OS09
K. Gopinath, IISc

Slides are from

- Tanenbaum, provided as part of his book
- Updated Tanenbaum slides from
  - by Darrell Long/Ethan Miller at UCSC
- Mine own (K. Gopinath)
- Some papers/books too numerous to list
  - Hence PL. DO NOT CIRCULATE

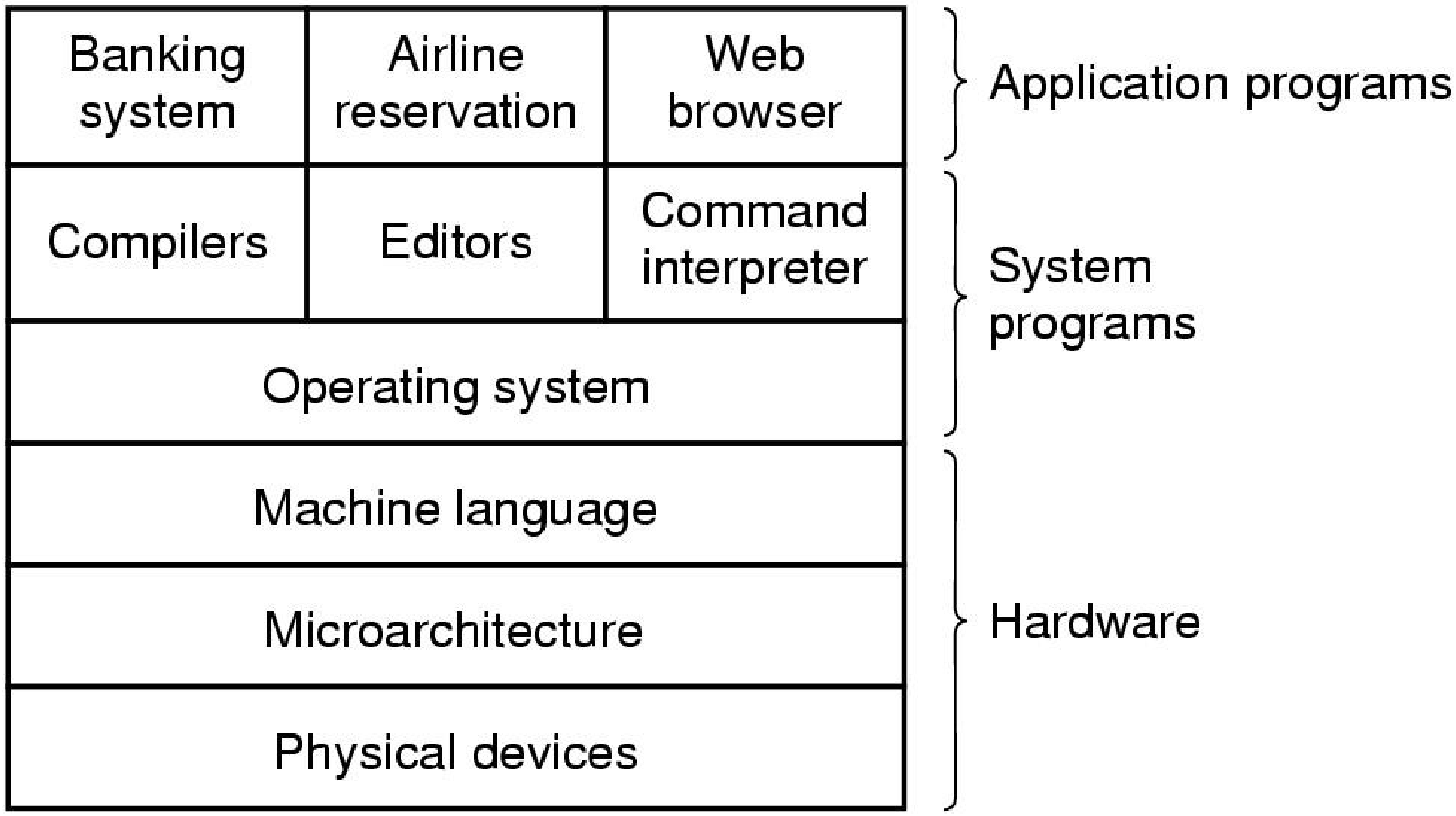
Overview: Chapter 1

- 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

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

Introduction



- A computer system consists of
  - hardware
  - system programs
  - application programs

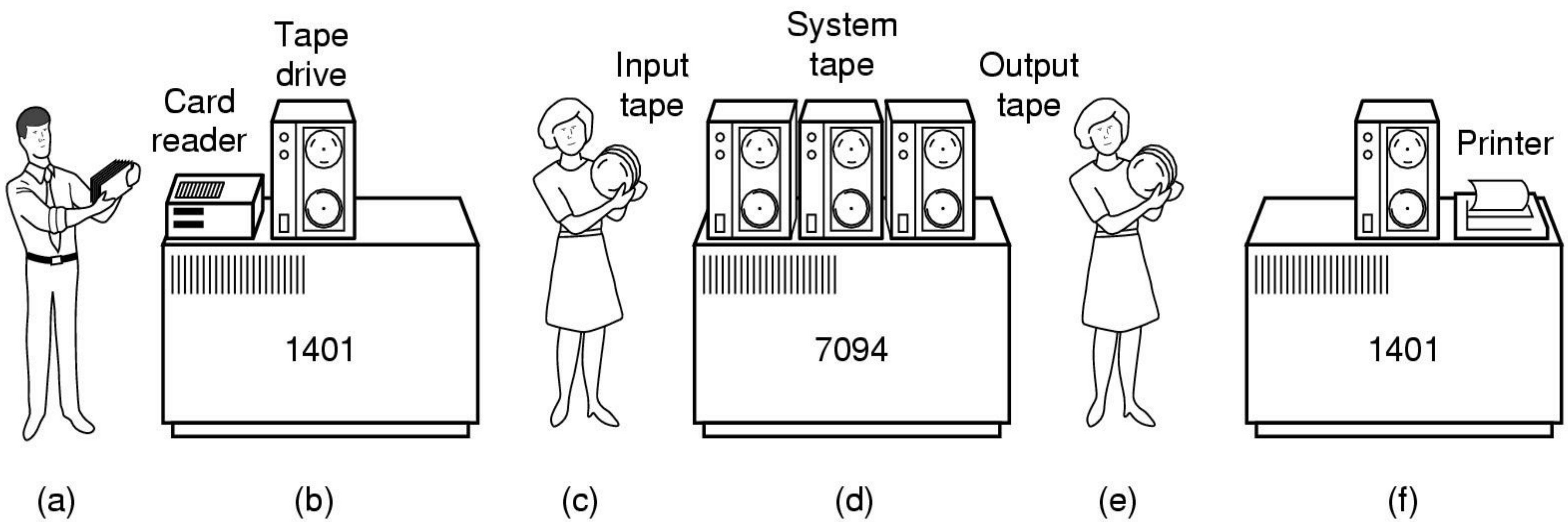
Operating system timeline

- 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?

First generation: direct input

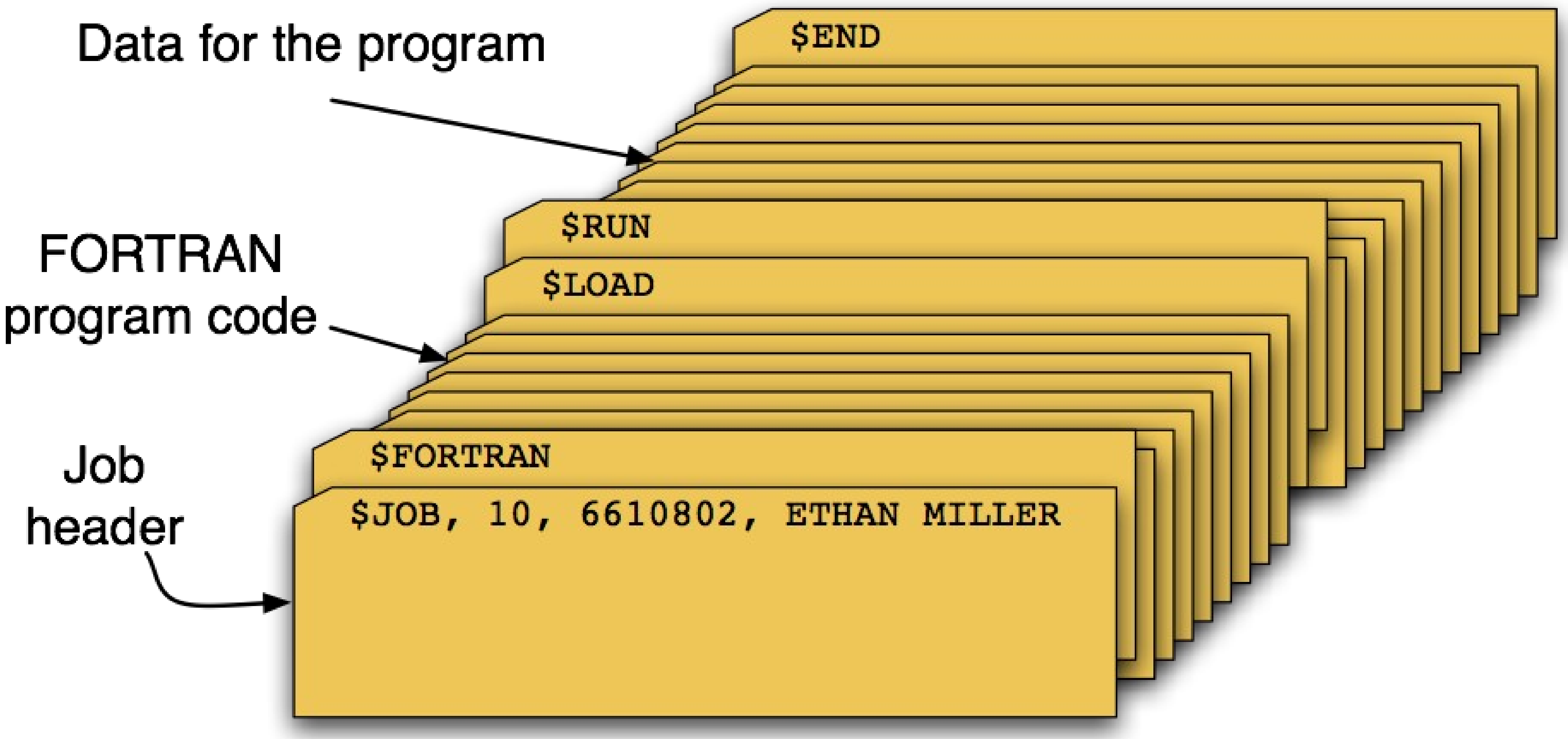
- Run one job at a time
  - Enter it into the computer (might require rewiring!)
  - Run it
  - Record the results
- Problem: lots of wasted computer time!
  - Computer was idle during first and last steps
  - Computers were **very** expensive!
- Goal: make better use of an expensive commodity: computer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

