CSCI 3753
Operating Systems

Design Issues

Lecture Notes By
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Three Design Issues

- System Boot
  - What happens when you switch on or reset a computing system
- Protecting OS from applications
  - How can we prevent an application program from corrupting the operating system
- System Call API
  - How is the system call interface that enables application programs to access OS services implemented

System Boot

- Operating system manages all programs: where they are stored, when to run them, etc.
- But how does the system know where the operating system is or how to load the kernel?
- *Booting* the system: Procedure of starting a computer by loading the operating system
- Bootstrap program (also called bootstrap loader)
  - Locates the kernel, loads it into main memory, and starts its execution
  - Typically a 2-step process: a simple bootstrap loader fetches a more complex boot program from disk, which in turn loads the kernel

System Boot

- When CPU receives a reset event (powered/reboot)
  - IR is loaded with a predefined memory location that contains the initial bootstrap program
  - In ROM: needs no initialization and cannot easily be infected
- Bootstrap program
  - Run diagnostics to determine the state of the machine
  - Initialize registers, main memory, device controllers, etc.
  - Start OS
- Smaller systems: store entire OS in ROM or EPROM (firmware)

System Boot (Larger Systems)

- Multi-stage procedure:
  1. Power On Self Test (POST) from ROM
     - Check hardware, e.g. CPU and memory, to make sure it's OK
  2. BIOS (Basic Input/Output System) looks for a device to boot from…
     - May be prioritized to look for a USB flash drive or a CD/DVD-ROM drive before a hard disk drive
     - Can also boot from network

System Boot (Larger Systems)

- Multi-stage procedure: (continued)

3. BIOS finds a hard disk drive to boot from
   - Looks at Master Boot Record (MBR) in sector 0 of disk
   - Only 512 bytes long (Intel systems), contains primitive code for later stage loading and a partition table listing an active partition, or the location of the bootloader

System Boot (Larger Systems)

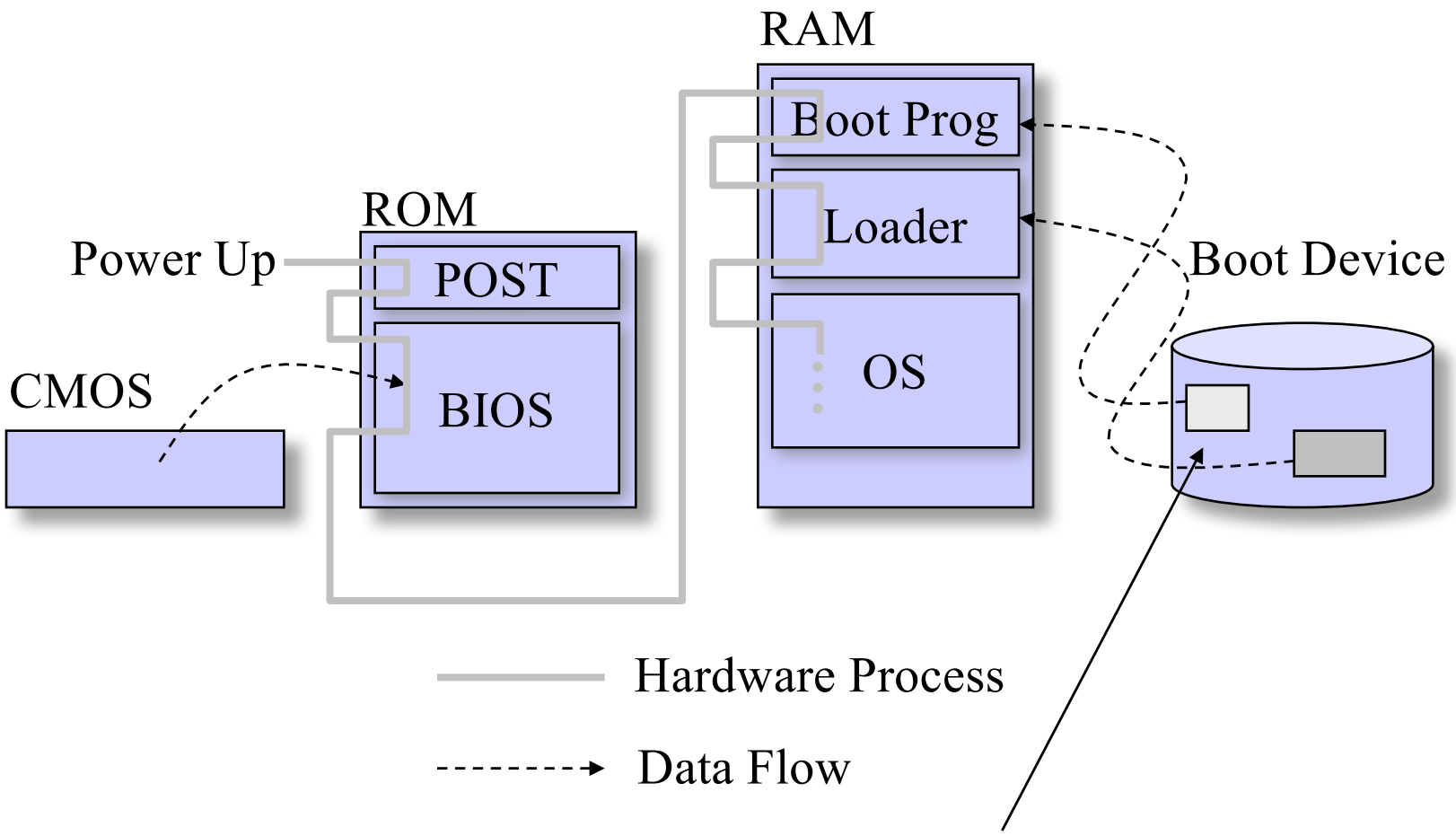
- Multi-stage procedure: (continued)

