Operating Systems (INFR10079)

2023/2024 Semester 2

Structure

(Syscalls)

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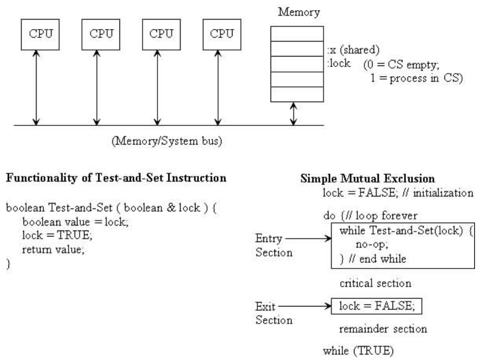
Chapter 2.1, 2.2, 2.3

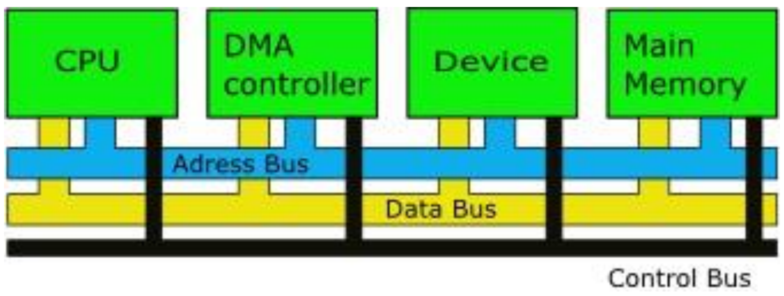
Overview

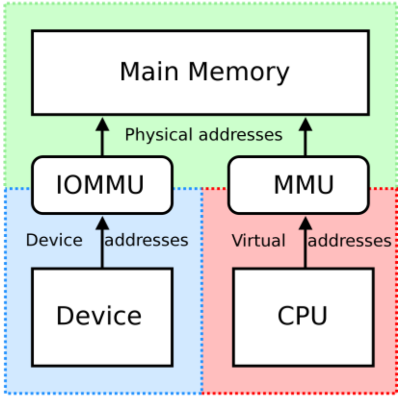
- **Architecture Features to Support OSes**
- **Application-Operating System Interaction**
- *Operating System structure*

Hardware Architecture Affects (is Affected by) the OS

- Operating system supports **sharing and protection** of HW
  - multiple applications can run concurrently, sharing HW resources
  - a buggy or malicious application should not disrupt other applications or the system
- The HW architecture determines **what is viable** (reasonably efficient, or even possible)
  - includes instruction set (synchronization, I/O, …)
  - also hardware components like MMU, DMA controllers, etc.

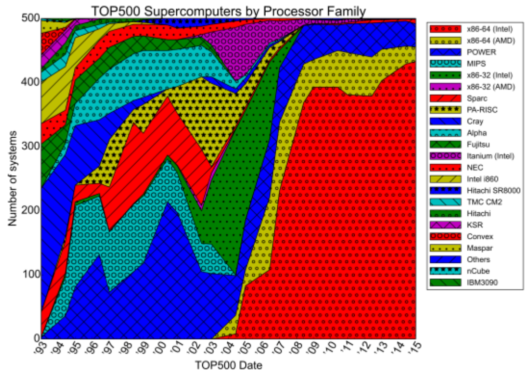






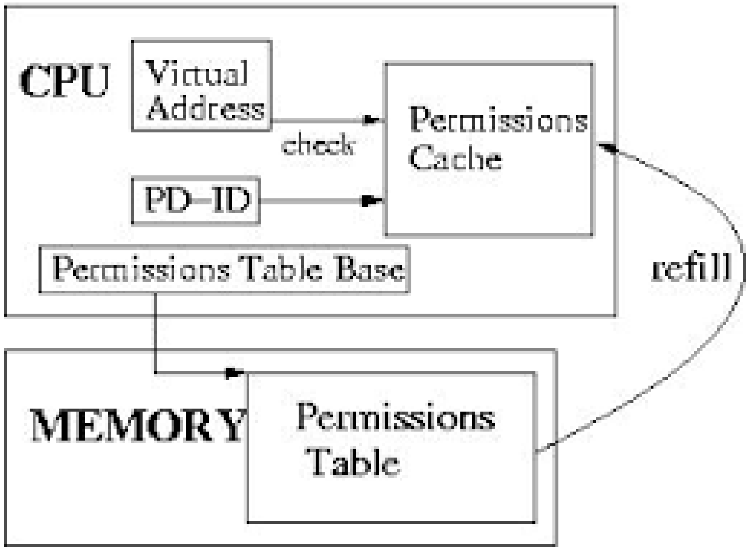
Hardware Architecture Support for the OS

