MAIN MEMORY

Operating Systems 2015 Spring by Euiseong Seo

Today's Topics

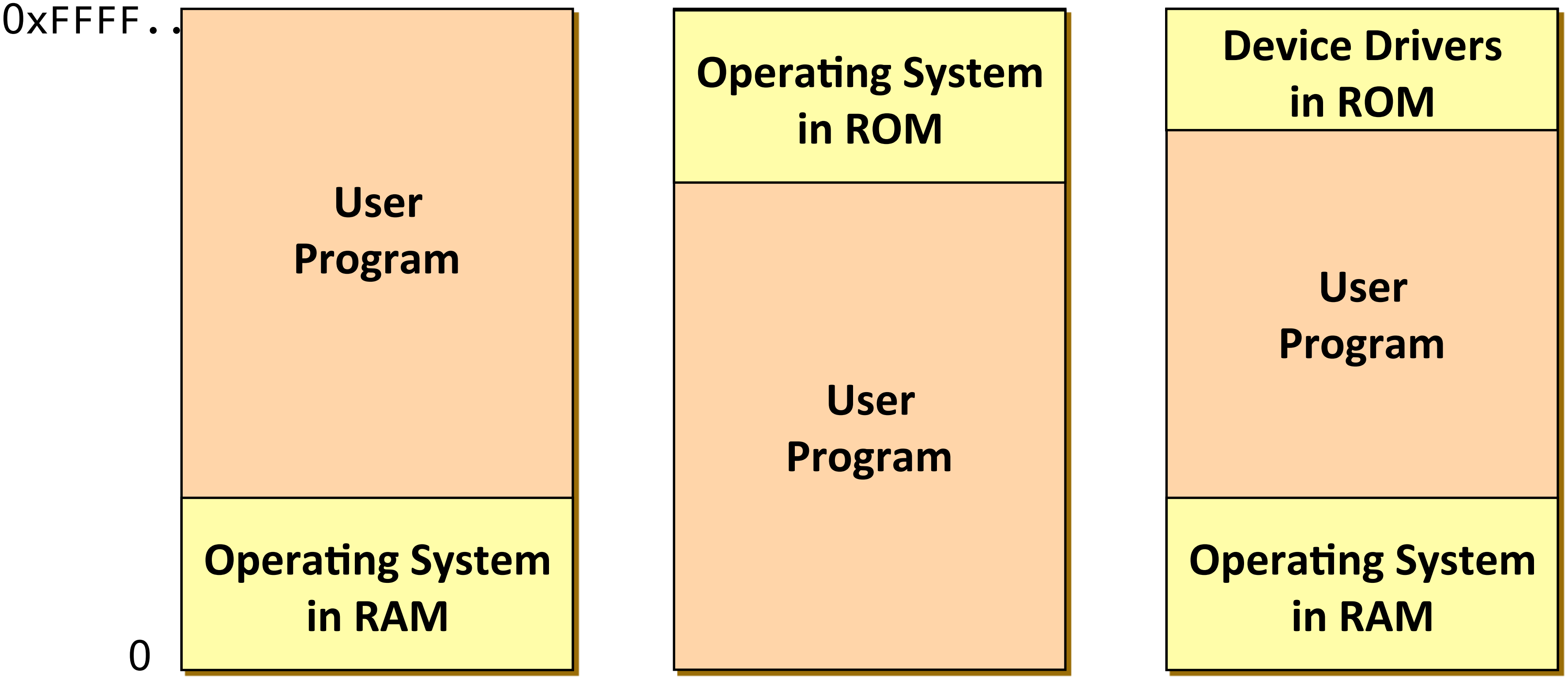
- Why is memory management difficult?
- Old memory management techniques:
  - Fixed partitions
  - Variable partitions
  - Overlays
  - Swapping
- Introduction to virtual memory

Memory Management

- Goals
  - To provide a convenient abstraction for programming
  - To allocate scarce memory resources among competing processes to maximize performance with minimal overhead
  - To provide isolation between processes.
- Why is it so difficult?

