Memory Management (3)

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CSE325 Principles of Operating Systems

10/23/2019

Pros and Cons of Segmentation

- Advantages
  - Segment sharing
  - Easier to relocate segment than entire program
  - Advoid allocating unused memory
  - Flexible protection
  - Efficient translation
    - Segment table small -> fit in MMU
- Disadvantages
  - Segments have varible lengths -> How to fit
  - External fragmentation: wasted memory

Paging

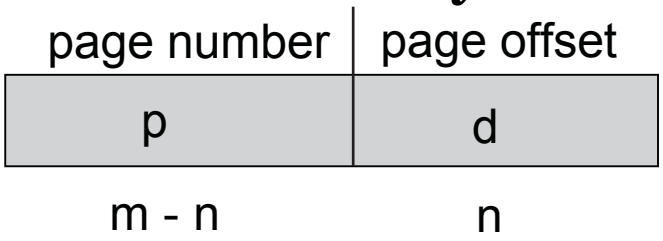
- Physical address space of a process can be noncontiguous; process is allocated fixed sized units of physical memory whenever the latter is available
  - Avoids external fragmentation
  - Avoids problem of varying sized memory chunks
- Still have Internal fragmentation

Paging

- Divide physical memory into fixed-sized blocks called **frames**
  - Size is power of 2, between 512 bytes and 16 Mbytes
- 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 addresses