  4. Primitive loader then loads the secondary stage bootloader
     - Examples of this bootloader include LILO (Linux Loader), and GRUB (Grand Unified Bootloader)
     - Can select among multiple OS's (on different partitions) – i.e. dual booting
     - Once OS is selected, the bootloader goes to that OS's partition, finds the boot sector, and starts loading the OS's kernel

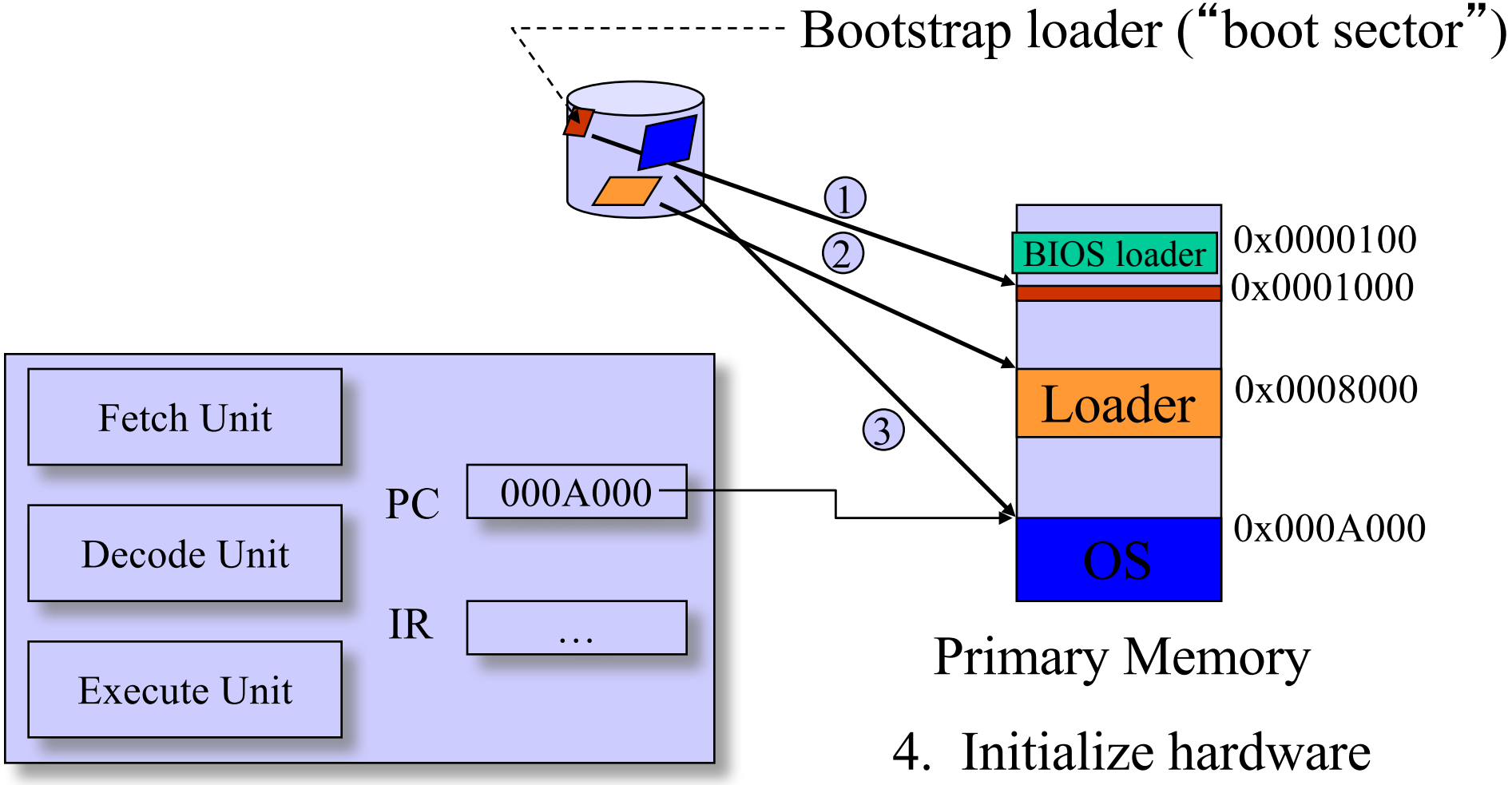
Protecting OS from applications

- In early CPUs, there was no way to differentiate between the OS and applications:
  - Want to protect OS from being overwritten by app's
  - Want to prevent applications from executing certain privileged instructions, like resetting the time slice register, resetting the interrupt vector, etc.
- Processors include a hardware *mode* bit that identifies whether the system is in *user* mode or *supervisor/kernel* mode
  - Requires extra support from the CPU hardware for this OS feature

Intel System Initialization



Bootstrapping Example



4. Initialize hardware
5. Create user environment
6. …

Dual Mode Operation

- Processor mode: distinguish between execution on behalf of an OS and execution on behalf of a user.
- Kernel: trusted software module that supports the correct operation of all other software; core part of OS.
- OS interface: how a user interacts with an OS to request OS services.