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

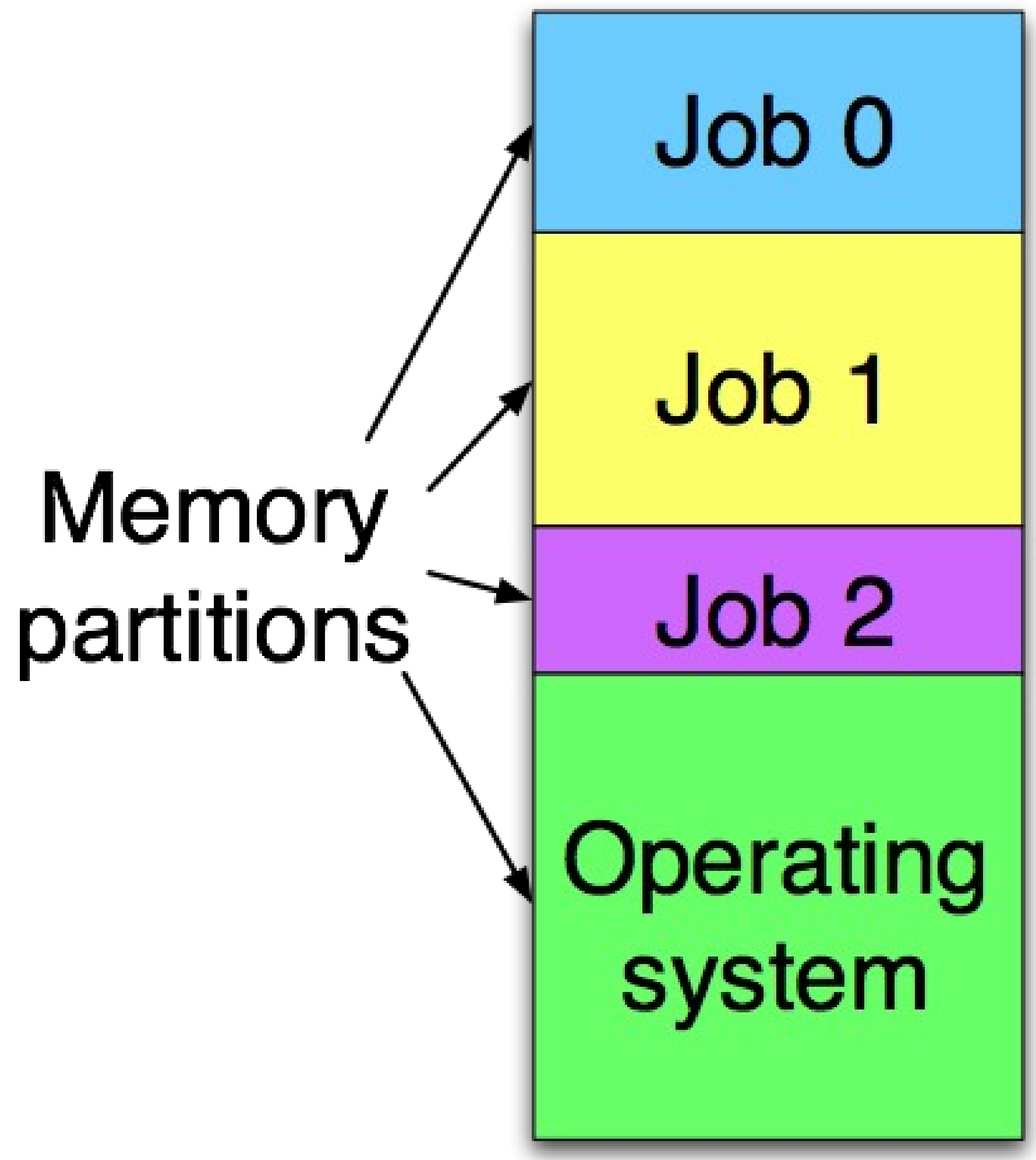
Structure of a typical 2nd generation job



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 on-line (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

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

Timesharing

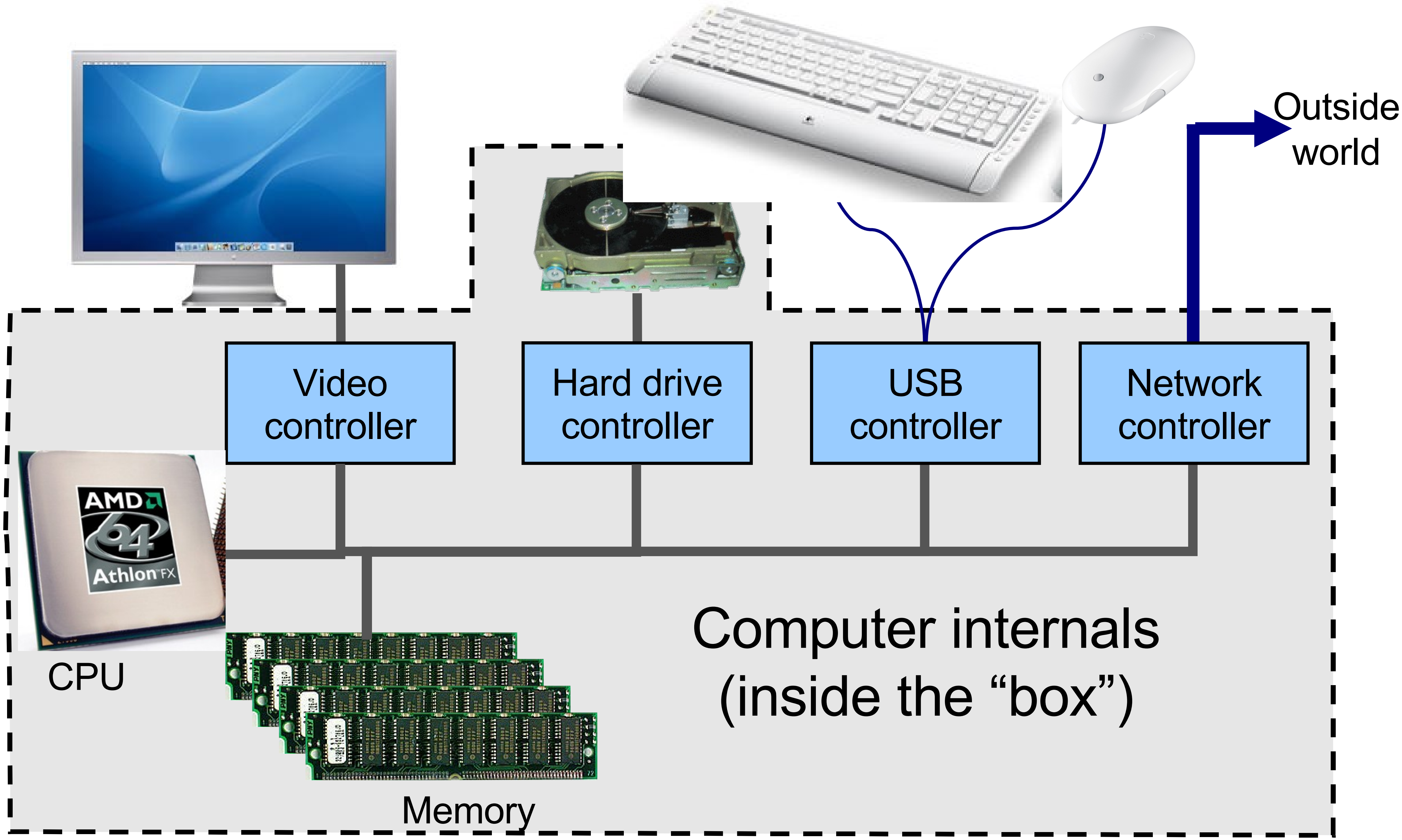
- Multiprogramming allowed several jobs to be active at one time
  - Initially used for batch systems
  - Cheaper hardware terminals ⇒ interactive use
- Computer use got much cheaper and easier
  - No more "priesthood"
  - Quick turnaround meant quick fixes for problems

Types of modern operating systems

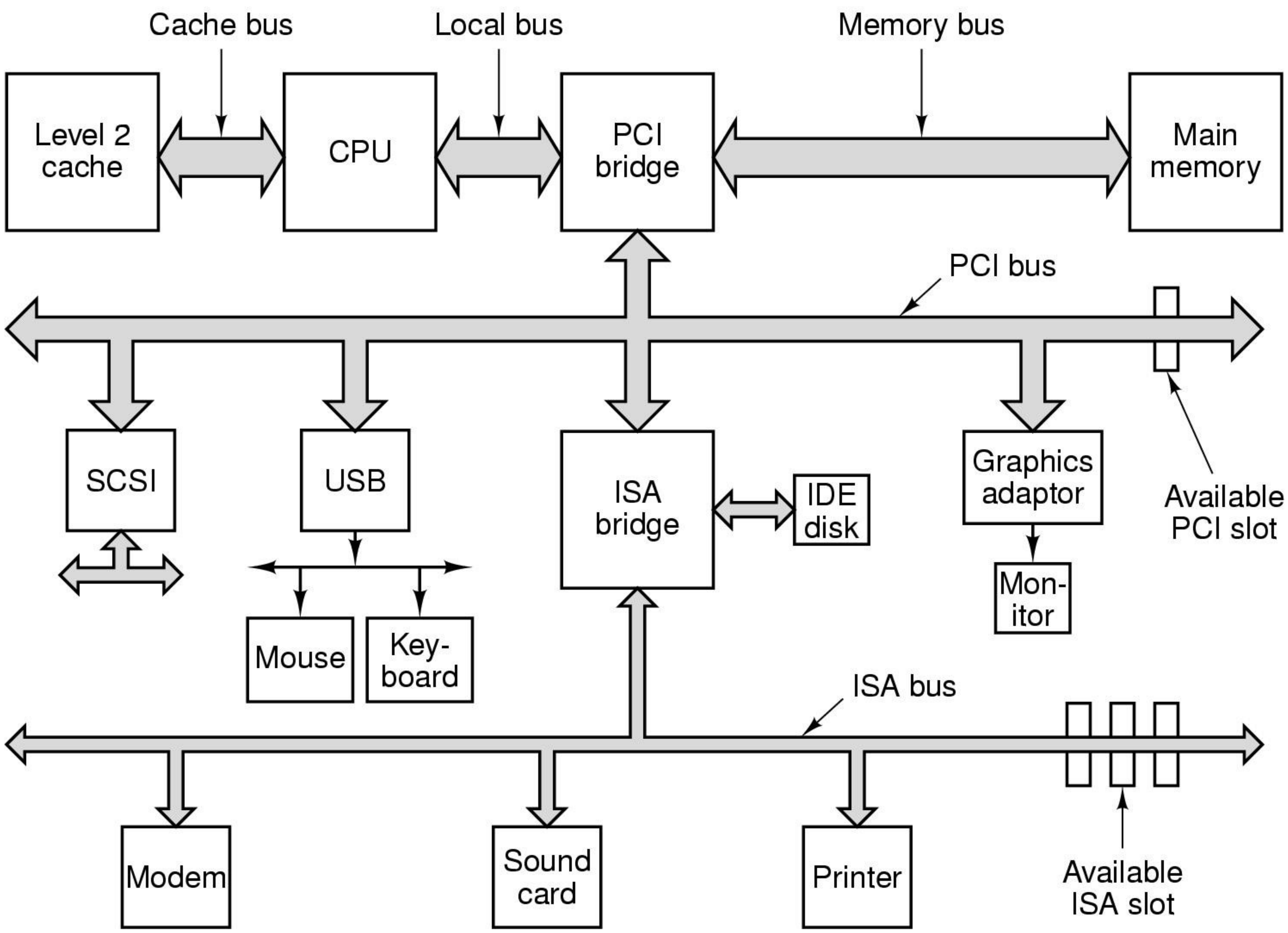
- Mainframe operating systems: MVS
- Server operating systems: FreeBSD, Solaris, Linux
- Multiprocessor operating systems: Cellular IRIX
- Personal computer operating systems: MacOS X, Windows Vista, Linux
- Real-time operating systems: VxWorks
- Embedded operating systems
- Smart card operating systems