Single/Batch Programming

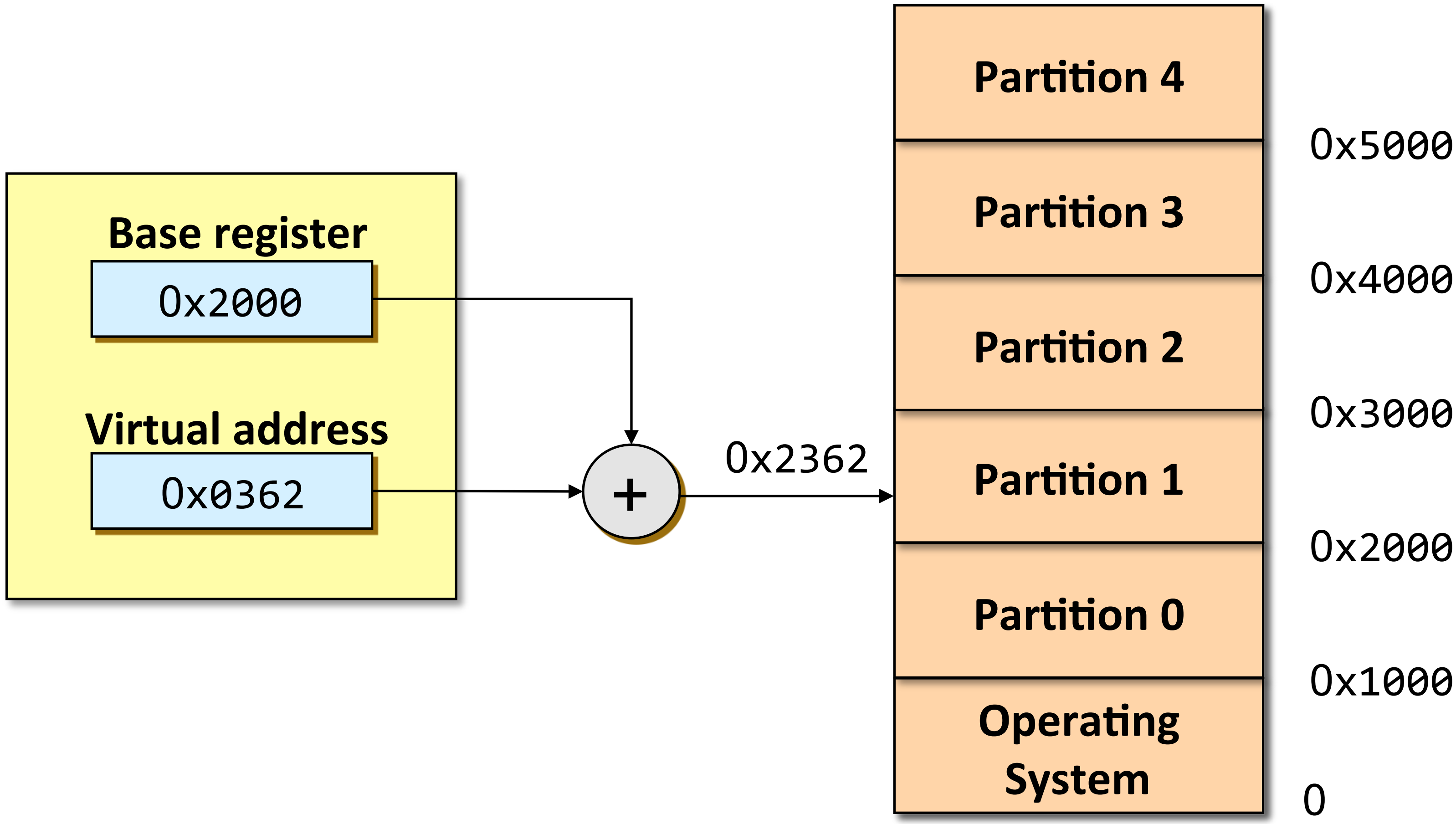
- An OS with one user process
  - Programs use physical addresses directly.
  - OS loads job, runs it, unloads it.



Multiprogramming

- Multiprogramming
  - Need multiple processes in memory at once
    - To overlap I/O and CPU of multiple jobs
    - Each process requires variable-sized and contiguous space
  - Requirements
    - Protection: restrict which addresses processes can use
    - Fast translation: memory lookups must be fast, in spite of protection scheme
    - Fast context switching: updating memory hardware (for protection and translation) should be quick