Processor mode

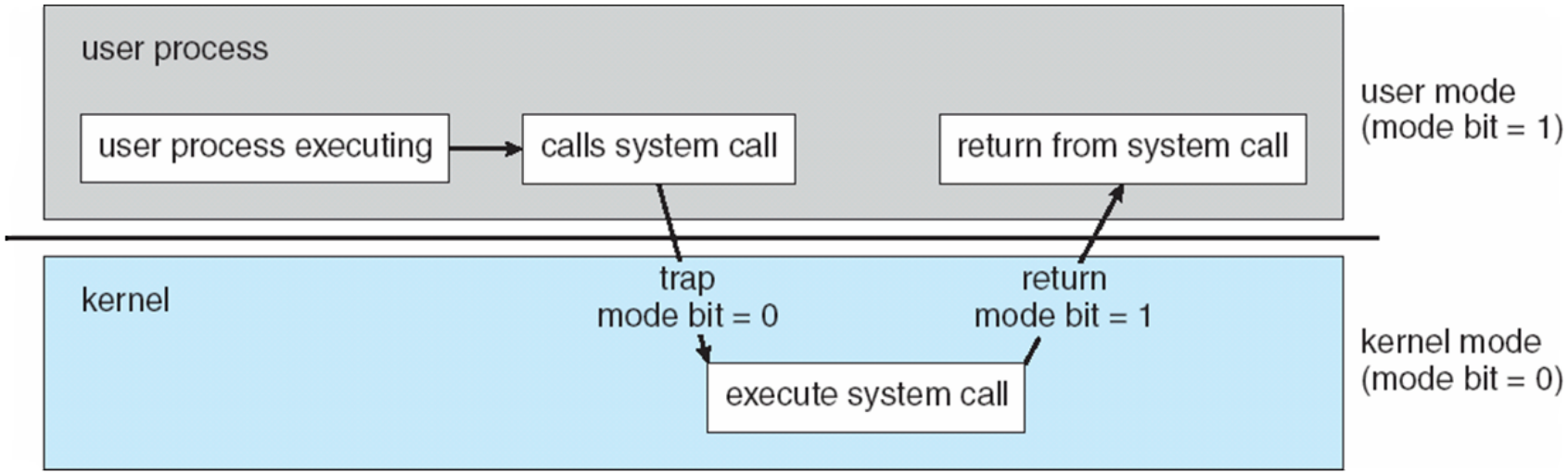
- Supervisor mode or user mode:
  - Supervisor mode (mode bit = 0): processor can execute every instruction available in the instruction set.
  - User mode (mode bit = 1): processor can execute only a subset of instructions available in the instruction set.
- Privileged (protected) instructions:
  - Instructions that can be executed only in supervisor mode.
  - I/O instructions
  - Protection and security: privileged load and store instructions
- Used to define two classes of memory space: user space and system space.

User / Kernel Modes

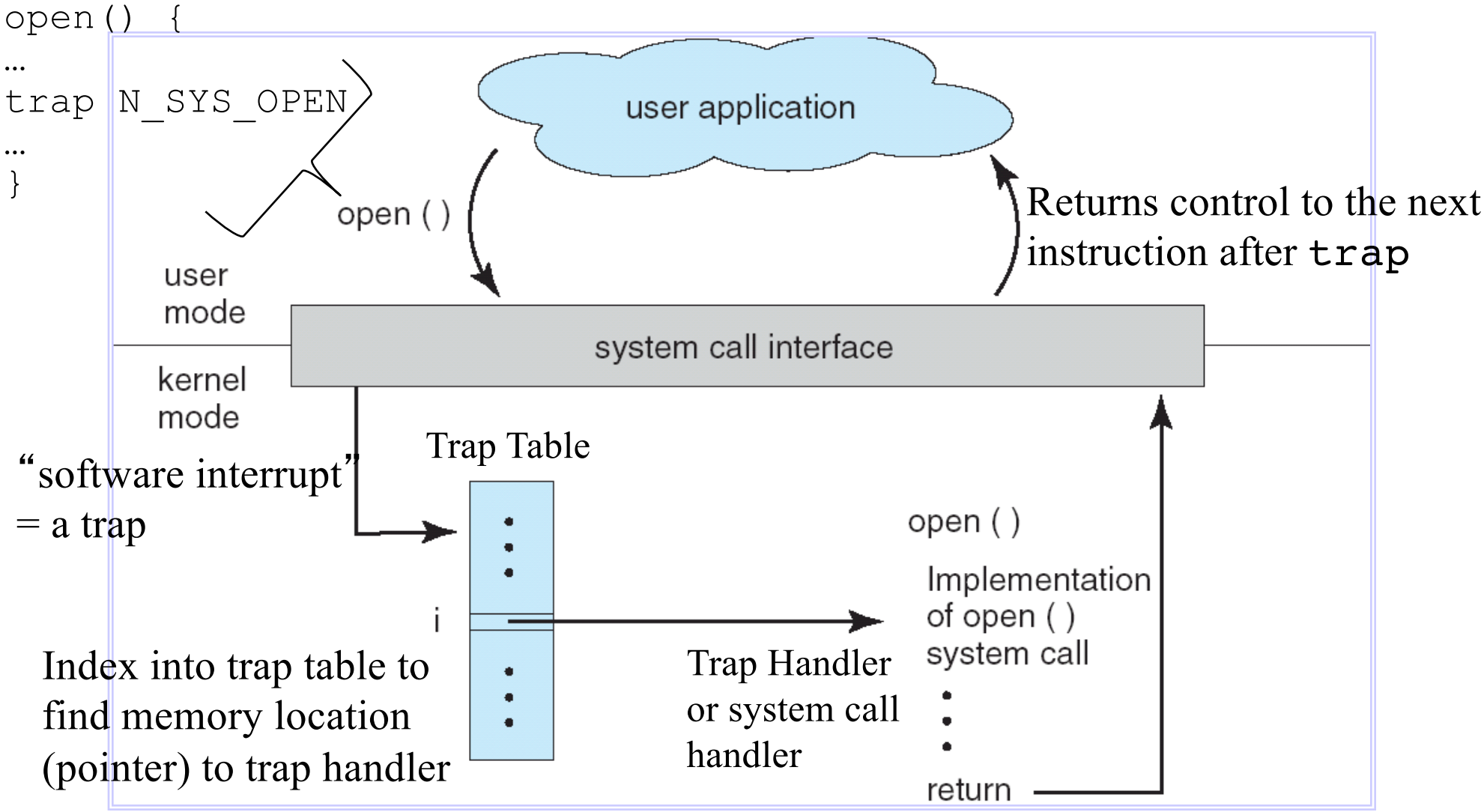
- Most modern CPU's support this mode bit
  - Intel x86 CPUs have four modes or rings, but not all are necessarily used by the OS
    - Example: an OS like Linux or Windows might set itself as ring/mode 0 (highest privilege, can execute any CPU instruction and access any location in memory), while all applications run in ring/mode 3 (lowest privilege, if an app attempts to run a privileged instruction or access restricted memory, it will generate a fault, invoking the higher privileged OS). Rings 1 and 2 unused.
    - Example: a virtual machine monitor (VMM) such as VMWare might set itself as ring 0, while a guest OS VM might run as ring 1 or 2, and user applications would run as ring 3
  - Embedded microcontrollers typically don't have a mode bit