- Some operating systems can fit into more than one category

Components of a simple PC

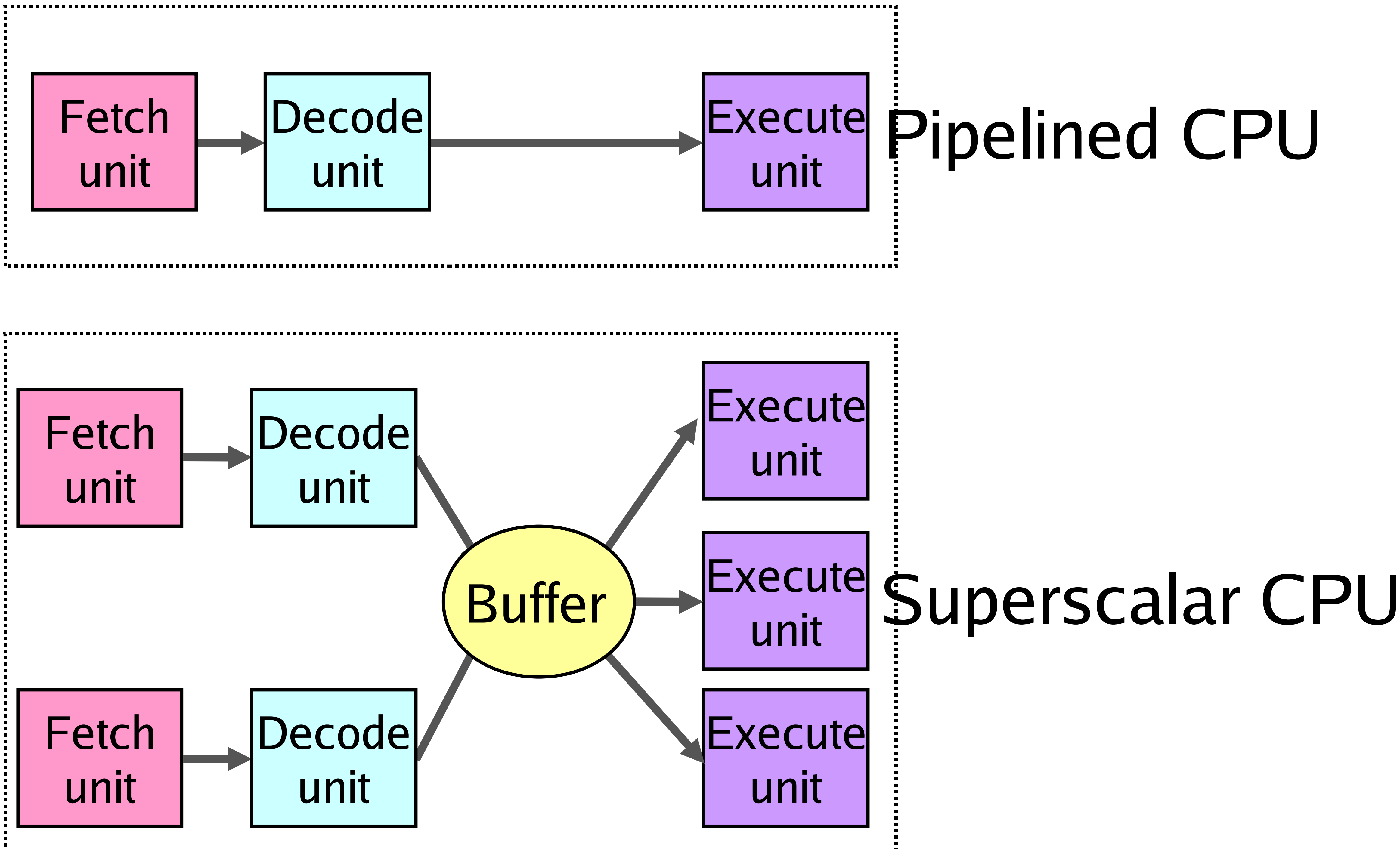


Computer Hardware

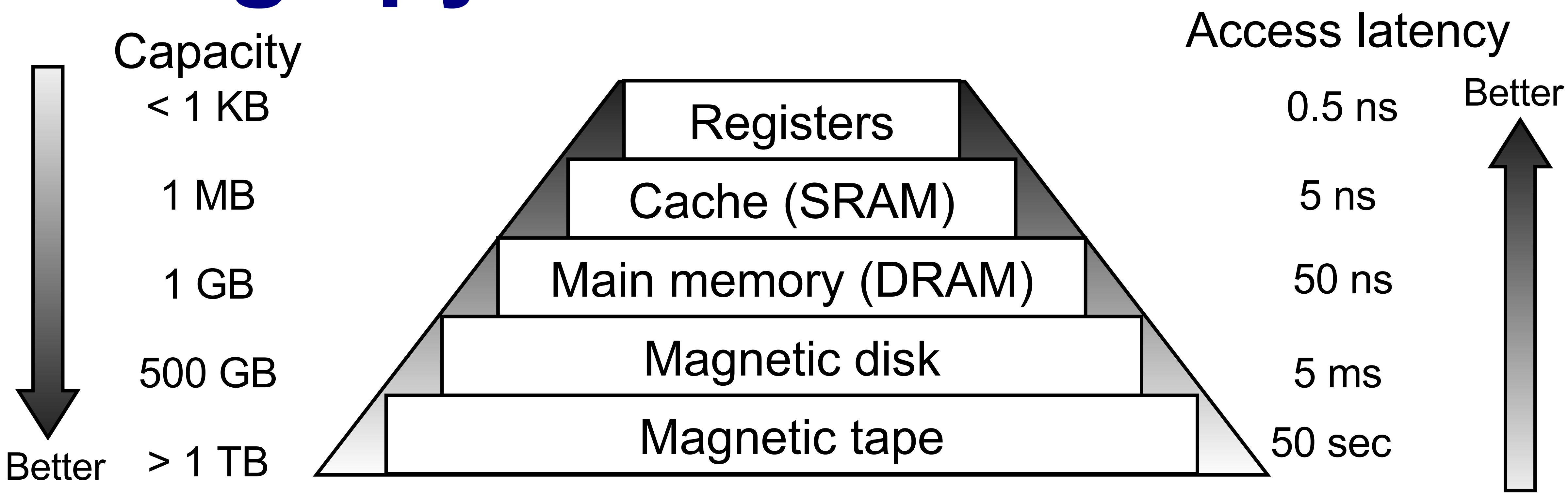


Structure of a large PC

CPU internals



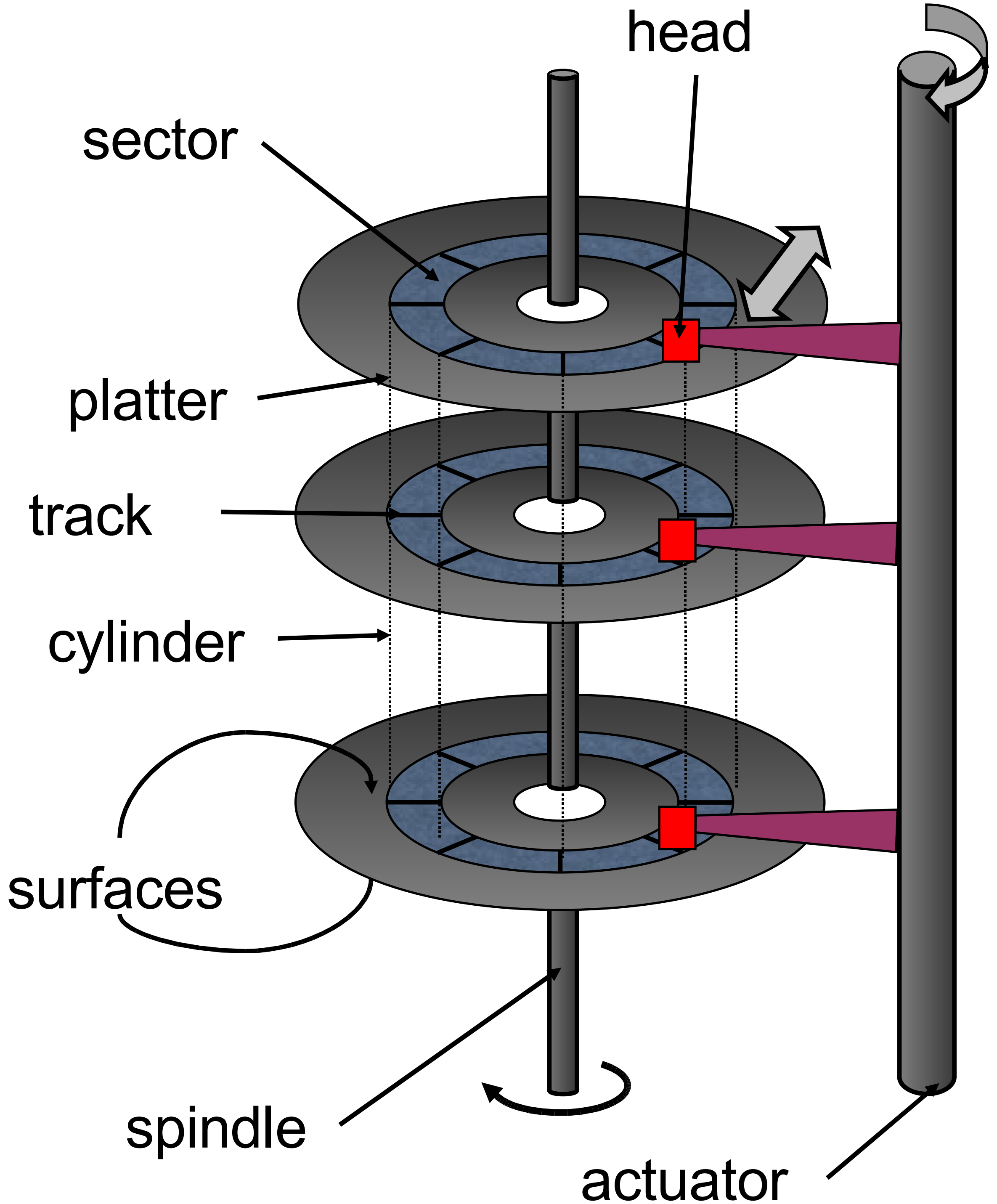
Storage pyramid



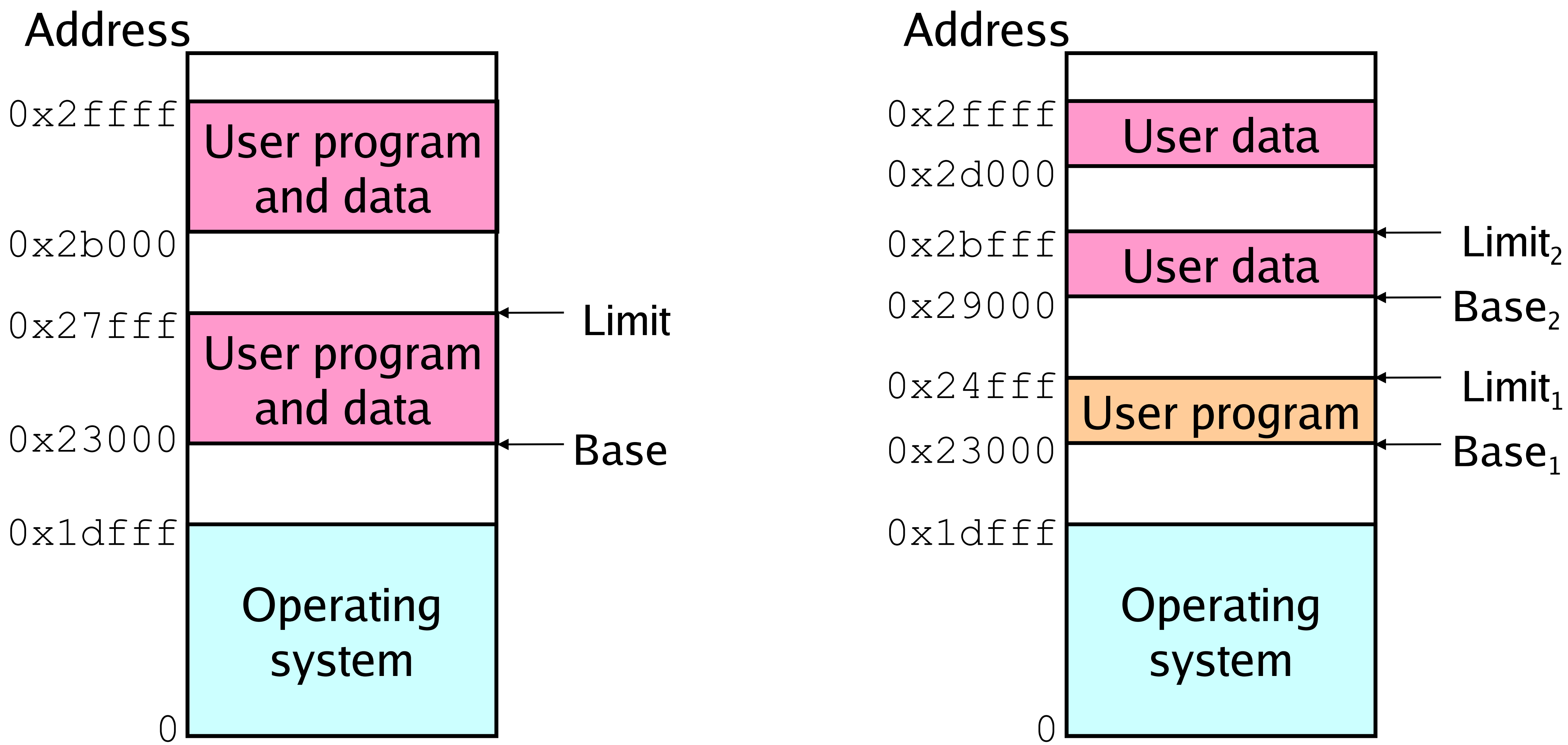
- Goal: really large memory with very low latency
  - Latencies are smaller at the top of the hierarchy
  - Capacities are larger at the bottom of the hierarchy
- Solution: move data between levels to create illusion of large memory with low latency

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

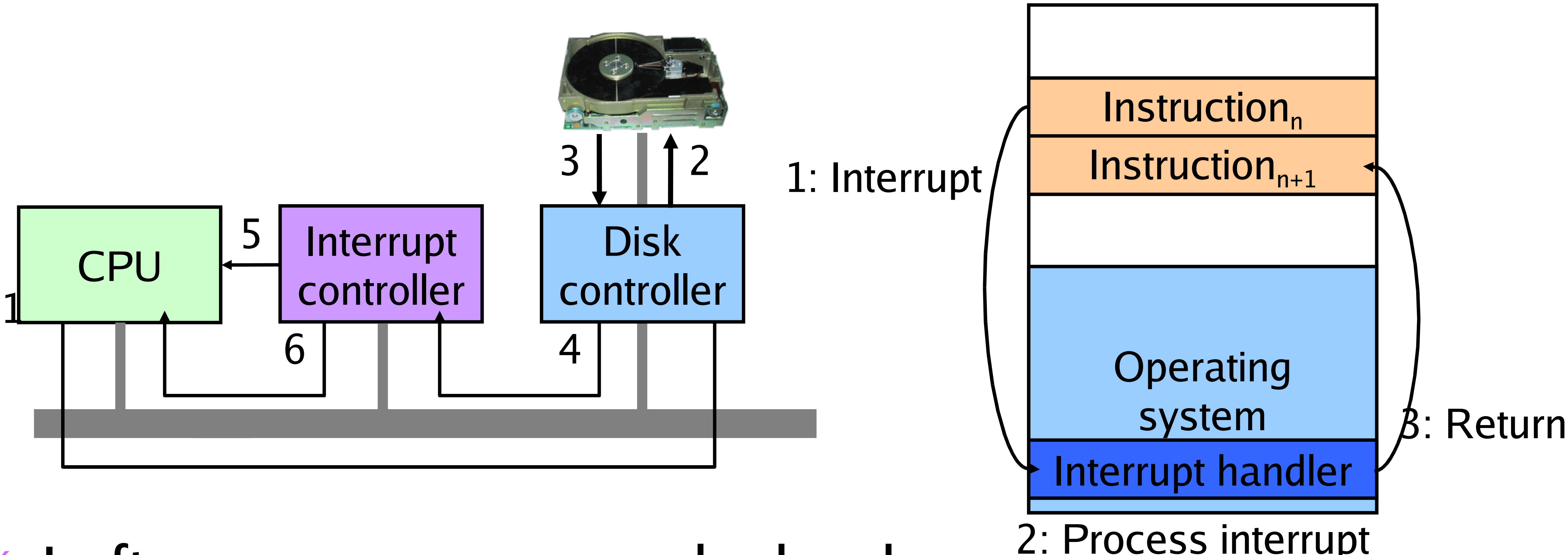


Memory