Fixed Partitions



Fixed Partitions

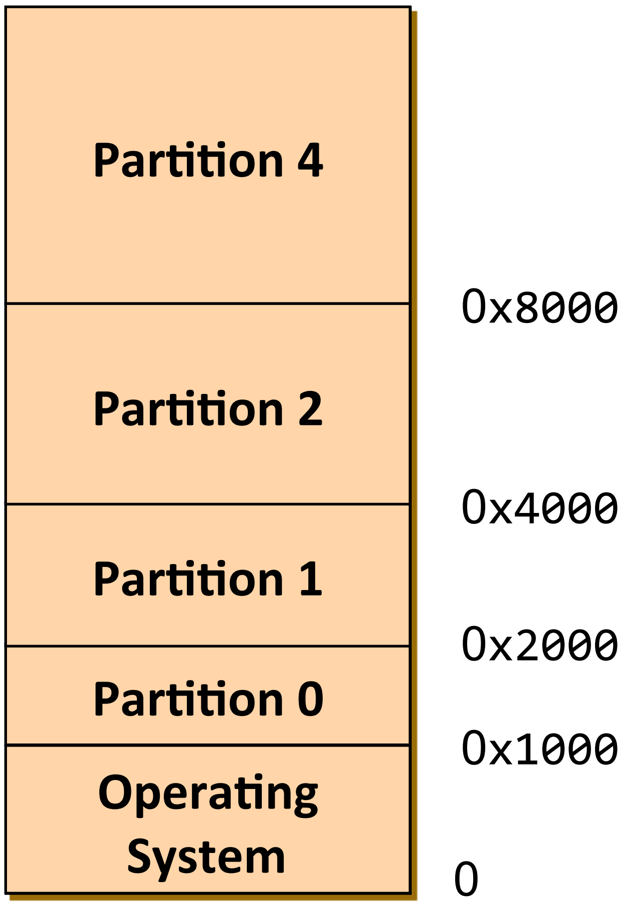
- Physical memory is broken up into fixed partitions
  - Size of each partition is the same and fixed
  - the number of partitions = degree of multiprogramming
  - Hardware requirements: base register
    - Physical address = virtual address + base register
    - Base register loaded by OS when it switches to a process

- Advantages
  - Easy to implement, fast context switch

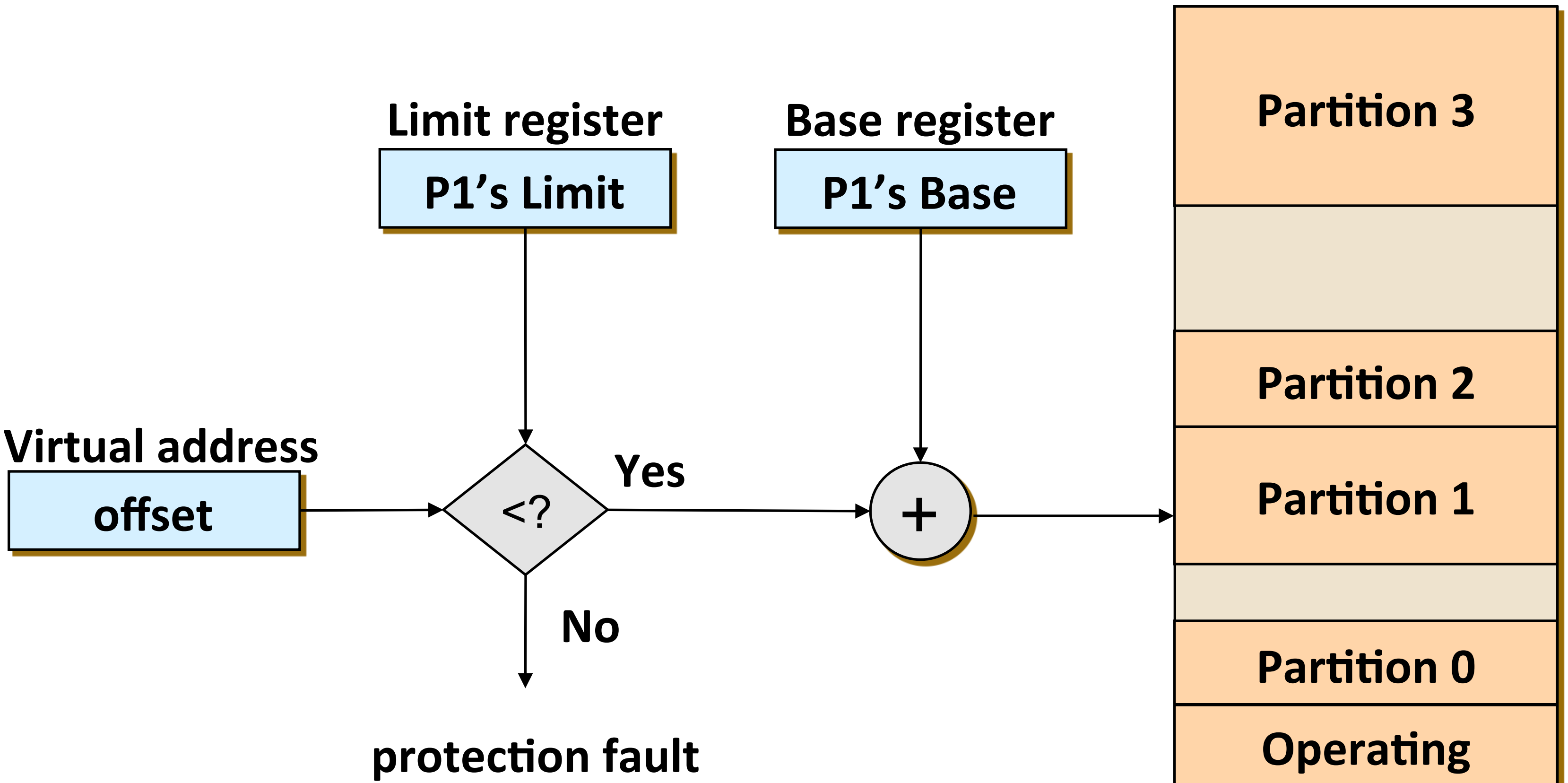
- Problems
  - Internal fragmentation: memory in a partition not used by a process is not available to other processes
  - Partition size: one size does not fit all
    - Fragmentation vs. fitting large programs

