CSC 4103 - Operating Systems
Spring 2008

LECTURE - XI
# MAIN MEMORY

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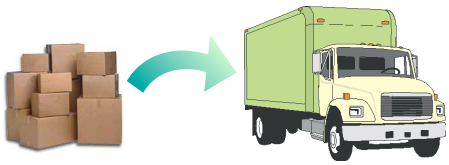
## Memory Management Requirements

- **The O/S must fit multiple processes in memory**
  - ✓ memory needs to be subdivided to accommodate multiple processes
  - ✓ memory needs to be allocated to ensure a reasonable supply of ready processes so that the CPU is never idle
  - ✓ memory management is an **optimization** task under **constraints**

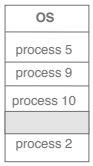


**Fitting processes into memory is like fitting boxes into a fixed amount of space**



## Memory Allocation - contiguous

- Fixed-partition allocation
  - Divide memory into fixed-size partitions
  - Each partition contains exactly one process
  - The degree of multi programming is bound by the number of partitions
  - When a process terminates, the partition becomes available for other processes

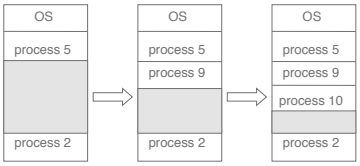



➔no longer in use



## Memory Allocation (Cont.)

- Variable-partition Scheme
  - When a process arrives, search for a hole large enough for this process
  - Hole – block of available memory; holes of various size are scattered throughout memory
  - Allocate only as much memory as needed
  - Operating system maintains information about: a) allocated partitions b) free partitions (hole)






## Dynamic Storage-Allocation Problem

How to satisfy a request of size *n* from a list of free holes

- **First-fit**: Allocate the *first* hole that is big enough
- **Best-fit**: Allocate the *smallest* hole that is big enough; must search entire list, unless ordered by size. Produces the smallest leftover hole.
- **Worst-fit**: Allocate the *largest* hole; must also search entire list. Produces the largest leftover hole.

First-fit and best-fit better than worst-fit in terms of speed and storage utilization



## Example

Given five memory partitions of 100 KB, 500 KB, 200 KB, 300 KB, and 600 KB (in order), how would each of the first-fit, best-fit, and worst-fit algorithms place processes of 212 KB, 417 KB, 112 KB, and 426 KB (in order)? Which algorithm makes the most efficient use of memory?

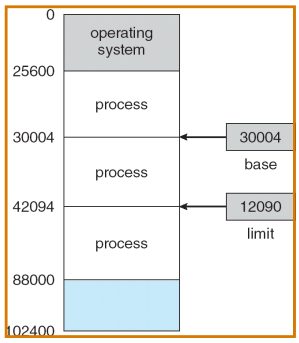
## Fragmentation

- **External Fragmentation** – total memory space exists to satisfy a request, but it is not contiguous (in average ~50% lost)
- **Internal Fragmentation** – allocated memory may be slightly larger than requested memory; this size difference is memory internal to a partition, but not being used
- Reduce external fragmentation by **compaction**
  - Shuffle memory contents to place all free memory together in one large block
  - Compaction is possible *only* if relocation is dynamic, and is done at execution time



## Logical Address Space

- Each process has a separate memory space
- Two registers provide address protection between processes:
- Base register: smallest legal address space
- Limit register: size of the legal range






## Address Binding

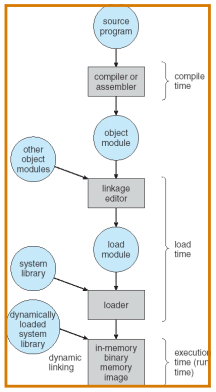
- Addresses in a source program are generally symbolic
  - eg. int count;
- A compiler binds these symbolic addresses to relocatable addresses
  - eg. 100 bytes from the beginning of this module
- The linkage editor or loader will in turn bind the relocatable addresses to absolute addresses
  - eg. 74014
- Each binding is mapping from one address space to another



## Binding of Instructions and Data to Memory

Address binding of instructions and data to memory addresses can happen at three different stages

- **Compile time**: If memory location known a priori, *absolute code* can be generated; must recompile code if starting location changes
- **Load time**: Must generate *relocatable code* if memory location is not known at compile time; need only reload if starting address changes
- **Execution time**: Binding delayed until run time if the process can be moved during its execution from one memory segment to another. Need hardware support for address maps.





