Computer Architecture and OS

EECS678

Heechul Yun

Administrivia

- Labs start this week

- Lab homepage
  - http://people.eecs.ku.edu/~frobinso/

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Agenda

- Computer architecture and OS
  - CPU, memory, disk
  - Architecture trends and their impact to OS
  - **Architectural support for OS**

Recap

- Batch
  - One at a time. CPU is idle while waiting for I/O
  - Low throughput
- Multiprogramming
  - If a job needs to way for I/O, switch to a new job
  - Maximize throughput
- Timesharing
  - Switch to next job after some time
  - Minimize response time

Recap

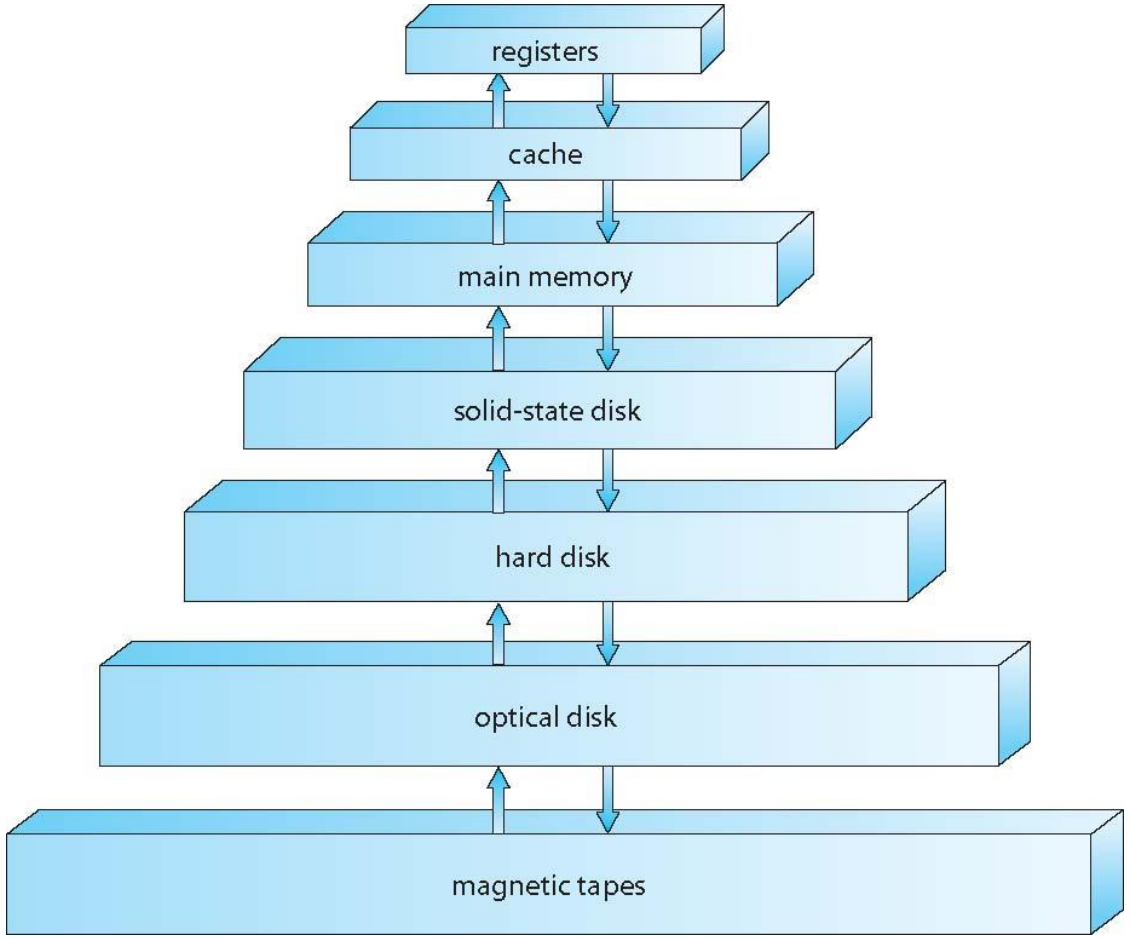
- Essential components of a computer
  - CPU
  - Memory
  - I/O