Fixed Partitions

- Improvement
  - Partition size need not be equal
  - Allocation strategies
    - Maintain a separate queue for each partition size
    - Maintain a single queue and allocate to the closest job whose size fits in an empty partition (first fit)
    - Search the whole input queue and pick the largest job that fits in an empty partition (best fit)
  - IBM OS/MFT
    (Multiprogramming with a Fixed number of Tasks)



Variable Partitions



Variable Partitions

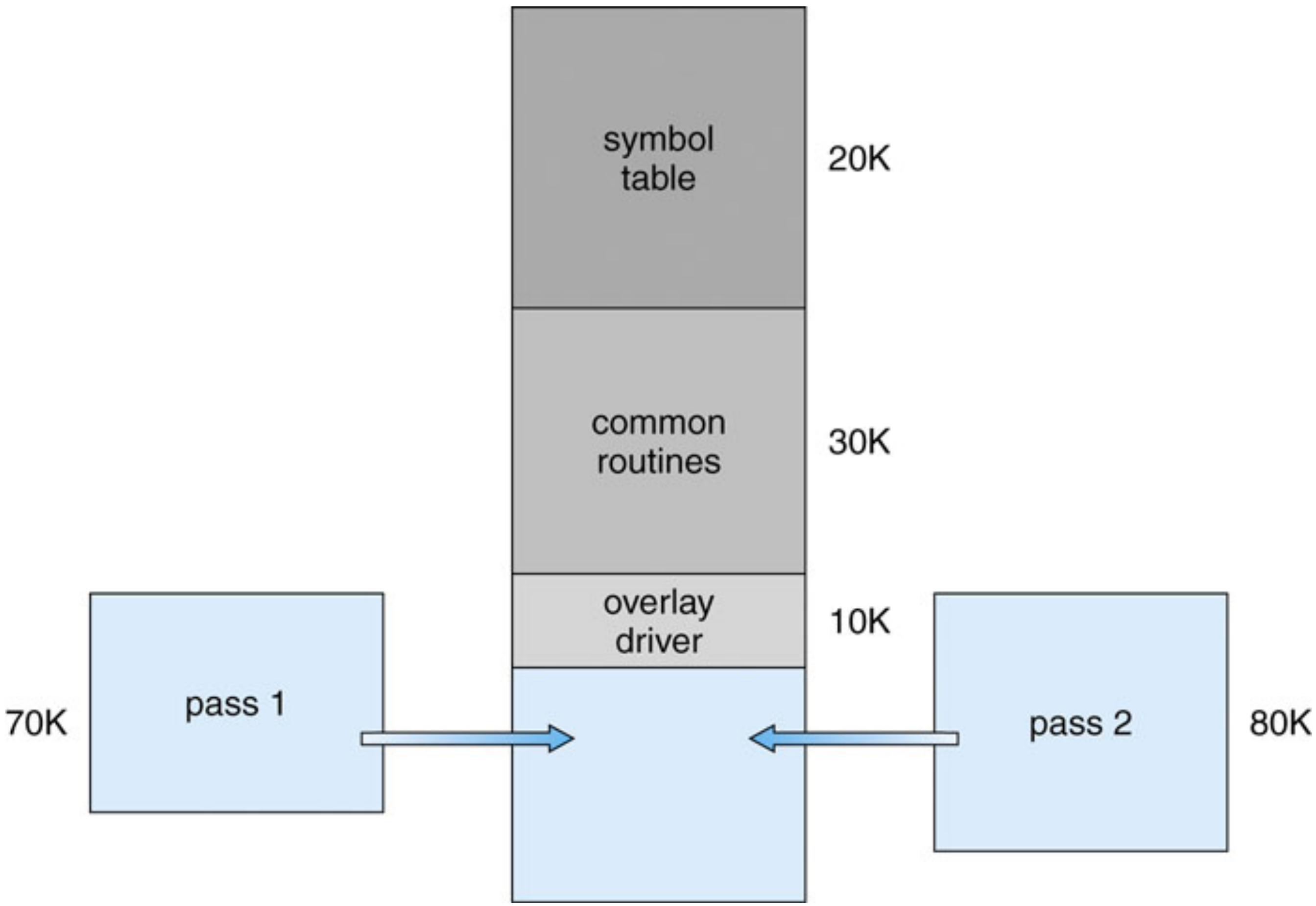
- Physical memory is broken up into variable-sized partitions
  - IBM OS/MVT
  - Hardware requirements: base register and limit register
    - Physical address = virtual address + base register
    - Base register loaded by OS when it switches to a process
  - The role of limit register: protection
    - If (physical address > base + limit), then raise a protection fault
- Allocation strategies
  - First fit: Allocate the first hole that is big enough
  - Best fit: Allocate the smallest hole that is big enough
  - Worst fit: Allocate the largest hole