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

Anatomy of a device request

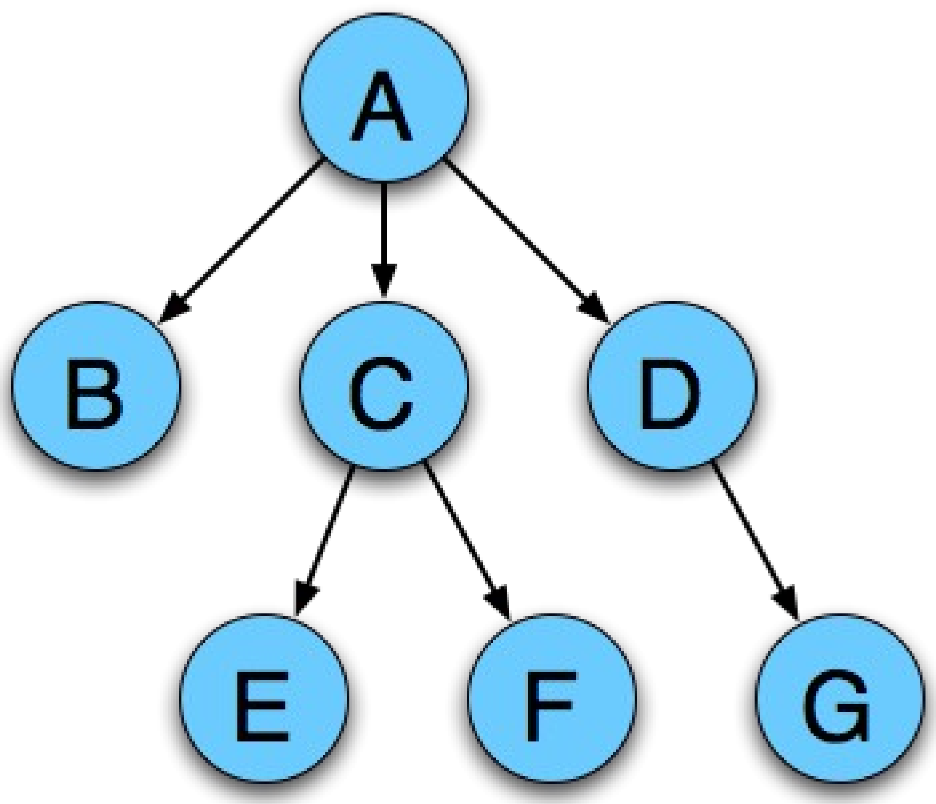


- Left: sequence as seen by hardware
  - Request sent to controller, then to disk
  - Disk responds, signals disk controller which tells interrupt controller
  - Interrupt controller notifies CPU
- Right: interrupt handling (software point of view)

Operating systems concepts

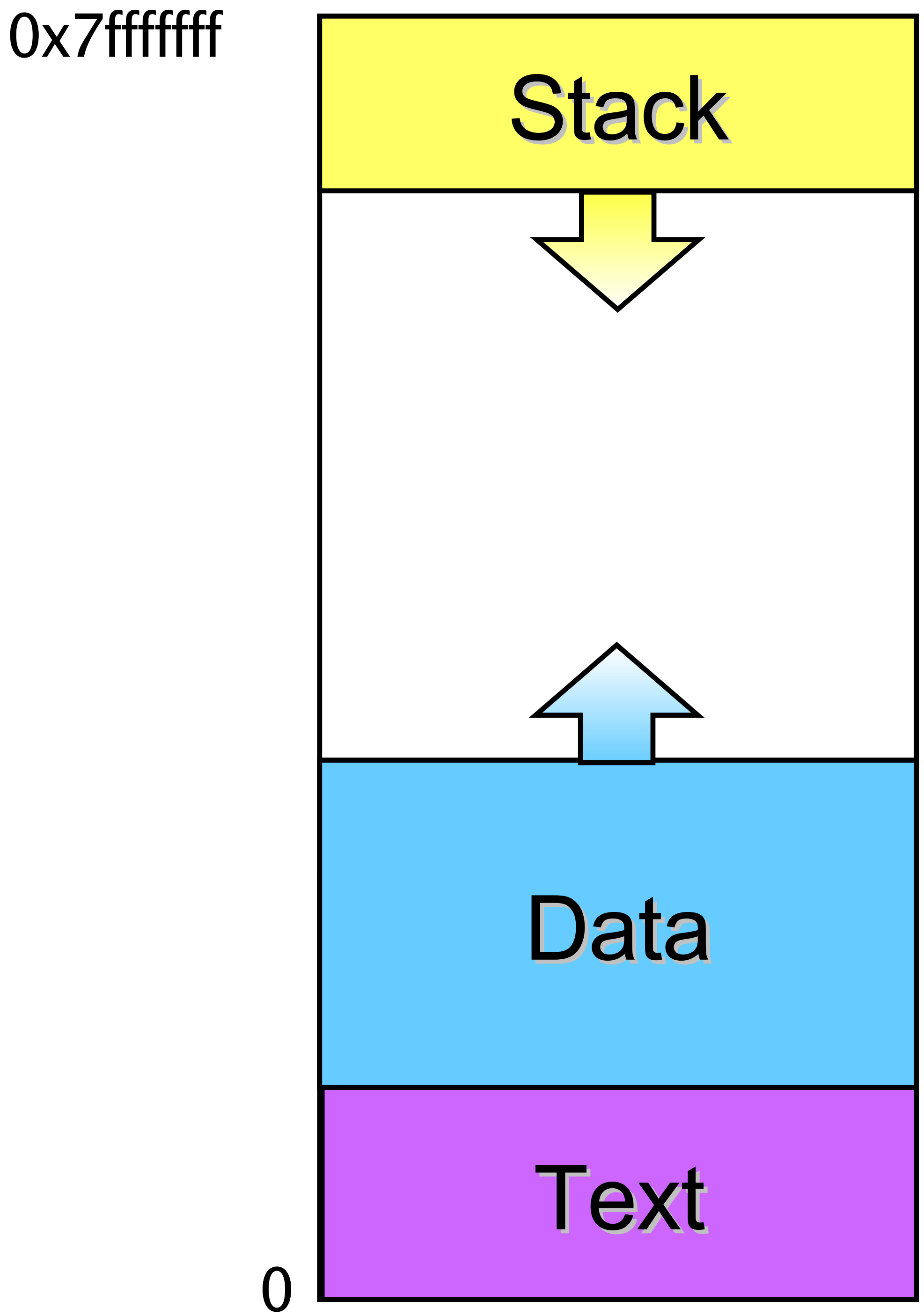
- Many of these should be familiar to Unix users…
- Processes (and trees of processes)
- Deadlock
- File systems & directory trees
- Pipes
- We'll cover all of these in more depth later on, but it's useful to have some basic definitions now

