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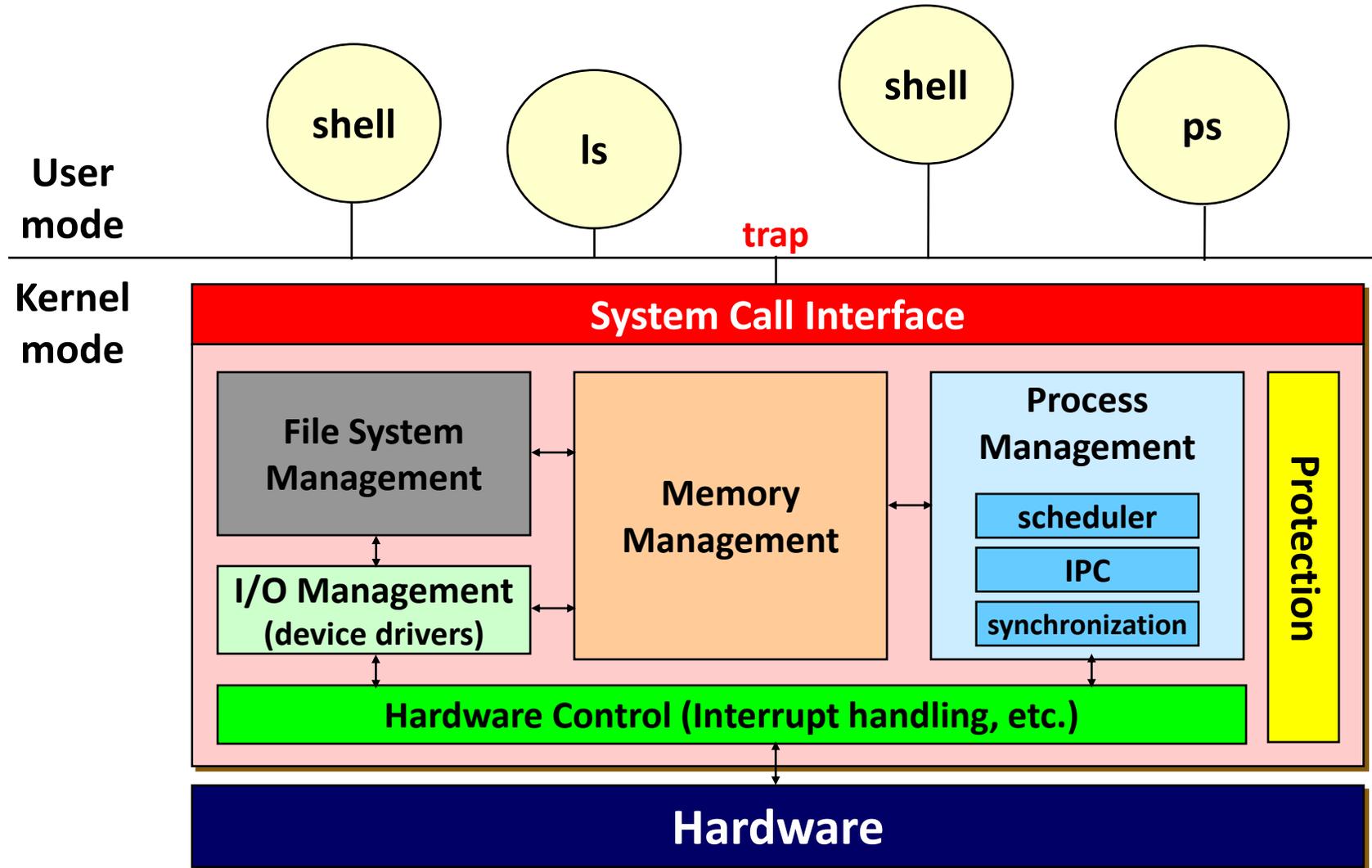
Seoul National University

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Introduction to Operating Systems



Operating System Internals



OS: Application View

- OS provides an execution environment for running programs
- OS provides a(an) _____ view of the underlying computer system
 - What are the correct abstractions?
 - How much of hardware should be exposed?
- Typical OS abstractions
 - Processors → Processes, Threads
 - Memory → Address space (virtual memory)
 - Storage → Volumes, Directories, Files
 - I/O Devices → Files (+ ioctls)
 - Networks → Files (sockets, pipes, ...)