- Architectural support can simplify OS tasks
  - Example #1
    - Early PC OSes (DOS, MacOS) lacked support for virtual memory
    - At that time PCs lacked necessary hardware support (MMU)
  - Example #2
    - Until recently, Intel-based PCs didn’t support for 64bit addresses
    - 64bit addressing has been available for decades on other HW architectures (MIPS, Alpha, IBM, etc.)
    - Changed driven by AMD’s 64-bit architecture



Hardware Architectural Features Affecting OS

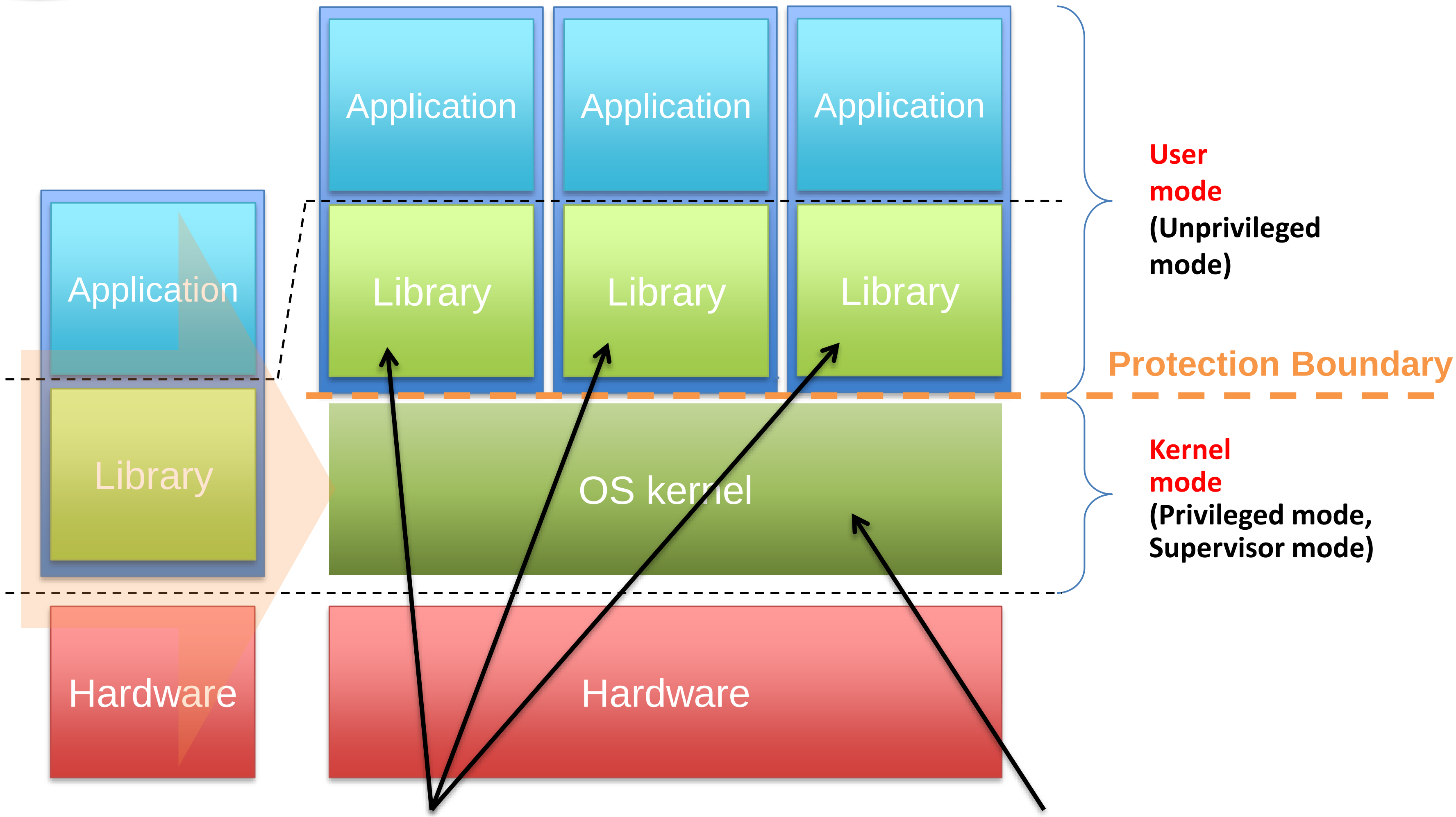
- At the very beginning **hardware/software co-design**
  - Not anymore
- Features built primarily to **support OS**
  - Timer (clock)
  - Memory protection
  - I/O control operations
  - Interrupts
  - **Protected mode(s) of execution**
    - **kernel vs user mode**
    - **privileged instructions**
    - **system calls**
  - Virtualization
  - …