How do Apps and the OS communicate

- The trap instruction is used to switch from user to supervisor mode, thereby entering the OS
  - trap sets the mode bit to 0
  - Also called syscall in MIPS
  - mode bit set back to 1 on return
- Any instruction that invokes trap is called *a system call*
- trap indexes into a *trap table* (stored in kernel) and runs the function pointed to from that location



API – System Call – OS Relationship



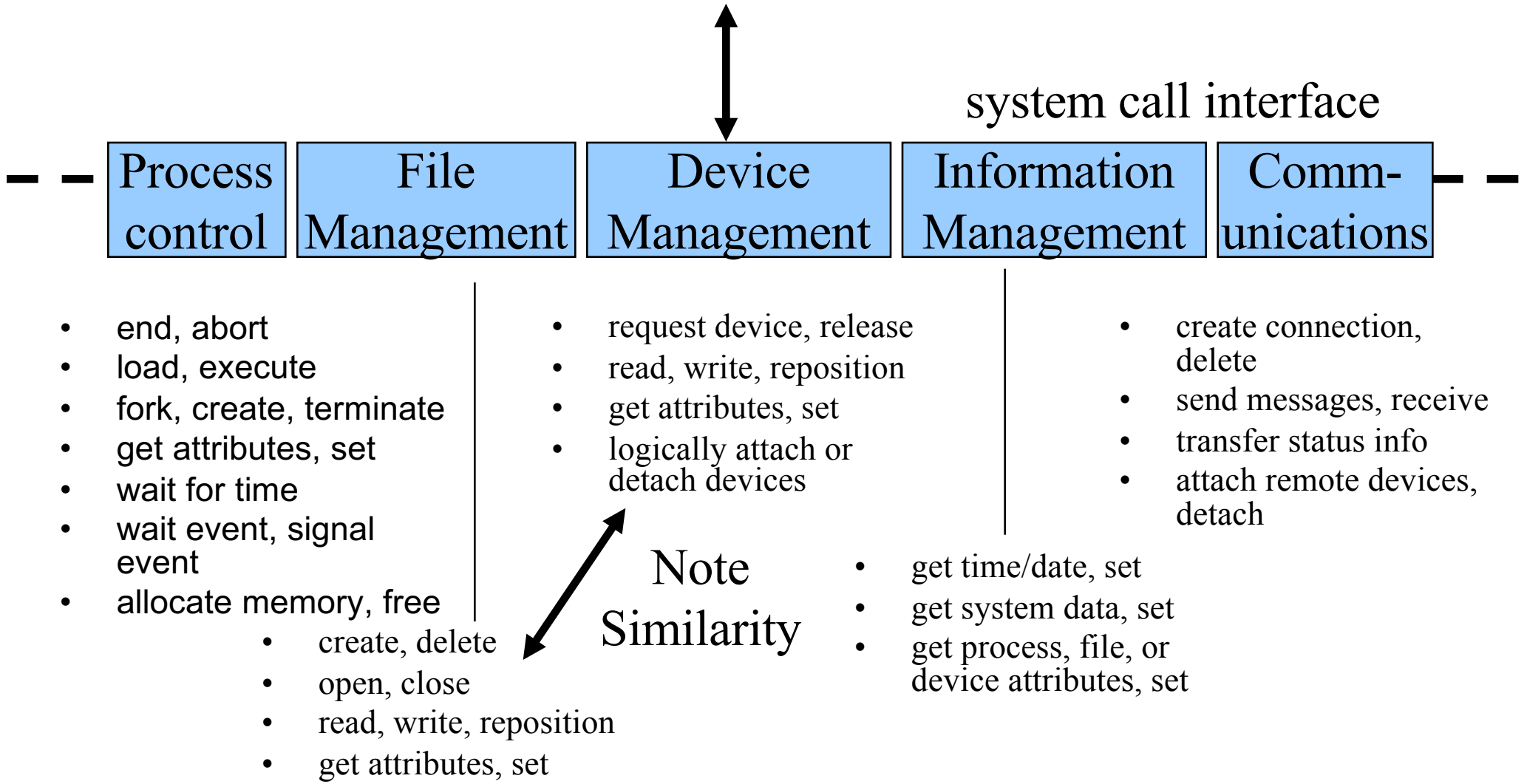
Trap Table

- The process of indexing into the trap table to jump to the trap handler routine is also called dispatching
- The trap table is also called a *jump table* or a *branch table*
- "A trap is a software interrupt"
- Trap handler (or system call handler) performs the specific processing desired by the system call/trap

System Call Parameter Passing

- Often, more information is required than simply identity of desired system call
  - type and amount of information vary according to OS and call
- Three general methods used to pass parameters to the OS
  - Simplest: pass the parameters in *registers*
    - In some cases, may be more parameters than registers
  - Parameters stored in a *block* in memory, and block address passed as a parameter in a register
    - This approach taken by Linux and Solaris
  - Parameters placed, or *pushed,* onto the *stack* by the program and *popped* off the stack by the operating system
  - Block and stack methods do not limit the number or length of parameters being passed

Classes of System Calls Invoked by `trap`



Examples of Exceptions in x86 Systems

Class	Cause	Examples	Return behavior
Trap	Intentional exception, i.e. "software interrupt"	System calls	always returns to next instruction, synchronous
Fault	Potentially recoverable error	Divide by 0, stack overflow, invalid opcode, page fault	might return to current instruction, sync
Abort	nonrecover-able error	Hardware bus failure	never returns, sync
Interrupt	signal from I/O device	Disk read finished	always returns to next instruction, async

Course Outline

- Device Management (Chapter 13)
  - Managing I/O devices
- Process Management (Chapters 3 – 7)
  - Processes and threads
  - Process synchronization
  - CPU scheduling
  - Deadlocks
- Memory Management (Chapters 8 – 9)
  - Primary memory management
  - Virtual memory

- Storage Management (Chapters 10 – 12)
  - Mass-storage structure
  - File system interface and implementation
- Protection and security(Chapters 14 – 15)
- If time permits …
  - Virtual machines and distributed systems