- Memory hierarchy
- Caching

Recap: Memory Hierarchy

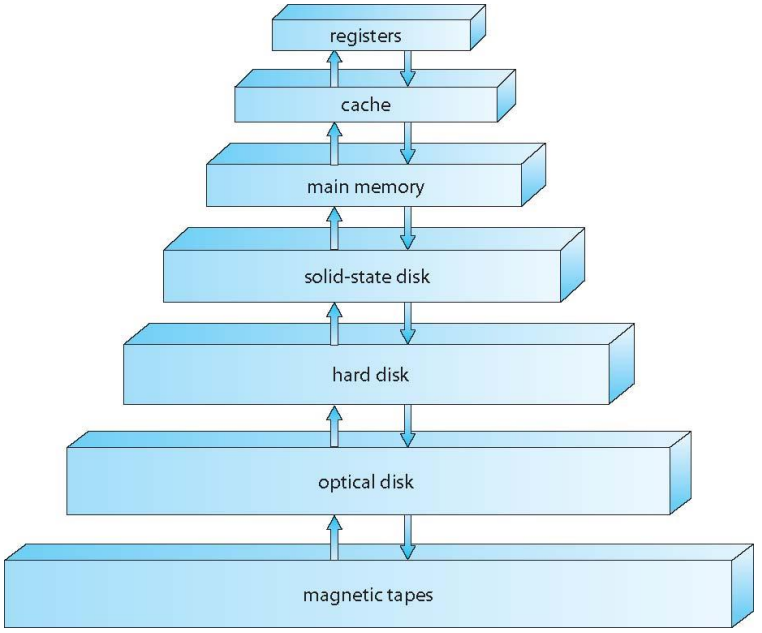
Fast,
Expensive

Slow,
Inexpensive



Recap: Caching

- A very important principle applied in all layers of hardware, OS, and software
  - Put frequently accessed data in a small amount of faster memory
  - Fast, most of the time (hit)
  - Copy from slower memory to the cache (miss)
  - Low cost, good performance



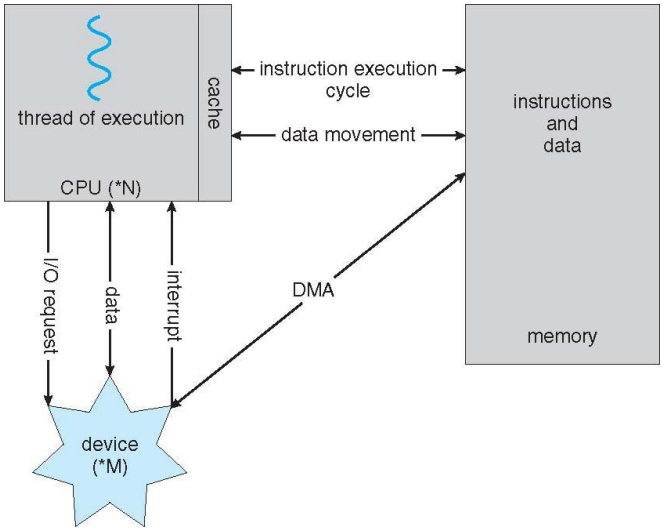
Architectural Support for OS

- Interrupts and exceptions
- Protected modes (kernel/user modes)
- Memory protection and virtual memory
- Synchronization instructions

Interrupt

- What is an interrupt?
  - A signal to the processor telling “do something now!”
- Hardware interrupts
  - Devices (timer, disk, keyboard, …) to CPU
- Software interrupts (exceptions)
  - Divide by zero, special instructions (e.g., int 0x80)

Interrupt Handling



- save CPU states (registers)
- execute the associated interrupt service routine (ISR)
- restore the CPU states
- return to the interrupted program

Timesharing

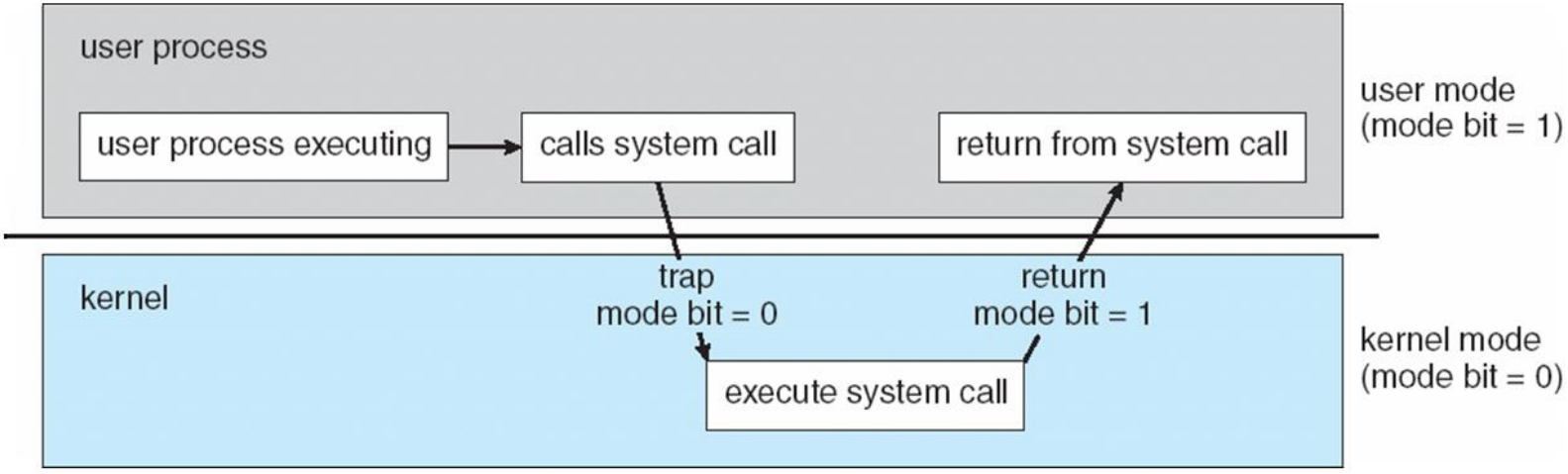
- Multiple tasks share the CPU at the same time
  - But there is only one CPU (assume single-core)
  - Want to schedule different task at a regular interval of 10 ms, for example.