NOTE Not all hardware provide the same features. Hence, there are OSes that do run without some hardware features.

Assume hardware protected mode

Privileged vs Unprivileged mode



One instance per application
(**no need** for protection)

One and only, shared, instance
(**needs** protection)

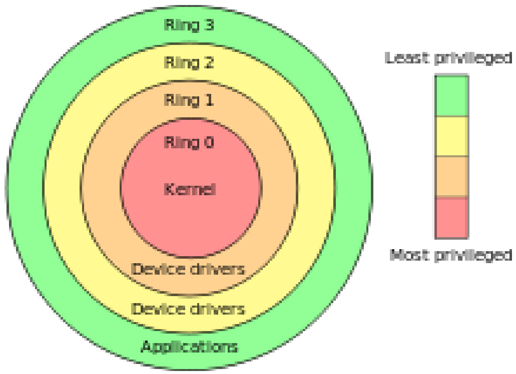
Privileged Instructions

- Some instructions are restricted to the OS
  - Known as **privileged** instructions
- Only the OS can
  - Directly access some classes of I/O devices
  - Manipulate memory state management
    - Page table pointers, TLB loads, etc.

  - Manipulate special ‘mode bits’
    - Interrupt priority level
- **Restrictions provide safety and security**

OS Protection

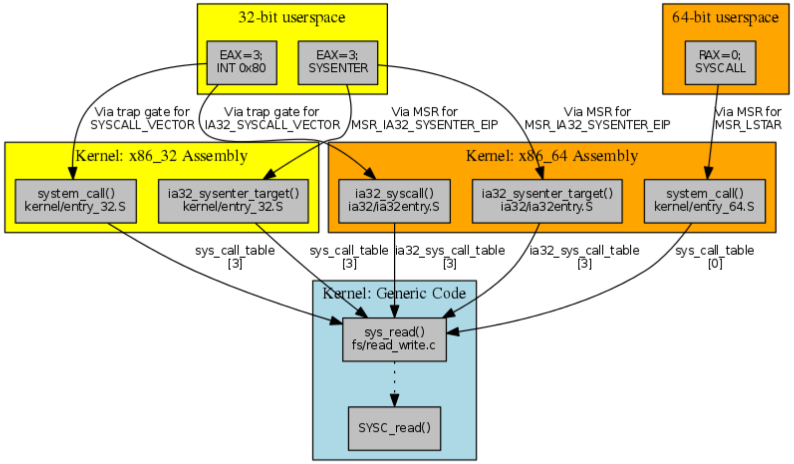
- How does the processor know if a privileged instruction can be executed?
  – Architecture must support **at least two modes** of operation
    - **kernel** mode
    - **user** mode
  – x86 supports 4 protection modes (rings)