OS: System View

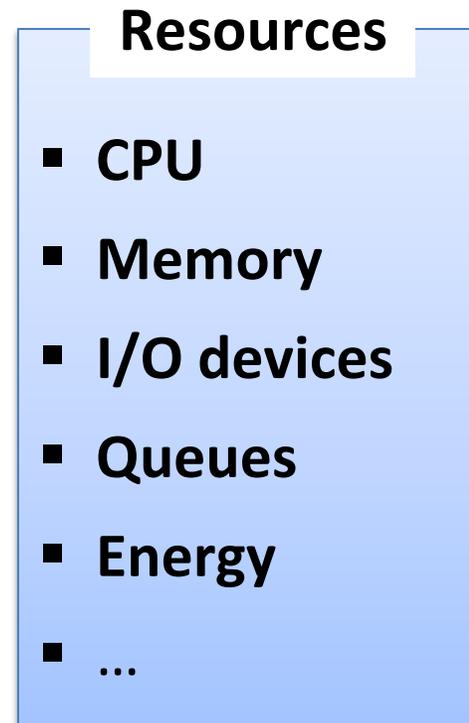
- OS manages various resources of a computer system

- Sharing



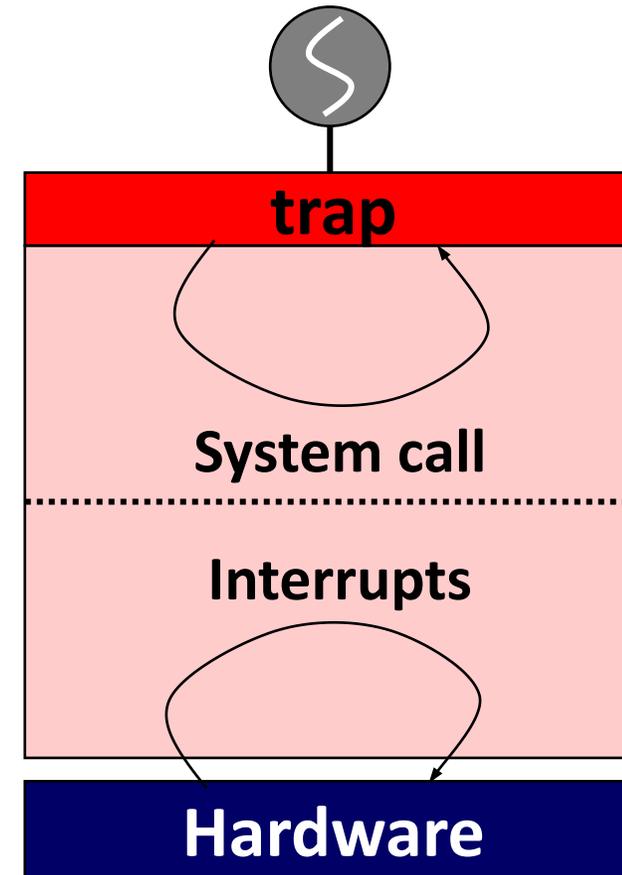
- Fairness

- Efficiency



OS: Implementation View

- OS is highly-concurrent, _____ software
- Two kinds of events
 - System calls
 - Interrupts



