Operating Systems

03. Definitions, Concepts, & Architecture

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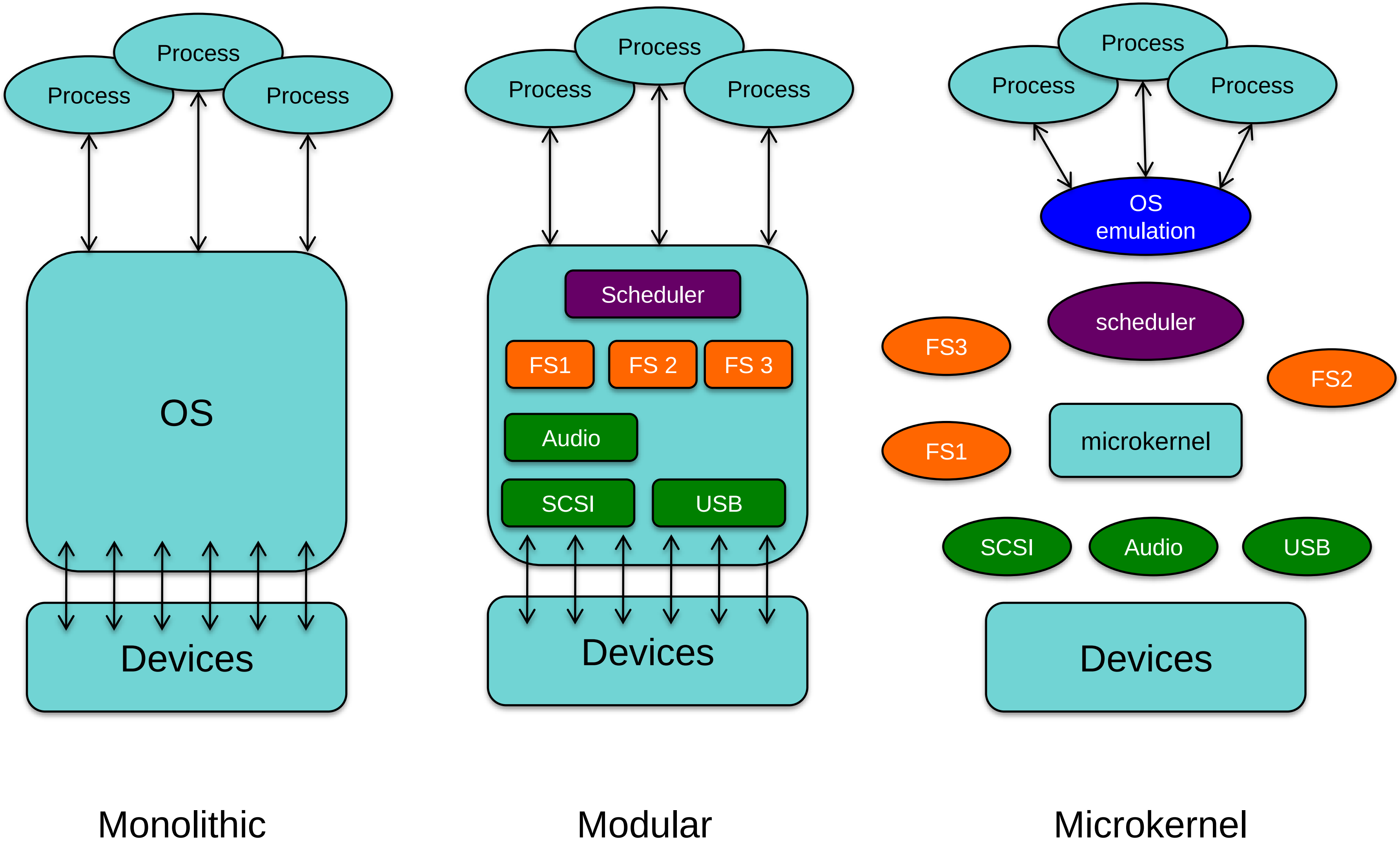
Definitions, Concepts, and Architecture

What is an operating system?

- The first program
- A program that lets you run other programs
- A program that provides controlled access to resources:
  - CPU
  - Memory
  - Display, keyboard, mouse
  - Persistent storage
  - Network

  This includes: naming, sharing, protection, communication

OS Structure



What’s a kernel?

- Operating System
  - Often refers to the complete system, including command interpreters, utility programs, window managers, …
- Kernel
  - Core component of the system that manages resource access, memory, and process scheduling

Some of the things a kernel does

- Controls execution of processes
  - Creation, termination, communication
  - Schedules processes for execution on the CPU(s)
- Manages memory
  - Allocates memory for an executing process
  - Sets memory protection
  - Coordinates swapping pages of memory to a disk if low on memory
- Manages a file system
  - Allocation and retrieval of disk data
  - Enforcing access permissions & mutual exclusion
- Provides access to devices
  - Disk drives, networks, keyboards, displays, printers, …
  - Enforces access permissions & mutual exclusion

Execution: User Mode vs. Kernel Mode

- Kernel mode = privileged, system, supervisor mode
  - Access restricted regions of memory
  - Modify the memory management unit
  - Set timers
  - Define interrupt vectors
  - Halt the processor
  - Etc.

