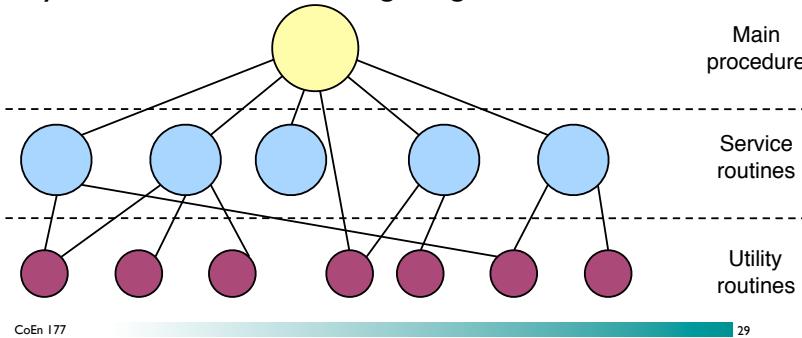
- ♦ OS is composed of lots of pieces
 - Memory management
 - Process management
 - Device drivers
 - File system
- ♦ How do the pieces of the operating system fit together and communicate with each other?
- ♦ Different ways to structure an operating system
 - Monolithic
 - Modular is similar, but more extensible
 - Virtual machines
 - Microkernel

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Monolithic OS structure

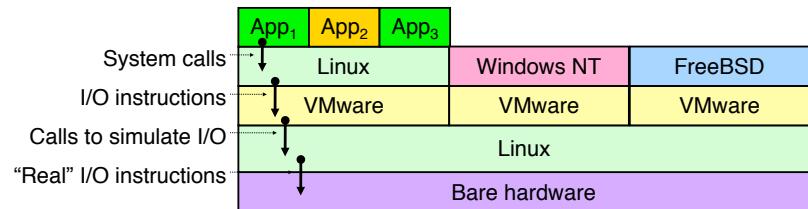
- All of the OS is one big “program”
 - Any piece can access any other piece
- Sometimes modular (as with Linux)
 - Extra pieces can be dynamically added
 - Extra pieces become part of the whole
- Easy to write, but harder to get right...



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Virtual machines

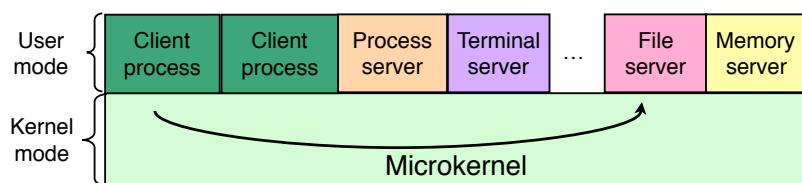


- First widely used in VM/370 with CMS
- Available today in VMware (and Qemu, sort of)
 - Allows users to run any x86-based OS on top of Linux or NT
- “Guest” OS can crash without harming underlying OS
 - Only virtual machine fails—rest of underlying OS is fine
- “Guest” OS can even use raw hardware
 - Virtual machine keeps things **separated**

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Microkernels (client-server)



- Processes (clients and OS servers) don't share memory
 - Communication via message-passing
 - Separation reduces risk of “byzantine” failures
- Examples include
 - Mach (used by MacOS X)
 - Minix

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