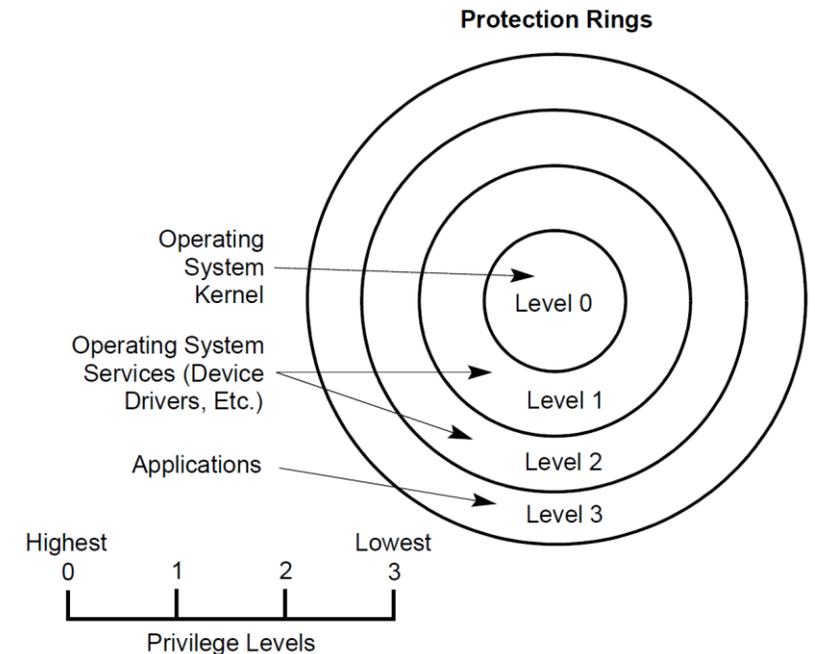
Unix Features

- **Process control**
 - `fork()`, `exec()`, `wait()`, `exit()`
 - Pipes for inter-process communication (IPC)
- **Hierarchical file systems**
 - Special files: uniform I/O, naming, and protection
 - Removable file systems via `mount/umount`
 - i-node
- **Signals**
- **Shells**
 - Standard I/O and I/O redirection, filters
 - Shell scripts

Architectural Support for OS (I)

- CPU modes of operation: kernel vs. user
 - 4 levels in x86: Ring 0 > 1 > 2 > 3
 - 3 levels in RISC-V: Machine > Supervisor > User

- Protected or privileged instructions
 - Direct I/O access (e.g., in/out instructions in x86)
 - Accessing system registers
 - Memory state management
 - ...



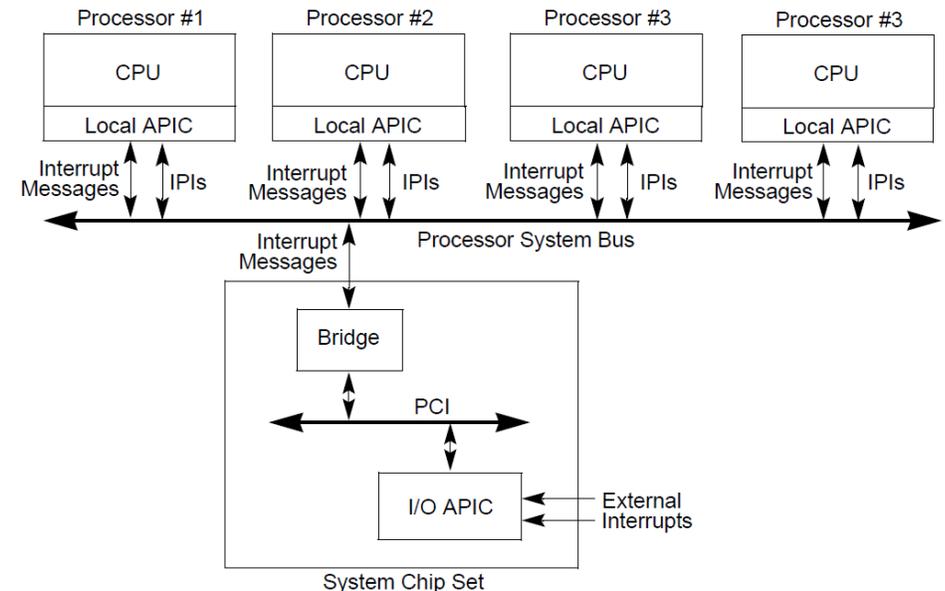
Architectural Support for OS (2)

■ Interrupts

- Generated by hardware devices
- External interrupts vs. IPIs
- Asynchronous

■ Exceptions

- Generated by software executing instructions
 - **Faults** (unintentional, but possibly recoverable): page faults, protection faults, ...
 - **Traps** (intentional): `syscall` instruction in x86_64 or `ecall` instruction in RISC-V
 - **Aborts** (unintentional and unrecoverable): parity error, machine error, ...
- Synchronous
- Exception handling is logically same as interrupt handling



Architectural Support for OS (3)

- **Memory protection**
 - Segmentation
 - Paging
- **Timer**
- **DMA (Direct Memory Access)**
- **Atomic instructions**
 - Atomic inc/dec
 - Test-and-Set
 - Compare-and-Swap
 - LL (Load Locked) & SC (Store Conditional)
 - ...