- Timer and OS scheduler tick
  - The OS programs a timer to generate an interrupt at every 10 ms.

Dual (User/Kernel) Mode

- Some operations must be restricted to the OS
  - accessing registers in the disk controller
  - updating memory management unit states
  - …
- User/Kernel mode
  - Hardware support to distinguish app/kernel
  - Privileged instructions are only for kernel mode
  - Applications can enter into kernel mode only via pre-defined **system calls**

User/Kernel Mode Transition



- System calls
  - Programs ask OS services (privileged) via system calls
  - Software interrupt. “int <num>” in Intel x86

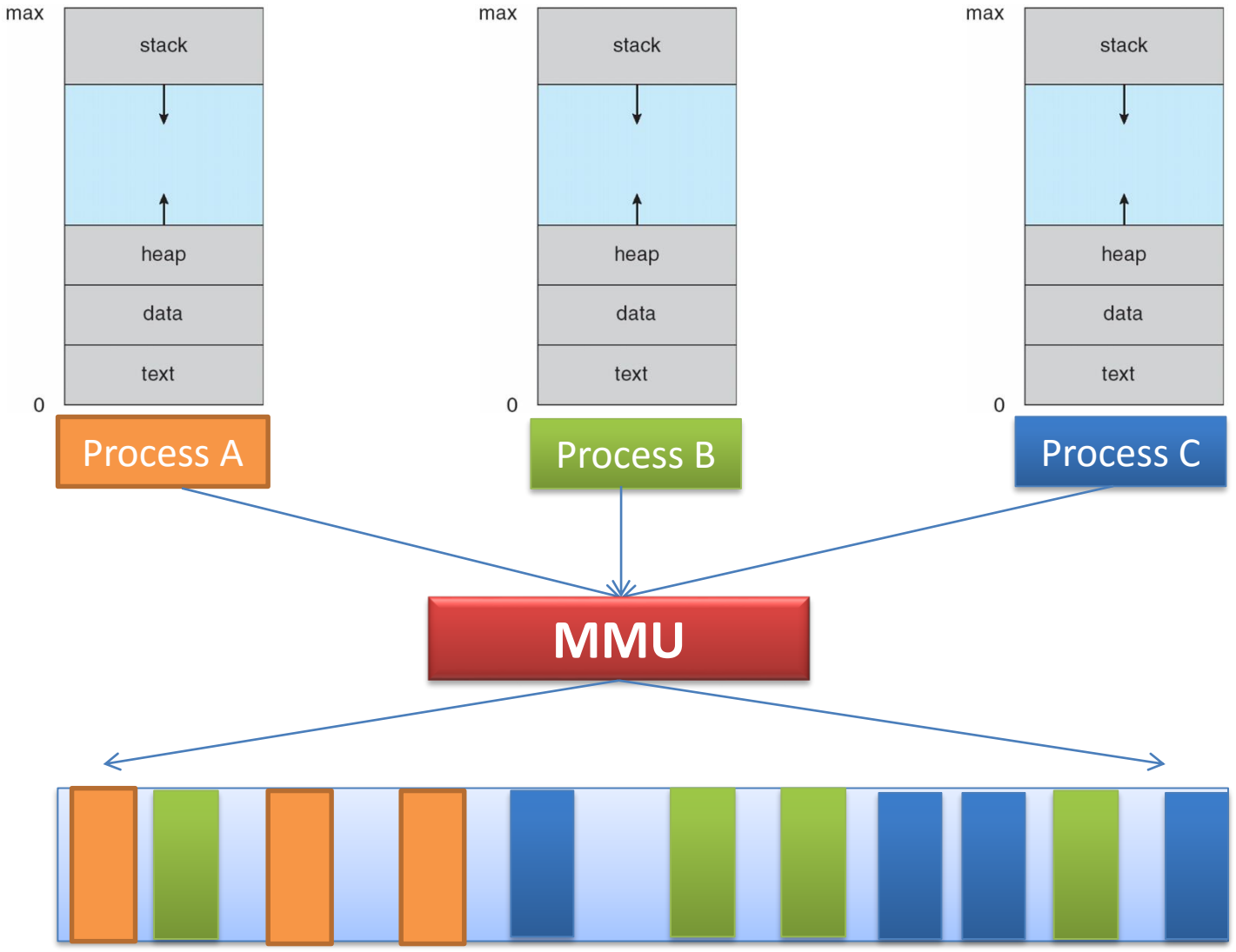
Memory Protection

- How to protect memory among apps/kernel?
  - Applications shouldn't be allowed to access kernel's memory
  - An app shouldn't be able to access another app's memory

Virtual Memory

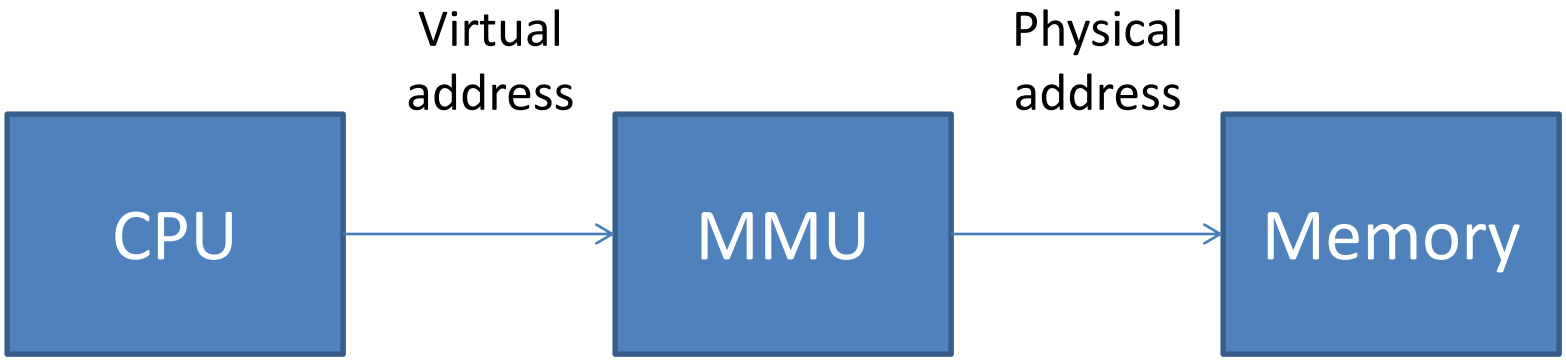
- How to overcome memory space limitation?
  - Multiple apps must share limited memory space
  - But they want to use memory as if each has dedicated and big memory space
  - E.g.,) 1GB physical memory and 10 programs, each of which wants to have a linear 4GB address space

Virtual Memory



MMU

- Hardware unit that translates *virtual address* to *physical address*
  - Defines the boundaries of kernel/apps