- CPU knows what mode it's in via a status register
  - You can set the register in kernel mode
  - OS & boot loaders run in kernel mode
  - User programs run in user mode

How do you get to kernel mode?

- Trap: Transfer of control
  - Like a subroutine call (return address placed on stack)
  - Mode switch: user mode → kernel mode
- Interrupt Vector Table
  - Configured by kernel at boot time
  - Depending on architecture
    - Code entry points
      - Control jumps to an entry in the table based on trap number
      - Table will contain a set of JMP instructions to different *handlers* in the kernel
    - List of addresses
      - Each entry contains a structure that defines the target address & privilege level
      - Table will contain a set of addresses for different *handlers* in the kernel
- Returning back to user mode
  - *Return from exception*

How do you get to kernel mode?

Three types of traps:

1. Software interrupt – explicit instruction
   - Intel architecture: INT instruction (interrupt)
   - ARM architecture: SWI instruction (software interrupt)
2. Violation
3. Hardware interrupt

Traps give us a mechanism to transfer to *well-defined* entry points in the kernel

System Calls: Interacting with the OS

- A system call is a way for a user program to request services from the operating system
  - The operating system remains in control of devices
  - Enforces policies

- Use *trap* mechanism to switch to the kernel
  - User ↔ Kernel mode switch: Mode switch
  - Note: most architectures support an optimized trap for system calls
    - Intel: SYSENTER/SYSEXIT
    - AMD: SYSCALL/SYSRET

System Calls: Interacting with the OS

- Use *trap* mechanism to switch to the kernel
- Pass a number that represents the OS service (e.g., *read*)
  - System call number; usually set in a register
- A system call does the following:
  - Set the system call number
  - Save parameters
  - Issue the trap (jump to kernel mode)
    - OS gets control
    - Saves registers, does the requested work
    - Return from exception (back to user mode)
  - Retrieve results and return them to the calling function
- System call interfaces are encapsulated as library functions

Regaining control: Timer interrupts

- How do we ensure that the OS can get control?
  - If your process is running, the operating system is *not* running
- Program a timer interrupt
- Crucial for:
  - Preempting a running process to give someone else a chance (force a context switch)
    - Including ability to kill the process
  - Giving the OS a chance to poll hardware
  - OS bookkeeping

Timer interrupts

- Windows
  - Typically 64 or 100 interrupts per second
  - Apps can raise this to 1024 interrupts per second
- Linux
  - Interrupts from Programmable Interval Timer (PIT) or HPET (High Precision Event Timer) and from a local APIC timer (one per CPU)
  - Interrupt frequency varies per kernel and configuration
    - Linux 2.4: 100 Hz
    - Linux 2.6.0 – 2.6.13: 1000 Hz
    - Linux 2.6.14+ : 250 Hz
    - Linux 2.6.18 and beyond: aperiodic – tickless kernel
      - PIT not used for periodic interrupts; just APIC timer interrupts

Context switch & Mode switch

- An interrupt or trap results in a *mode switch*:
- An operating system may choose to save a process' state and restore another process' state → preemption
  - Context switch
  - Save all registers
    (including stack pointers, PC, and flags)
  - Load saved registers (including SP, PC, flags)
  - To return to original context: restore registers and return from exception
- Context switch:
  - Switch to kernel mode
  - Save state so that it can be restored later
  - Load another process' saved state
  - Return (to the restored process)

Devices

- Character: mice, keyboard, audio, scanner
  - *Byte streams*
- Block: disk drives, flash memory
  - *Addressable blocks (suitable for caching)*
- Network: Ethernet & wireless networks
  - *Packet based I/O*
- Bus controllers
  - *Interface with communication busses*

Interacting with devices

- Devices have command registers
  - *Transmit, receive, data ready, read, write, seek, status*
- Memory mapped I/O
  - Map device registers into memory
  - Memory protection now protects device access
  - Standard memory load/store instructions can be used to interact with the device