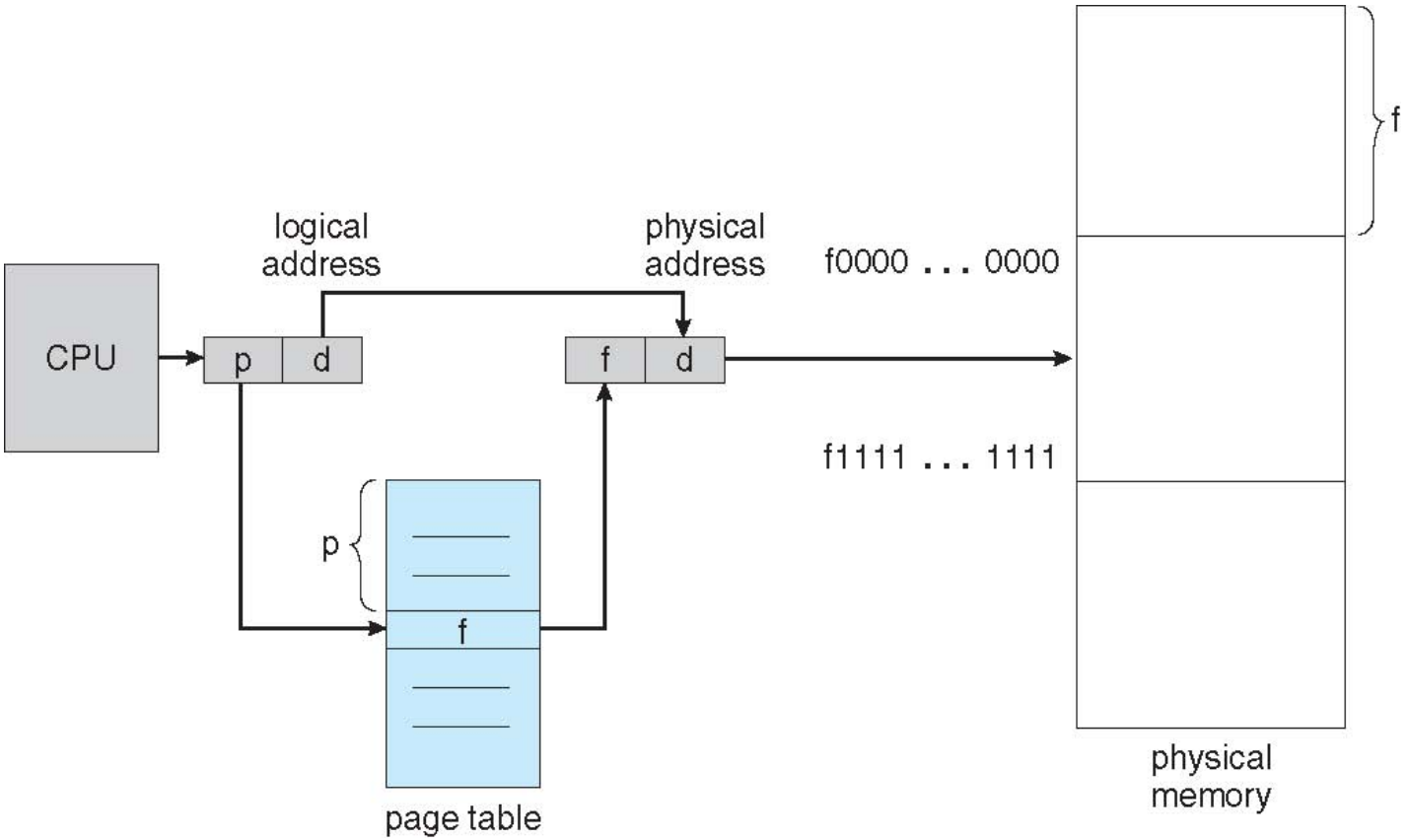
Address Translation Scheme

- 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

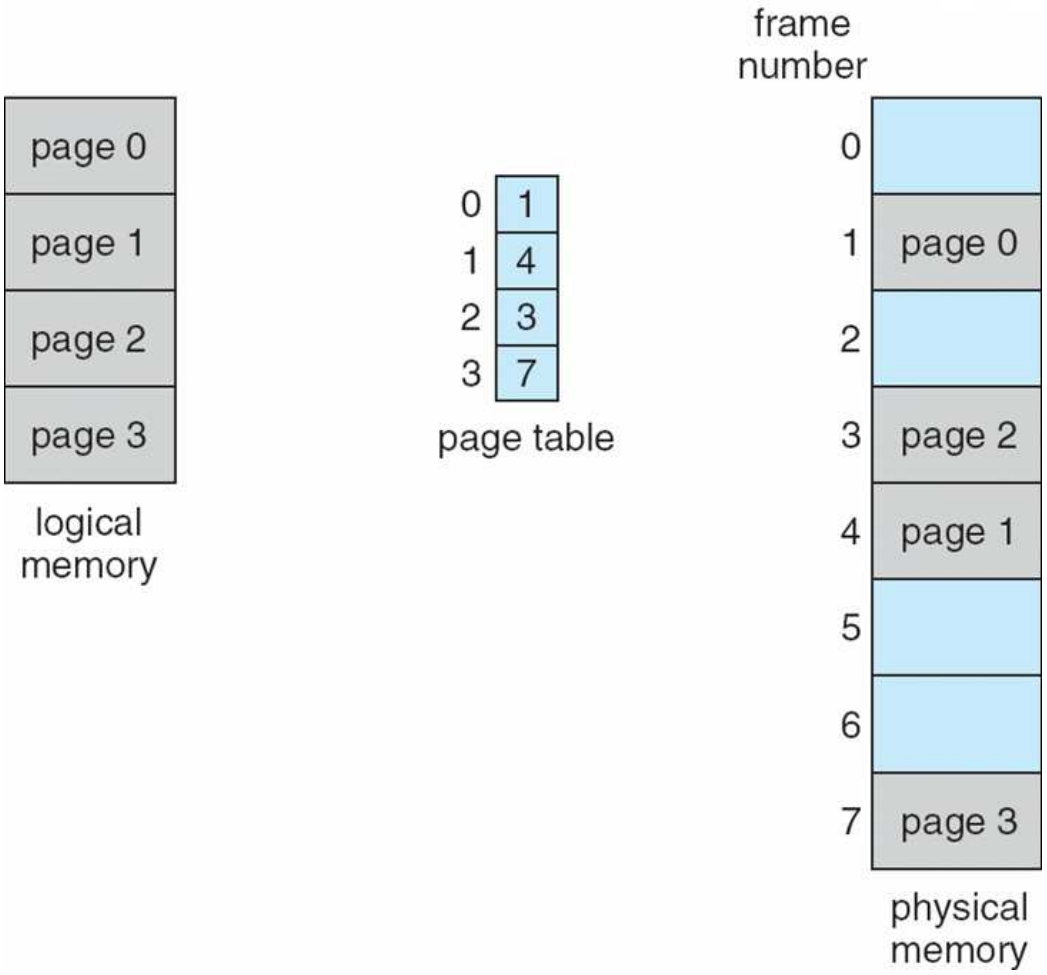


  - For given logical address space 2^m and page size 2^n

Page Translation



Page Translation Example



Page Translation Exercise

- 8-bit virtual address, 10-bit physical address, and each page is 64 bytes
  - How many virtual pages?
  - How many physical pages?
  - How many entries in page table?
  - Given page table = [2, 5, 1, 8], what's the physical address for virtual address 241?
- m-bit virtual address, n-bit physical address, k-bit page size
  - What are the answers to the first three questions above?

Internal Fragmentation

- Calculating internal fragmentation
  - Page size = 2,048 bytes
  - Process size = 72,766 bytes
  - 35 pages + 1,086 bytes
  - Internal fragmentation of 2,048 - 1,086 = 962 bytes
  - Worst case fragmentation = 1 frame – 1 byte
  - On average fragmentation = 1 / 2 frame size
- So small frame sizes desirable?
  - But each page table entry takes memory to track
  - Page sizes growing over time
    - Solaris supports two page sizes – 8 KB and 4 MB

Page Protection

- Implemented by associating protection bits with each virtual page in page table
- Protection bits
  - present bit: map to a valid physical page?
  - read/write/execute bits: can read/write/execute?
  - user bit: can access in user mode?
  - x86: `PTE_P, PTE_W, PTE_U`
- Checked by MMU on each memory access