  – **Mode** is set by status bit in a protected processor register
    - User programs execute in user mode
    - OS kernel executes in kernel (privileged, supervisor) mode
- Privileged instructions can only be executed in kernel mode
  – When code running in **user mode** attempts to execute a privileged instruction the “Privileged Instruction” exception is triggered

Crossing Protection Boundaries

- So how do user programs do something privileged?
  - e.g., how can you write to a disk if you can't execute an I/O instructions?
- User programs must call an OS procedure – i.e., ask the OS to do that for them
  - OS defines a set of system calls
  - User-mode program executes system call instruction
- **Syscall instruction**
  - "protected procedure call"



Syscall

- The **syscall** instruction, **atomically,** on a single CPU/core
  - Saves the current PC
  - Sets the execution mode to privileged
  - Sets the PC to a handler address
- Similar to a **procedure call**
  - Caller puts arguments in a place callee expects (usually, registers)
    - One arg is a **syscall number**, indicating what OS function to call
    - Callee (OS) saves caller's state (registers, other control state) so it can use the CPU
  - OS **function** code runs
    - OS must verify caller's arguments (e.g., pointers)
  - OS **returns** using a special instruction
    - Automatically sets PC to return address and sets execution back to user mode

Kernel Crossing Illustrated

Firefox: read(int fileDescriptor, void *buffer, int numBytes)

Save user PC
PC = trap handler address
Enter kernel mode

user mode

kernel mode

trap handler

Save app state
Verify syscall number
Find sys_read( ) handler in vector table

sys_read( ) kernel routine

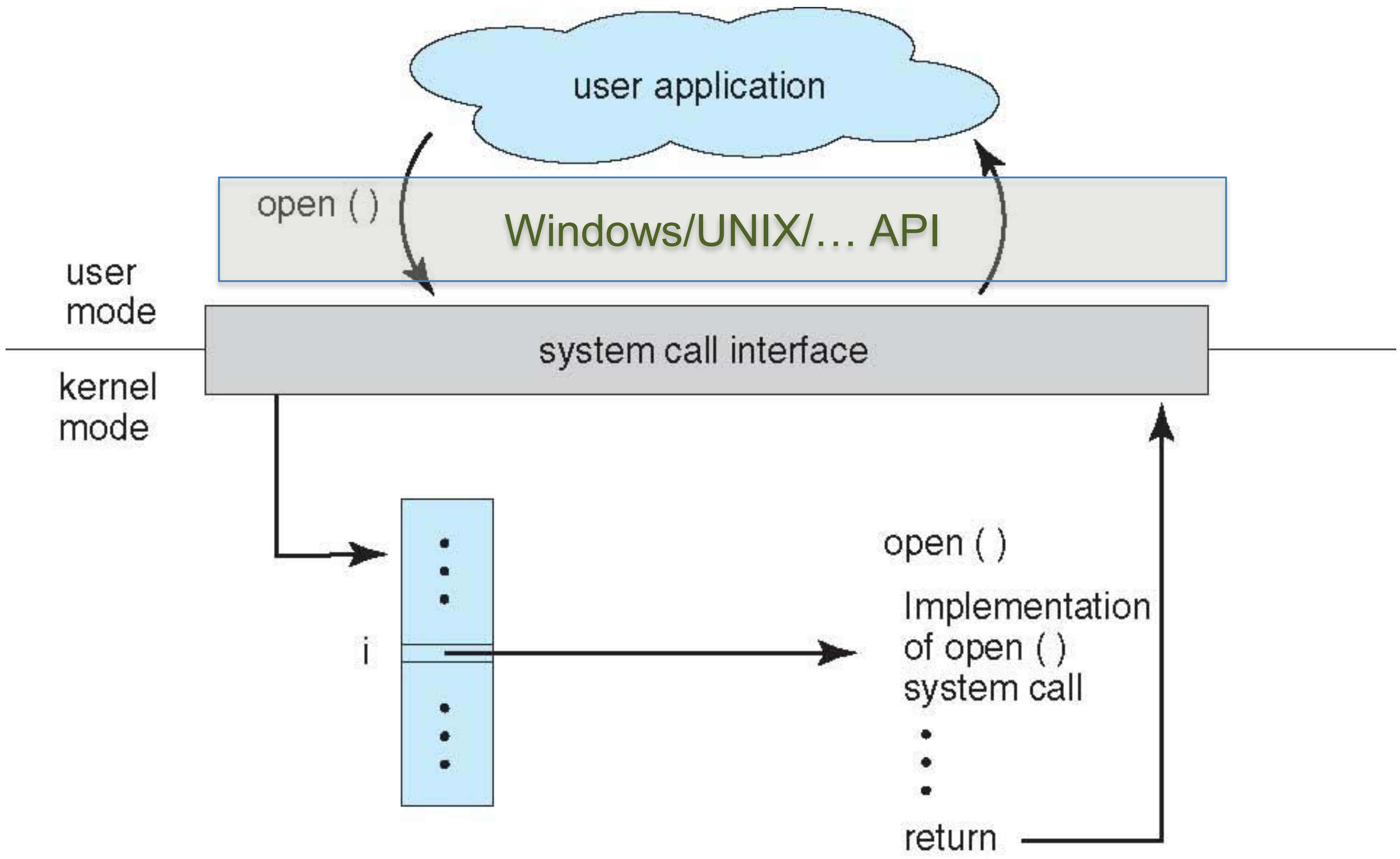
Verify args
Initiate read
Choose next process to run
Setup return values
Restore app state

