System Stack

Users
- Mary
- John

Applications
- Web-browser
- Word Processor
- Video Game

Operating System
- Scheduler
- Monitor Driver
- Network Driver
- Memory manager
- Disk manager

Hardware
- CPU
- Memory
- Disk
- Network card
- Monitor
HW-OS & OS-App Interface

- Device
- Device controller
- CPU
- OS
- Device driver
- Application
- Memory
HW-OS & OS-App Interface

- **Driver to Controller:**
  - Memory-mapped I/O
  - Programmed I/O

- **Controller to driver:**
  - Polling
  - Interrupts

- **Application to Driver:**
  - System Calls (change privilege level using SYSCALL)

- **Driver to Application:**
  - Pass data from OS memory space to application memory space.
Process

• A **process** consists of at least:
  • Code, data, stack, PC, registers, OS resources.

• **State**
  • Ready, running, waiting

• **PCB**

• **Context Switch**
  • Caused by interrupts
  • Store/Restore PCBs
  • Useful for timesharing.
Thread

- Basic unit of CPU utilization.
- It **belongs** to a process.
- It **shares** code, data, OS resources (files, etc) with the other threads of the same process.
CPU Scheduling

• Scheduler selects one process from the ready queue to run.

• **Non-preemptive** or **Preemptive**

• Scheduling **Metrics**: Turnaround time, Waiting time, Response time.

• Scheduling **Algorithms**: FCFS, LIFO, Round Robin, SJF

• Priority Scheduling

• Multilevel Queue Scheduling
Synchronization

- Problem to solve: Race Condition
- Solution: Lock
- Semaphores
  - wait, signal
  - Usage: mutex, counting, synchronization
- Classic problems: Producer-Consumer, Readers-Writers.
- Monitors
Deadlocks

• **Four** necessary conditions:
  • Mutual Exclusion, Hold and wait, No preemption, Circular wait
• Resource-allocation graph
• Handling deadlocks
  • **Prevention**
    – Negate one of necessary conditions.
  • **Avoidance**
    – The system tries to be in a safe state.
    – Banker's algorithm
• **Detect & Recover**
Memory Management

• Basic concerns: Allocation, Relocation, Protection.

• Paging
  • Noncontiguous physical address space of a process
  • Page Table: Page Number $\rightarrow$ Frame Number
  • TLB
  • Structure: Hierarchical Paging, Hashed Page Tables, Inverted Page Tables
Virtual Memory

- The content of a page might be in **memory** or in **hard disk**.
- Add *is_present* bit to every page table entry.
- **Page fault**
- **Page Replacement Algorithms**
  - FIFO, OPT, LRU
- **Thrashing** → Working Set, Page Fault Frequency