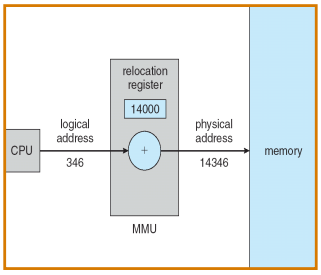

## Logical vs Physical Address Space

- Address generated by CPU is referred as logical address
- Address seen by the memory is seen as physical address
- Compile time and load time methods generate identical logical and physical addresses
- Execution-time method generates different logical and physical addresses
  - Logical address referred as virtual address



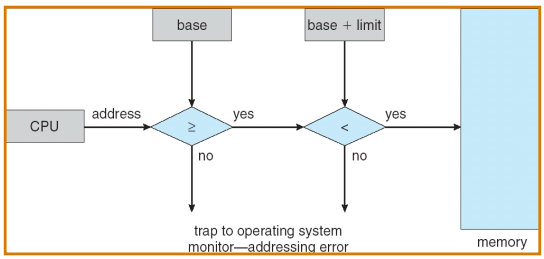
## Memory-Management Unit (MMU)

- Hardware device that maps virtual to physical address
- In MMU scheme, the value in the relocation register (base register) is added to every address generated by a user process at the time it is sent to memory
- The user program deals with *logical* addresses; it never sees the *real* physical addresses



## HW Address Protection

- CPU hardware compares every address generated in user mode with the registers
- Any attempt to access other processes' memory will be trapped and cause a fatal error






## Paging - noncontiguous

- Physical address space of a process can be noncontiguous
- Divide physical memory into fixed-sized blocks called **frames** (size is power of 2, between 512 bytes and 8192 bytes)
- Divide logical memory into blocks of same size called **pages**.
- Keep track of all free frames
- To run a program of size *n* pages, need to find *n* free frames and load program
- Set up a page table to translate logical to physical

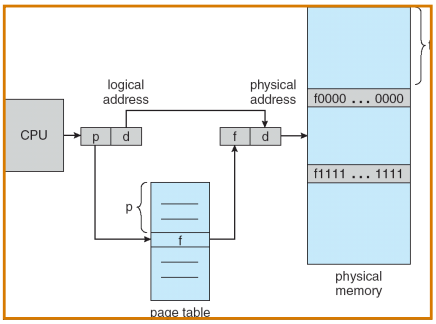


## Address Translation Scheme

- Address generated by CPU is divided into:
  - *Page number (p)* – used as an index into a *page table* which contains base address of each page in physical memory
  - *Page offset (d)* – combined with base address to define the physical memory address that is sent to the memory unit

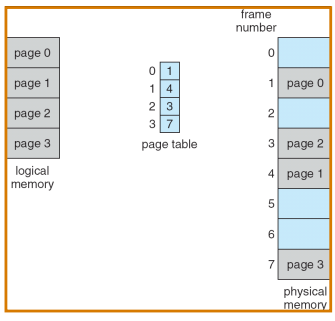


## Address Translation Architecture



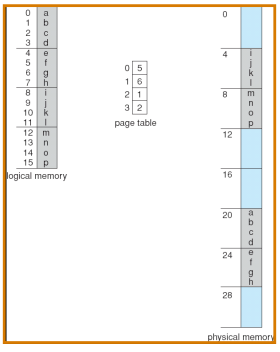



## Paging Example

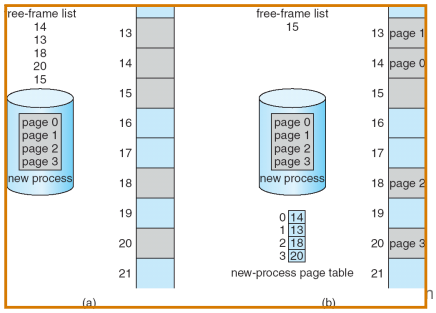





## Paging Example



# Free Frames



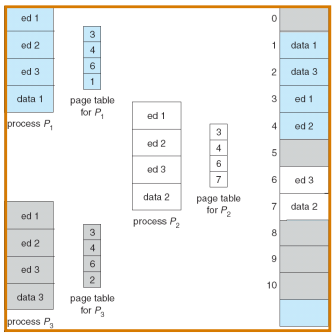



# Shared Pages

- **Shared code**
  - One copy of read-only (reentrant) code shared among processes (i.e., text editors, compilers, window systems).
  - Shared code must appear in same location in the logical address space of all processes
- **Private code and data**
  - Each process keeps a separate copy of the code and data
  - The pages for the private code and data can appear anywhere in the logical address space



# Shared Pages Example






# Midterm

- Chapters 1 - 7 from Silbershatz
- Important Topics:
  - Processes
  - Threads
  - CPU Scheduling
  - Process Syncronization
  - Threads
- Closed book exam
- Midterm review next Tuesday
- Solve the sample exam