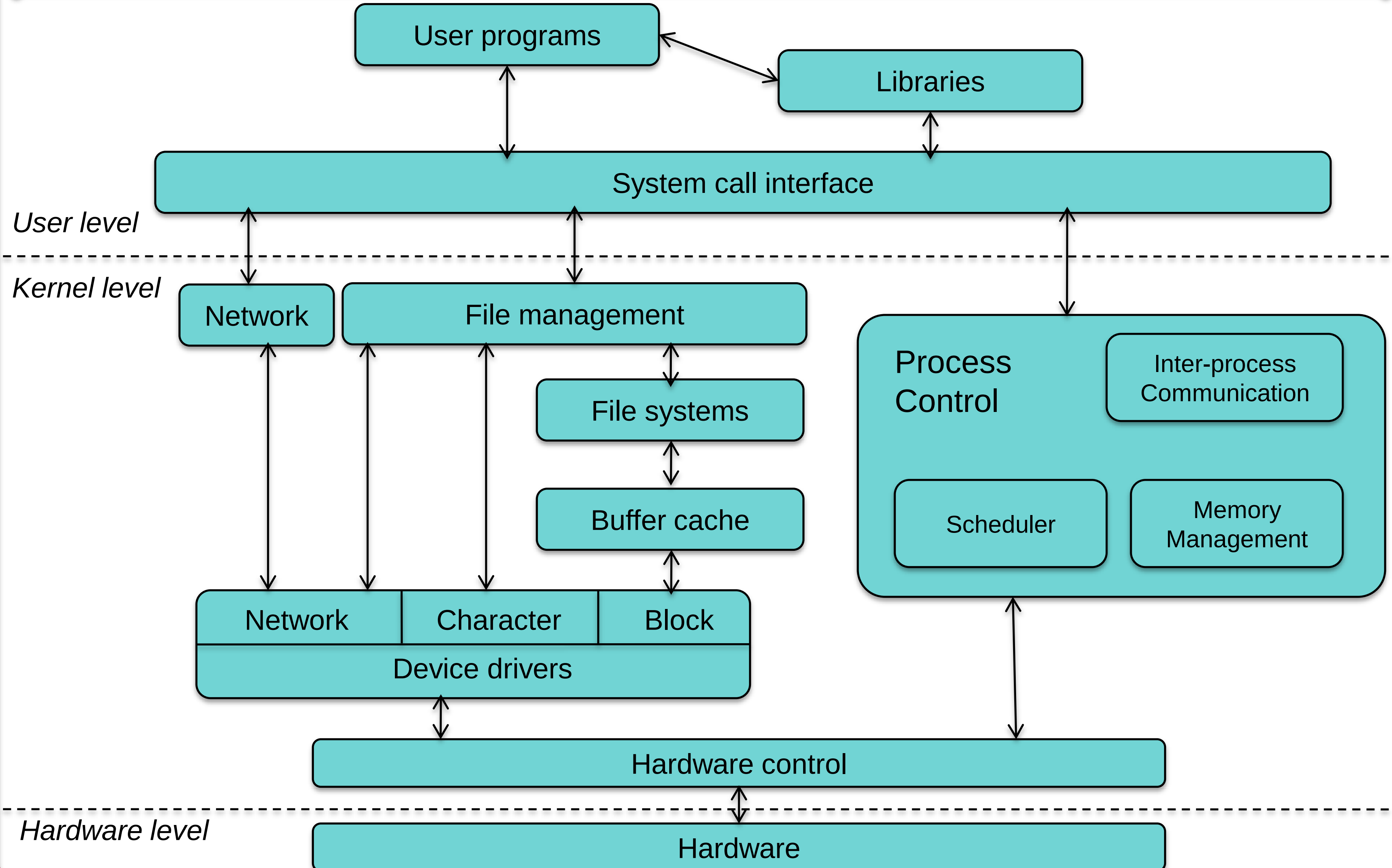
Getting data to/from devices

- When is the device ready?
  - Polling
    - Wait for device to be ready
    - To avoid busy loop, check each clock interrupt
  - Interrupts from the device
    - Interrupt when device has data or when the device is done transmitting
    - No checking needed – but context switch may be costly

Getting data to/from devices

- How do you move data?
  - Programmed I/O (PIO)
    - Use memory-mapped device registers
    - The processor is responsible for transferring data to/from the device by writing/reading these registers
  - DMA
    - Allow the device to access system memory directly

Structure of an operating system



Mechanisms & Policies

OS Mechanisms & Policies

- Mechanisms:
  - Presentation of a software abstraction:
    - Memory, data blocks, network access, processes
- Policies:
  - Procedures that define the behavior of the mechanism
    - Allocation of memory regions, replacement policy of data blocks
- Permissions
  - Enforcement of access rights
- Keep mechanisms, policies, and permissions separate

Processes

- Mechanism:
  - Create, terminate, suspend, switch, communicate
- Policy
  - Who is allowed to create and destroy processes?
  - What is the limit?
  - What processes can communicate?
  - Who gets priority?
- Permissions
  - Is the process making the request allowed to perform the operation?

Threads

- Mechanism:
  - Create, terminate, suspend, switch, synchronize
- Policy
  - Who is allowed to create and destroy threads?
  - What is the limit?
  - How do you assign threads to processors?
  - How do you schedule the CPU among threads of the same process?

Virtual Memory

- Mechanism:
  - Logical to physical address mapping

- Policy
  - How do you allocate physical memory among processes and among users?
  - How do you share physical memory among processes?
  - Whose memory do you purge when you're running low?

The End