Processes



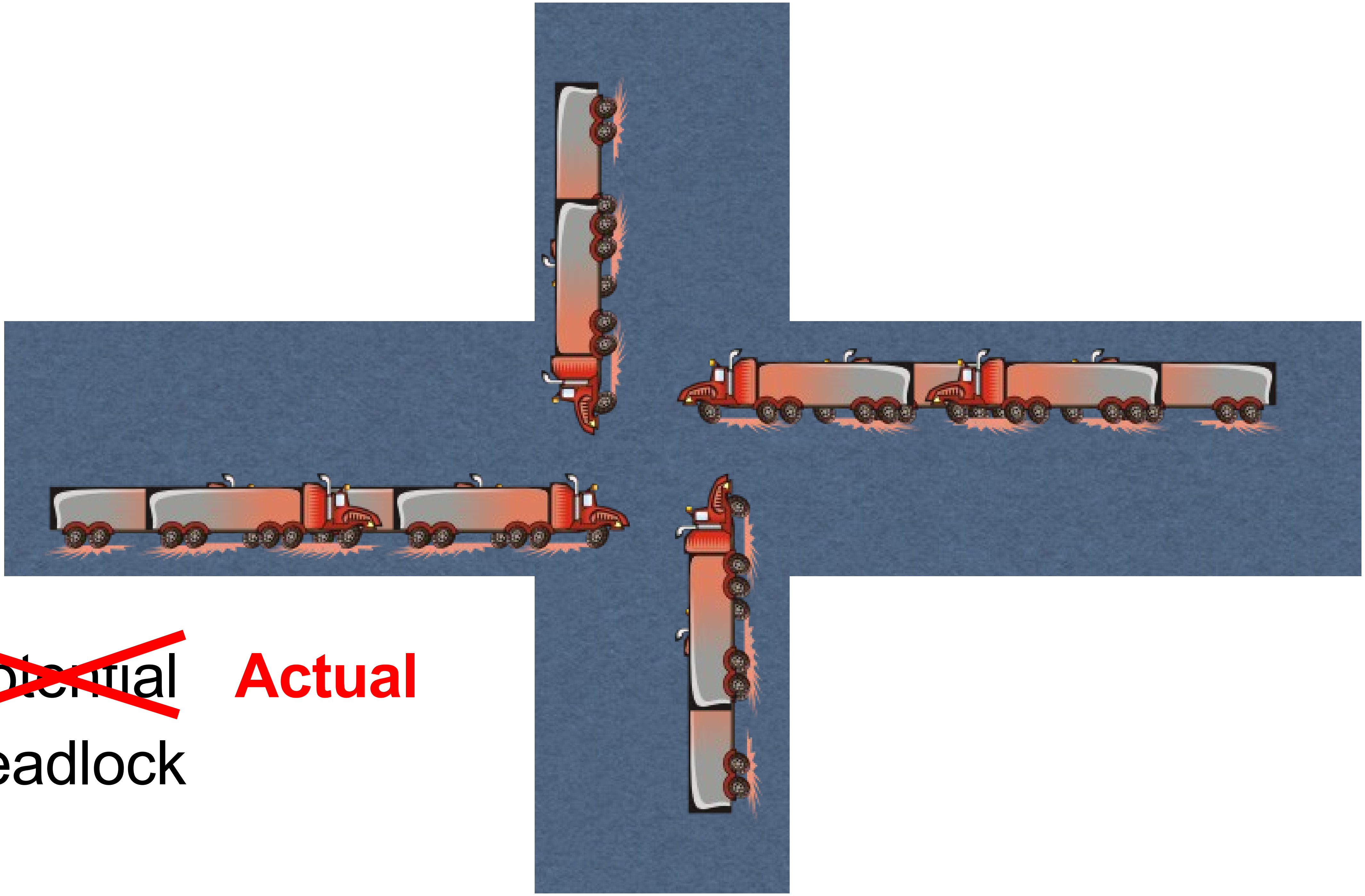
- Process: program in execution
  - Address space (memory) the program can use
  - State (registers, including program counter & stack pointer)
- OS keeps track of all processes in a process table
- Processes can create other processes
  - Process tree tracks these relationships
  - A is the root of 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

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"

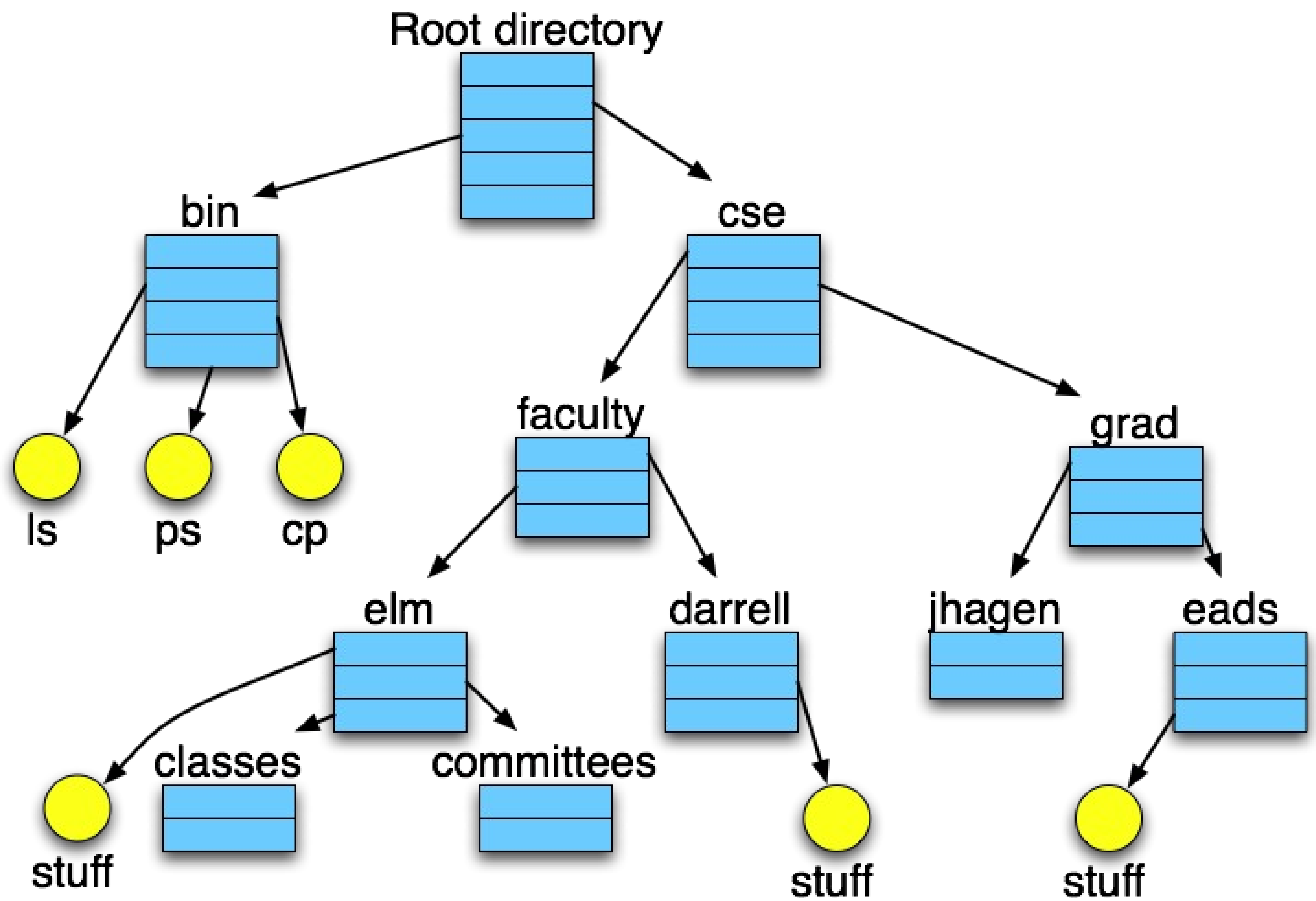
Deadlock



~~Potential~~ **Actual**

deadlock

Hierarchical file systems



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

System calls

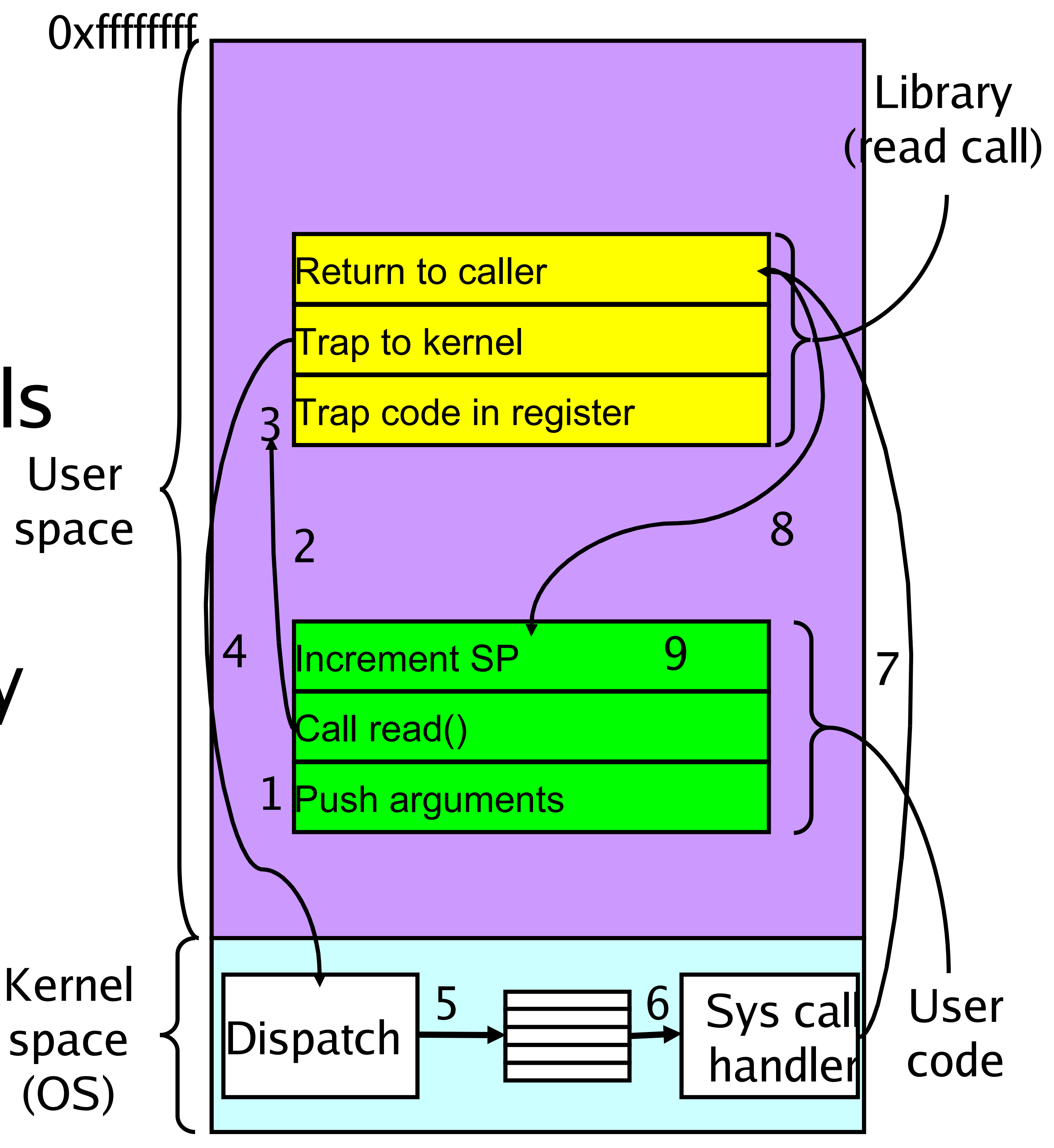
- OS runs in privileged mode
  - Some operations are permitted only in privileged (also called supervisor or system) mode
    - Example: access a device like a disk or network card
    - Example: change allocation of memory to processes
  - User programs run in user mode and can't do the operations
-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