ERET instruction

PC = saved PC
Enter user mode

http://syscalls.kernelgrok.com/

What Syscall to Run?

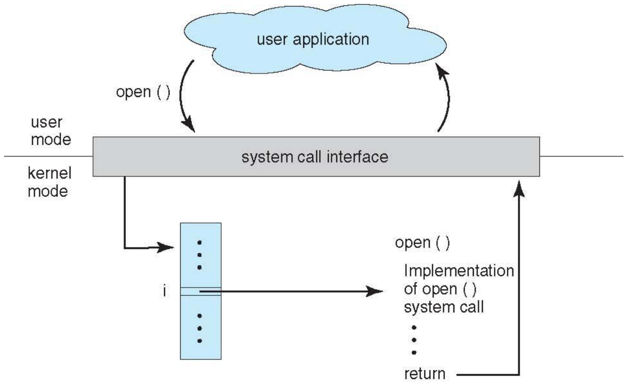


Examples of Windows and Unix System Calls

	Windows	Unix
Process Control	CreateProcess() ExitProcess() WaitForSingleObject()	fork() exit() wait()
File Manipulation	CreateFile() ReadFile() WriteFile() CloseHandle()	open() read() write() close()
Device Manipulation	SetConsoleMode() ReadConsole() WriteConsole()	ioctl() read() write()
Information Maintenance	GetCurrentProcessID() SetTimer() Sleep()	getpid() alarm() sleep()
Communication	CreatePipe() CreateFileMapping() MapViewOfFile()	pipe() shmget() mmap()
Protection	SetFileSecurity() InitlializeSecurityDescriptor() SetSecurityDescriptorGroup()	chmod() umask() chown()

System Call vs Subroutine Call

- Syscall **is not subroutine call**, with the caller specifying the next PC
  - Caller knows where the subroutines are located in memory
    - Syscall is an ID
  - Subroutines trust each other
  - All subroutines share memory



- The kernel saves state
  - Prevents overwriting of values
- The kernel verify arguments
  - Prevents buggy code crashing system
- Referring to kernel objects as arguments
  - Data copied between user buffer and kernel buffer

OS Services

- All entries to the OS occur via the mechanism just shown
  – Acquiring privileged mode and branching to the trap handler are **inseparable**
- **Terminology**
  – **Exception**: synchronous; unexpected problem with code
  – **Syscall**: synchronous; intended transition to OS
  – **Interrupt**: asynchronous; caused by an external device
- Privileged instructions and resources sharing are the basis for almost everything OS-related
  - memory protection, protected I/O, limiting user resource consumption, etc.