  - Enable efficient use of physical memory



Synchronization

- Synchronization problem with threads

```
Deposit(account, amount) {
{
   account->balance += amount;
}
```

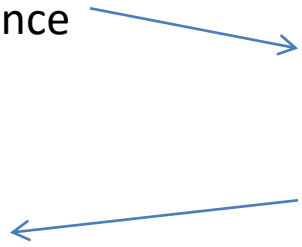
Thread 1: *Deposiit(acc, 10)*

```
LOAD R1, account->balance


ADD R1, amount
STORE R1, account->balance
```

Thread 2: : *Deposiit(acc, 10)*

```
LOAD R1, account->balance
ADD R1, amount
STORE R1, account->balance
```



Synchronization Instructions

- Hardware support for synchronization
  - *TestAndSet*, *CompareAndSwap* instructions
  - Atomic load and store
  - Used to implement **lock** primitives
  - New TSX instruction → hardware transaction

- Another methods to implement locks in single-core systems
  - Disabling interrupts

Summary

- OS needs to understand architecture
  - Hardware (CPU, memory, disk) trends and their implications in OS designs
- Architecture needs to support OS
  - Interrupts and timer
  - User/kernel mode and privileged instructions
  - MMU
  - Synchronization instructions

OS Abstractions

Reality	***Abstraction***
A single computer	Multiple computers
Limited RAM capacity	Infinite capacity
Mechanical disk	File system
Insecure and unreliable networks	Reliable and secure

Acknowledgements

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