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…

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



System calls for files & directories

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

More system calls

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

A simple shell

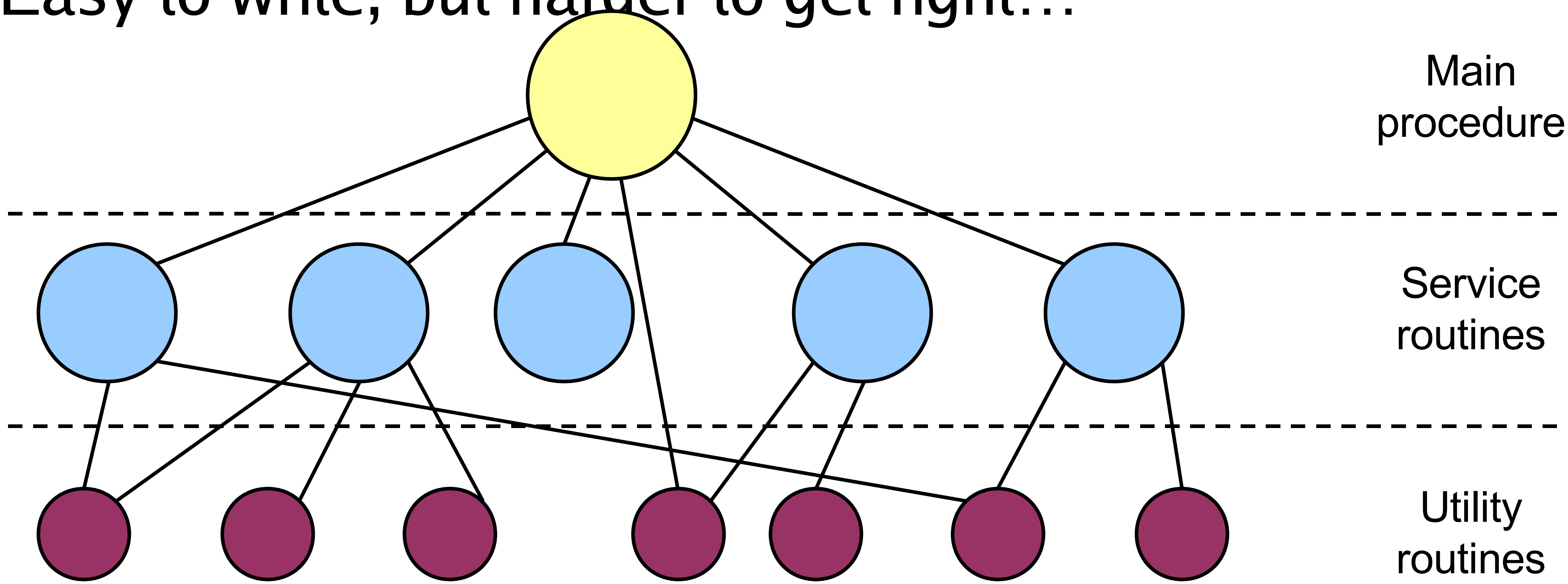
```
while (TRUE) {                          /* repeat forever */
  print_prompt( );                  /* display prompt */
  read_command (command, parameters) /* input from terminal */

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 */
 }
}
```

Operating system structure

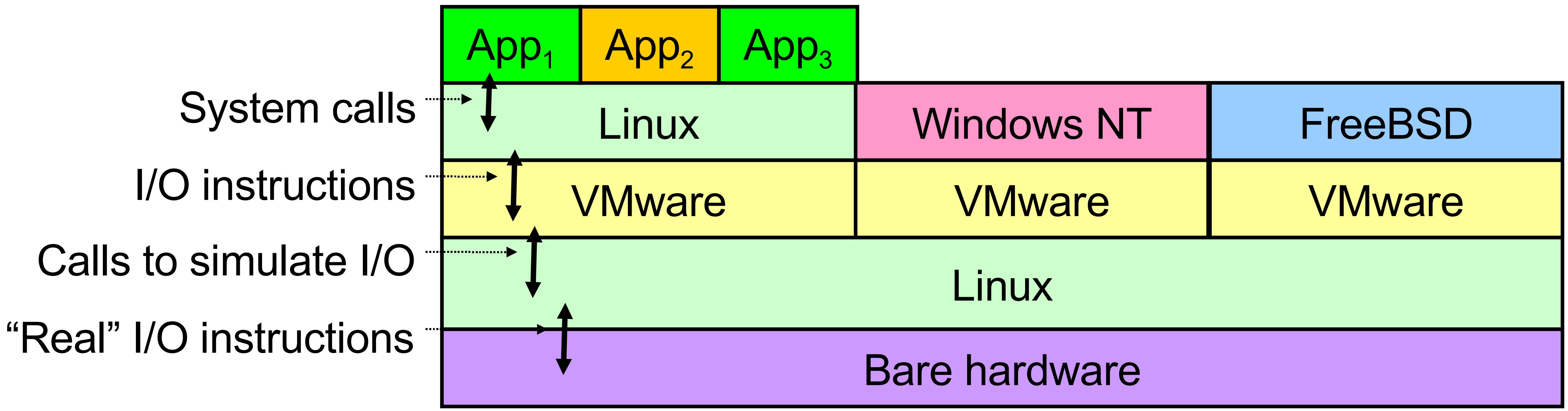
- OS is composed of lots of pieces
  - Memory management
  - Process management
  - Device drivers
  - File system
- How do the pieces of the operating system fit together and communicate with each other?
- Different ways to structure an operating system
  - Monolithic
    - Modular is similar, but more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

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…

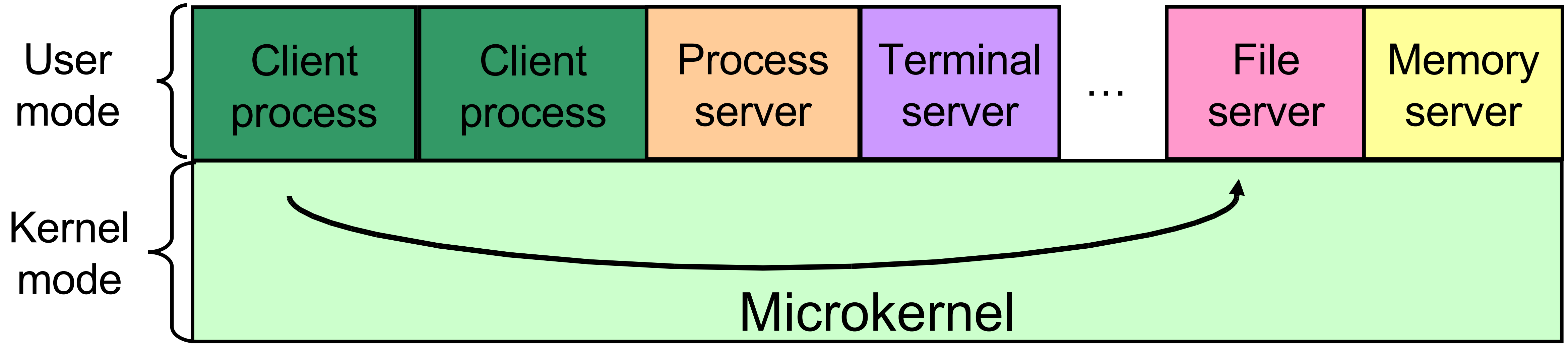


Virtual machines



- 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

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

History

- UNIX: 1969 Thompson & Ritchie AT&T Bell Labs
- BSD: 1978 Berkeley Software Distribution
- Commercial Vendors: Sun, HP, IBM, SGI, DEC
- GNU: 1984 Richard Stallman, FSF
- POSIX: 1986 IEEE Portable Operating System unIX
- Minix: 1987 Andy Tannenbaum
- SVR4: 1989 AT&T and Sun
- Linux: 1991 Linus Torvalds Intel 386 (i386)
- Open Source: GPL, LGPL, Cathedral and the Bazaar

GNU/Linux Features

- "UNIX-like". Multi-user, multi-tasking, UNIX system
- Goals
  - Speed, efficiency
  - "aims at"standards compliance (e.g., POSIX)
- "all the features you would expect in a modern UNIX"
  - preemptive multitasking
  - virtual memory (protected memory, paging)
  - shared libraries
  - demand loading, dynamic kernel modules
  - shared copy-on-write executables
  - TCP/IP networking
- other features:
  - SMP support, large memory, large files
  - advanced networking, advanced filesystems
  - efficient, stable, highly portable, supports most device hardware
  - active development community, support, documentation, open source
  - GUIs, applications
- Components: kernel (VM, proc mgmt), libraries (syscalls, buf I/O), system utils (netw daemons)

What's a Kernel?

(Also: executive, system monitor, nucleus)

- controls and mediates access to hardware
- implements and supports fundamental abstractions
  - processes, files, devices, users, net, etc.
- schedules "fair" sharing of system resources
  - memory, cpu, disk, descriptors, etc.
- enforces security and protection
- responds to user requests for service (system calls)
- performs routine maintenance, system checks, etc.

Highly concurrent!

Non-stop if possible! Even modifications on a live kernel

Highly extensible!

Needs to be designed to survive for a few decades (1 or 2) atleast!