Variable Partitions

- Advantages
  - No internal fragmentation
    - Simply allocate partition size to be just big enough for process
    - But, if we break the physical memory into fixed-sized blocks and allocate memory in unit of block sizes (in order to reduce bookkeeping), we have internal fragmentation
- Problems
  - External fragmentation
    - As we load and unload jobs, holes are left scattered throughout physical memory
  - Solutions to external fragmentation:
    - Compaction
    - Paging and segmentation

Overlays

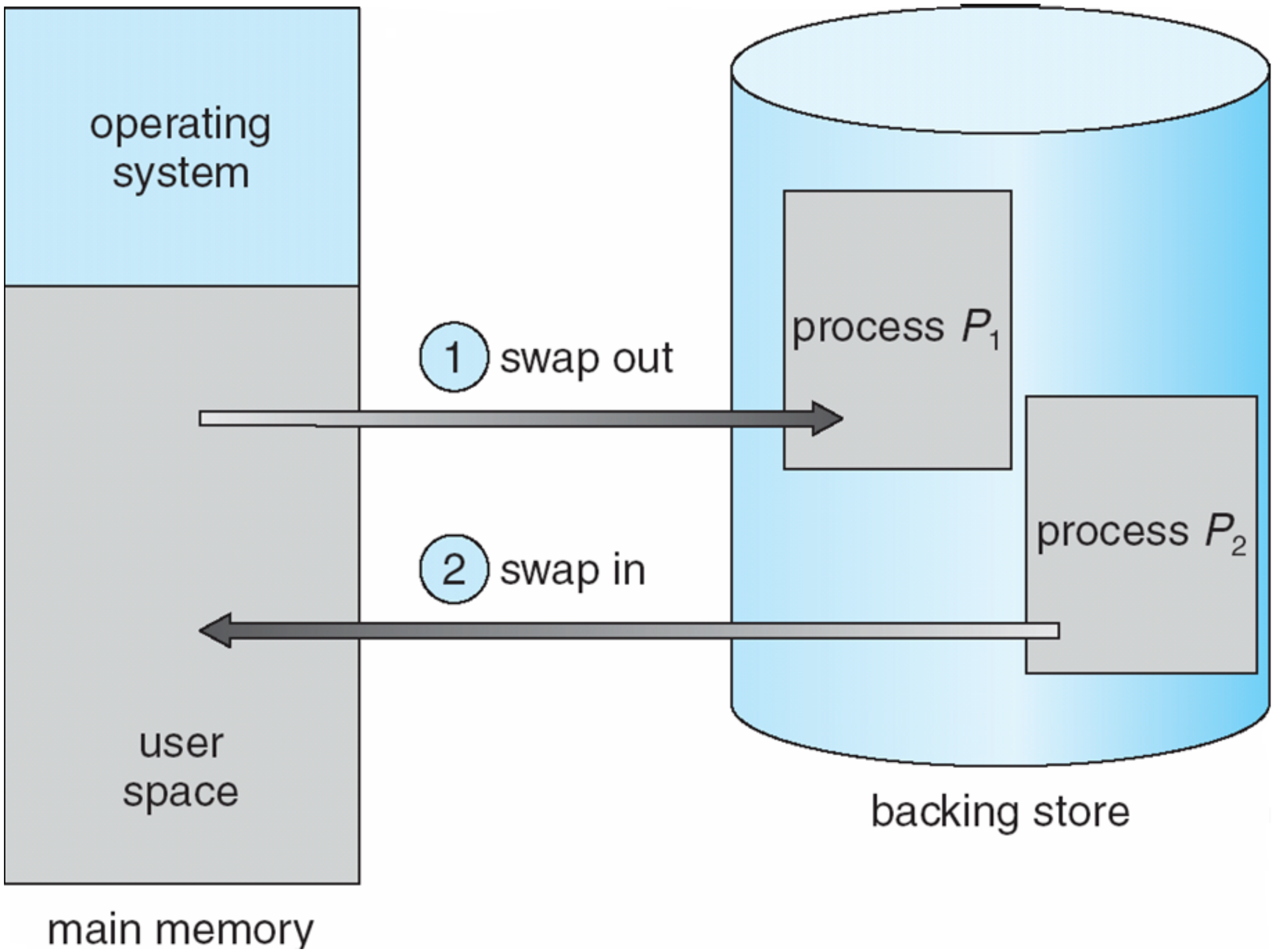
- Overlays for a two-pass assembler



Overlays

- Overlays
  - Keep in memory only those instructions and data that are needed at any given time.
  - Normally implemented by user
- Advantages
  - Needed when a process is larger than the amount of memory allocated to it.
  - No special support needed from operating system.
- Problems
  - Programming design of overlay structure is complex.

Swapping


operating
system
1 swap out
process P_1
process P_2
2 swap in
user
space
backing store
main memory

Swapping

- Swapping
  - A process can be swapped temporarily out of memory to a backing store and then brought back into memory later for continued execution
  - Backing store
    - Fast disk large enough to accommodate copies of all memory images for all users
    - Must provide direct access to these memory images
  - Major part of swap time is transfer time
    - Directly proportional to the amount of memory swapped
  - Swapping a process with a pending I/O
    - Do not swap a process with pending I/O
    - Execute I/O operations only into OS buffers

Virtual Memory

- Example

```
#include <stdio.h>

int n = 0;

int main ()
{
      printf (“&n = 0x%08x\n”, &n);
}

% ./a.out
&n = 0x08049508
% ./a.out
&n = 0x08049508
```

- What happens if two users simultaneously run this application?

Virtual Memory

- Virtual Memory (VM)
  - Use virtual addresses for memory references
    - Large and contiguous
  - CPU performs address translation at run time
    - From a virtual address to the corresponding physical address
  - Physical memory is dynamically allocated or released on demand
    - Programs execute without requiring their entire address space to be resident in physical memory
    - Lazy loading
  - Virtual addresses are private to each process
    - Each process has its own isolated virtual address space
    - One process cannot name addresses visible to others

Virtual Memory

- Virtual addresses
  - To make it easier to manage memory of multiple processes, make processes use virtual addresses (logical addresses)
    - Virtual addresses are independent of the actual physical location of data referenced
    - OS determines location of data in physical memory
    - Instructions executed by the CPU issue virtual addresses
    - Virtual addresses are translated by hardware into physical addresses (with help from OS)
    - The set of virtual addresses that can be used by a process comprises its virtual address space
  - Many ways to translate virtual addresses into physical addresses…

Virtual Memory

- Advantages
  - Separates user’s logical memory from physical memory
    - Abstracts main memory into an extremely large, uniform array of storage
    - Frees programmers from the concerns of memory-storage limitations
  - Allows the execution of processes that may not be completely in memory
    - Programs can be larger than physical memory
    - More programs could be run at the same time
    - Less I/O would be needed to load or swap each user program into memory
  - Allows processes to easily share files and address spaces
  - Provides an efficient mechanism for protection and process creation

Virtual Memory

- Disadvantages
  - Performance!!!
    - In terms of time and space
- Implementation
  - Paging
  - Segmentation