Software arch/engg critical to success

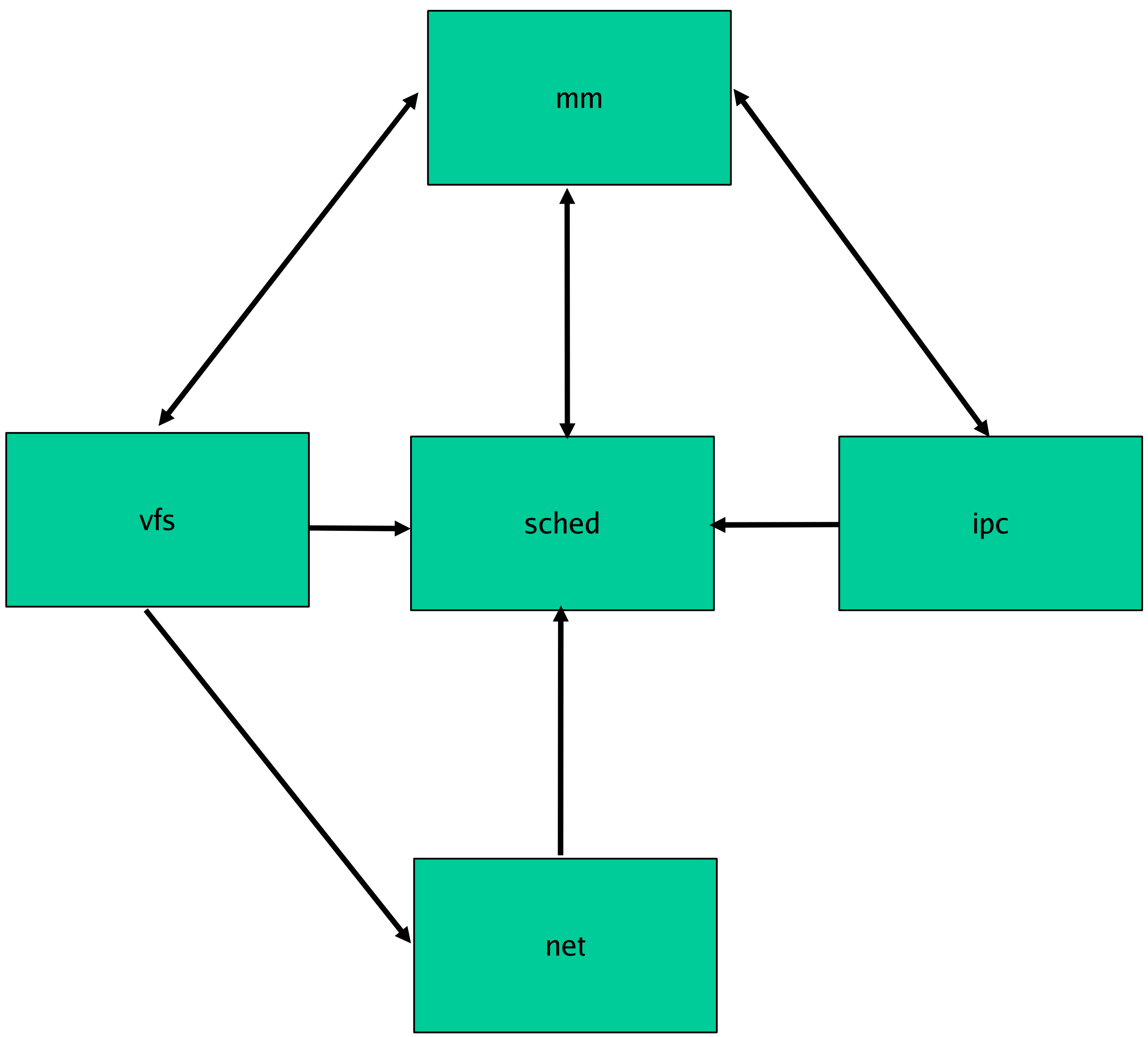
Kernel Design Goals

- performance: efficiency, speed
  - utilize resources to capacity, low overhead, code size
- stability: robustness, resilience
  - uptime, graceful degradation
- capability: features, flexibility, compatibility
- security, protection
  - protect users from each other, secure system from bad guys
- portability
- clarity
- extensibility

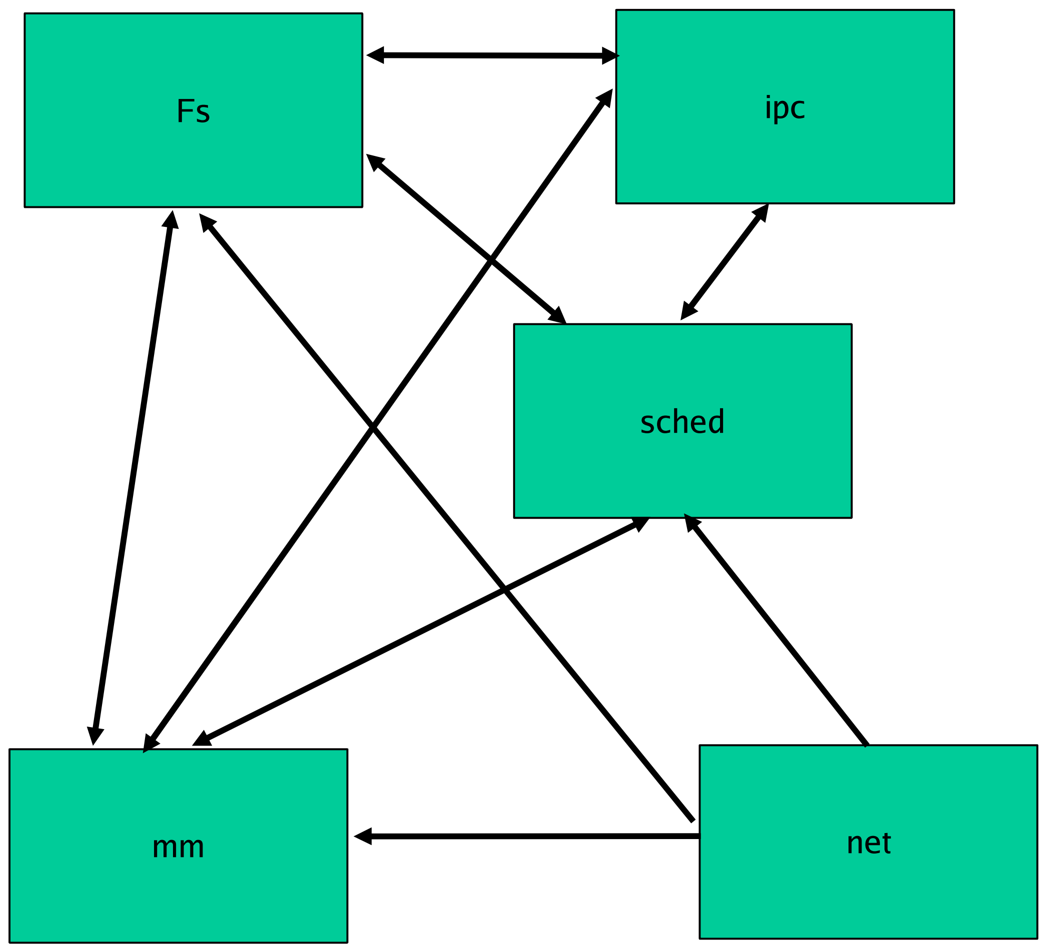
Design Tradeoffs

- Butler Lampson: "choose any three design goals"
- efficiency vs. protection
  - more checks, more overhead
- clarity vs. compatibility
  - ugly implementation of "broken" standards (e.g. signals)
- flexibility vs. security
  - the more you can do, the more potential security holes!
- not all are antagonistic
  - portability tends to enhance code clarity

Dependency Diagrams

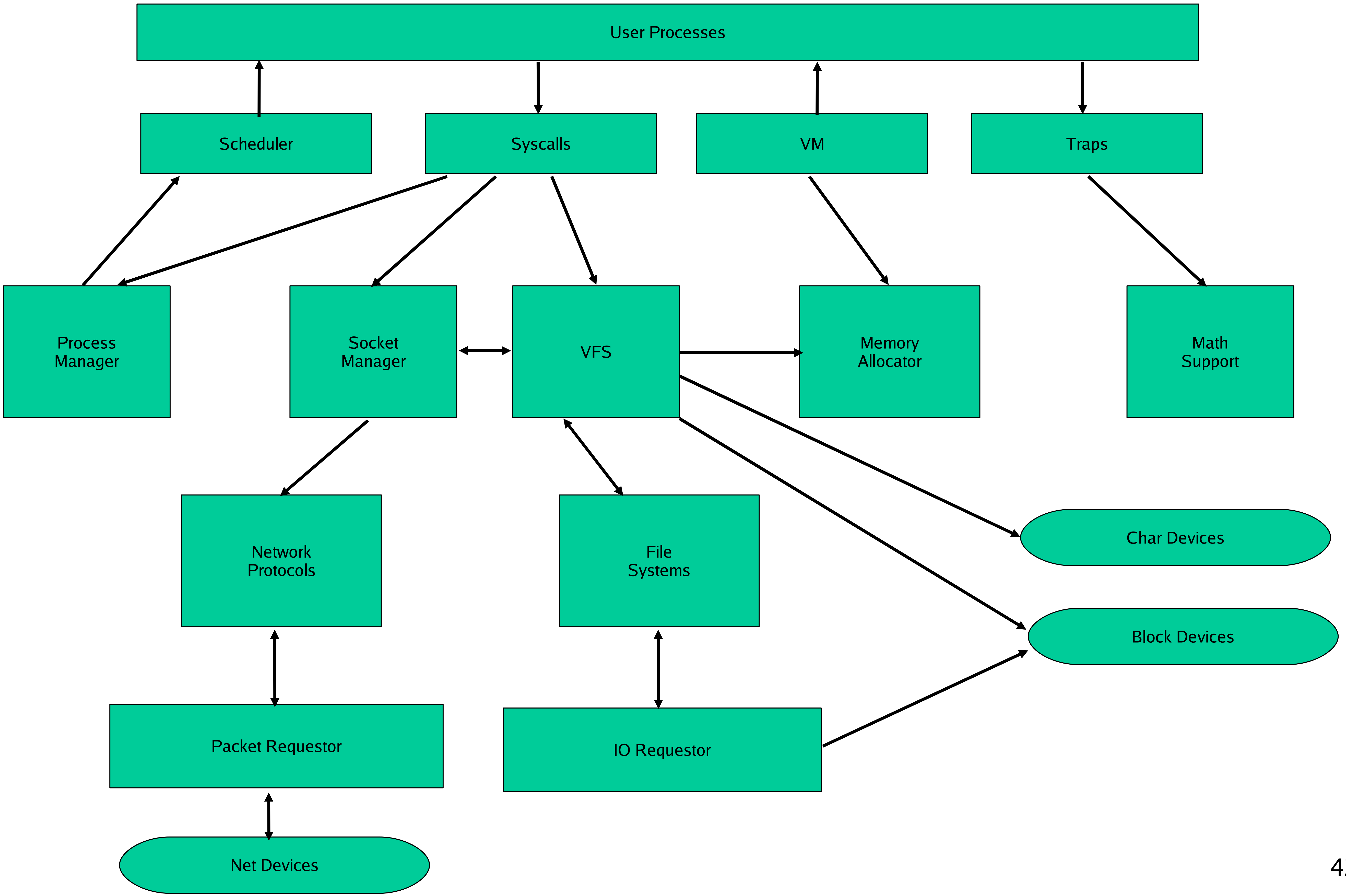


Conceptual



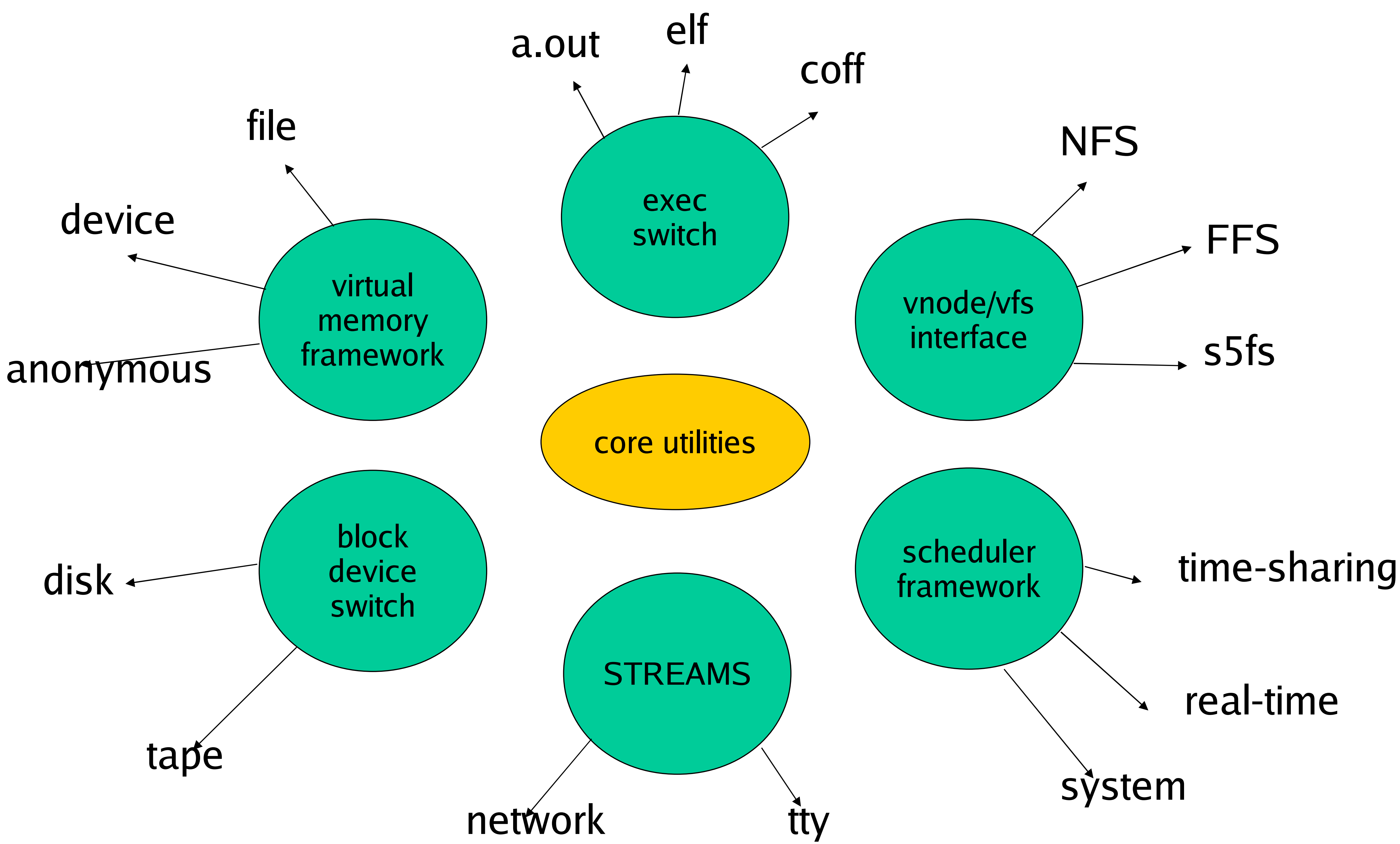
Concrete

Stephen Tweedie's Diagram

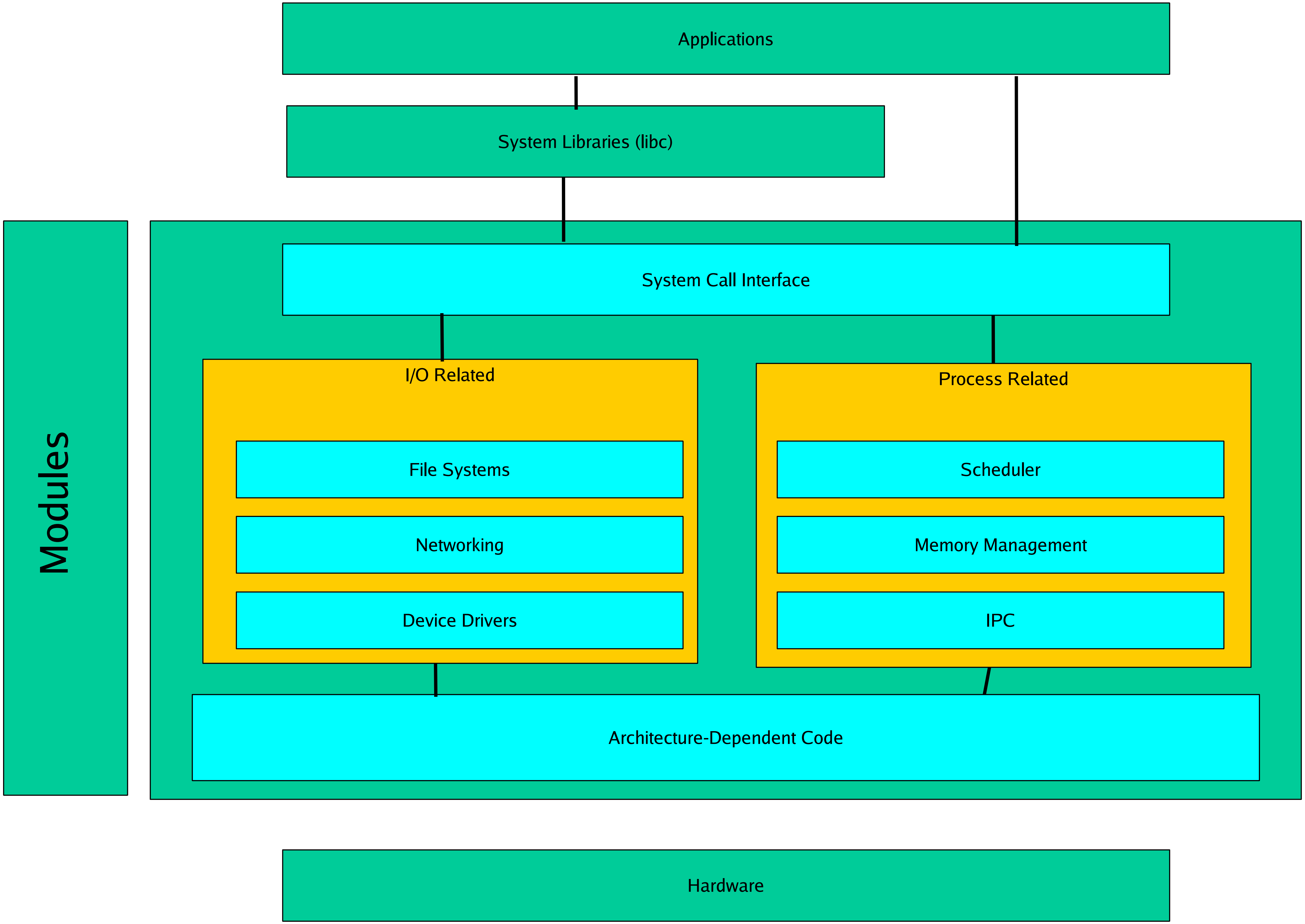


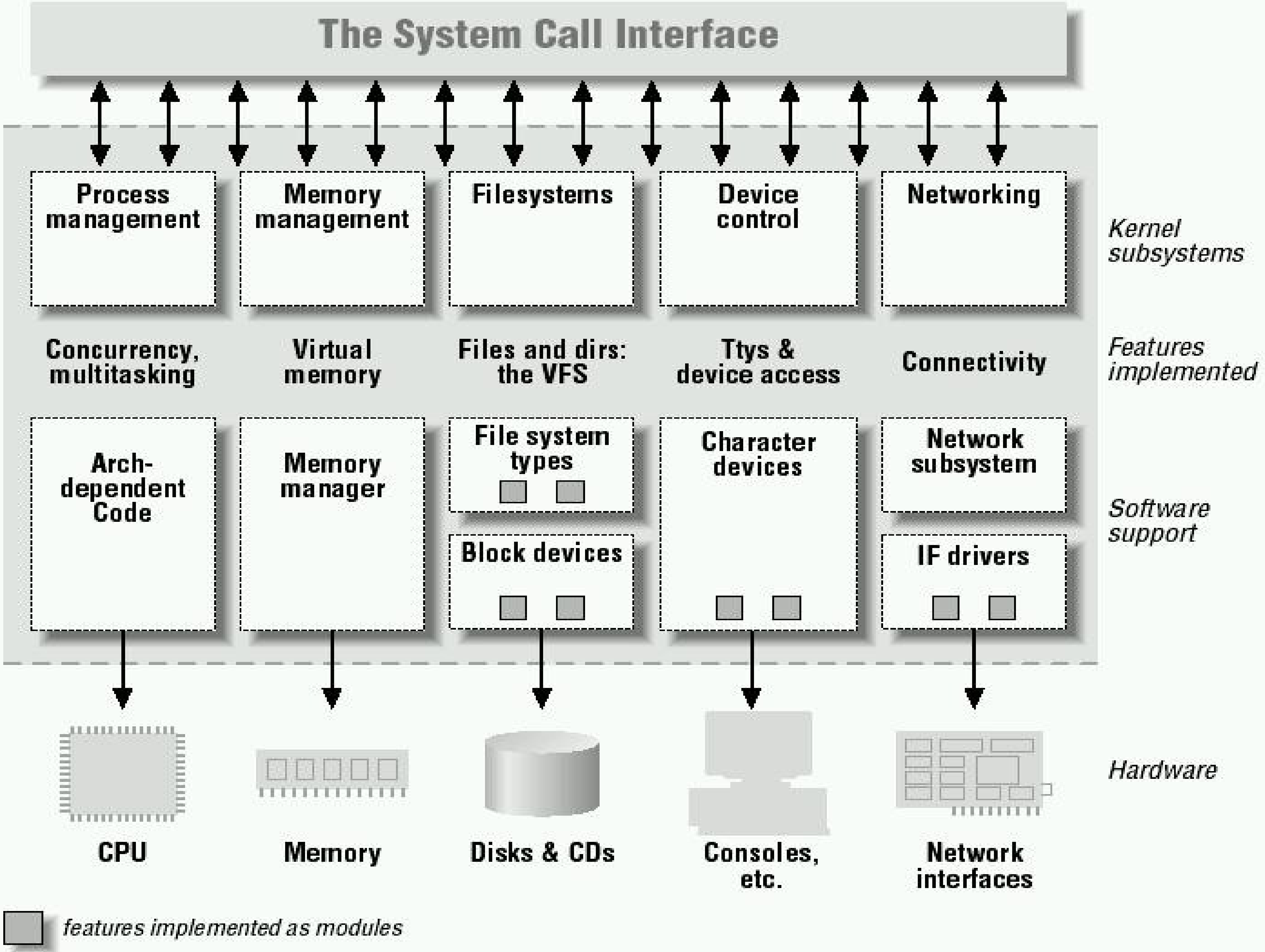
Vahalia's Diagram

from *Unix Internals: The New Frontiers*
Uresh Vahalia / Prentice-Hall 1996



“Core” Kernel


Applications
System Libraries (libc)
Modules
System Call Interface
I/O Related
File Systems
Networking
Device Drivers
Process Related
Scheduler
Memory Management
IPC
Architecture-Dependent Code
Hardware


The System Call Interface
Process management
Memory management
Filesystems
Device control
Networking
Kernel subsystems
Concurrency, multitasking
Virtual memory
Files and dirs: the VFS
Ttys & device access
Connectivity
Features implemented
Arch-dependent Code
Memory manager
File system types
Block devices
Character devices
Network subsystem
IF drivers
Software support
CPU
Memory
Disks & CDs
Consoles, etc.
Network interfaces
Hardware
features implemented as modules

Inserting a wireless card

- i82365: PCMCIA controller driver