CSC 4320/6320: Operating Systems

Chapter 09: Main Memory-II

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Announcement

- Final Exam will be on May 1st Thursday
- Time:13:30 -16:00 (1:30 PM – 4:00 PM)

Chapter 9: Memory Management

- Background
- Contiguous Memory Allocation
- Paging
- Structure of the Page Table
- Swapping
- Example: The Intel 32 and 64-bit Architectures
- Example: ARMv8 Architecture

Objectives

- To provide a detailed description of various ways of organizing memory hardware
- To discuss various memory-management techniques,
- To provide a detailed description of the Intel Pentium, which supports both pure segmentation and segmentation with paging

Review: 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 (may be more useful)

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

Review: Fragmentation

- **External Fragmentation** – total memory space exists to satisfy a request, but it is not contiguous
- **Internal Fragmentation** – allocated memory may be slightly larger than requested memory; this size difference is memory internal to a partition, but not being used
- First fit analysis reveals that given *N* blocks allocated, 0.5 *N* blocks lost to fragmentation
  - 1/3 may be unusable -> **50-percent rule**
  - **N blocks are of varying sizes and this observation is related to external fragmentation**

Review: Fragmentation (Cont.)

- 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
  - I/O problem
    - Latch job in memory while it is involved in I/O
    - Do I/O only into OS buffers
- Now consider that backing store has same fragmentation problems

Review: Questions

1. _____ is the dynamic storage-allocation algorithm which results in the smallest leftover hole in memory.
A) First fit
B) Best fit ✓
C) Worst fit
D) None of the above
2. _____ is the dynamic storage-allocation algorithm which results in the largest leftover hole in memory.
A) First fit
B) Best fit
C) Worst fit ✓
D) None of the above
3. Which of the following is true of compaction?
A) It can be done at assembly, load, or execution time.
B) It is used to solve the problem of internal fragmentation.
C) It cannot shuffle memory contents.
D) It is possible only if relocation is dynamic and done at execution time. ✓

Paging

- Physical address space of a process can be noncontiguous; process is allocated physical memory whenever the latter is available
  - Avoids external fragmentation
  - Avoids problem of varying sized memory chunks
- 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
- Backing store likewise split into pages
- Still have Internal fragmentation (leftover space inside the last page is internal fragmentation.)

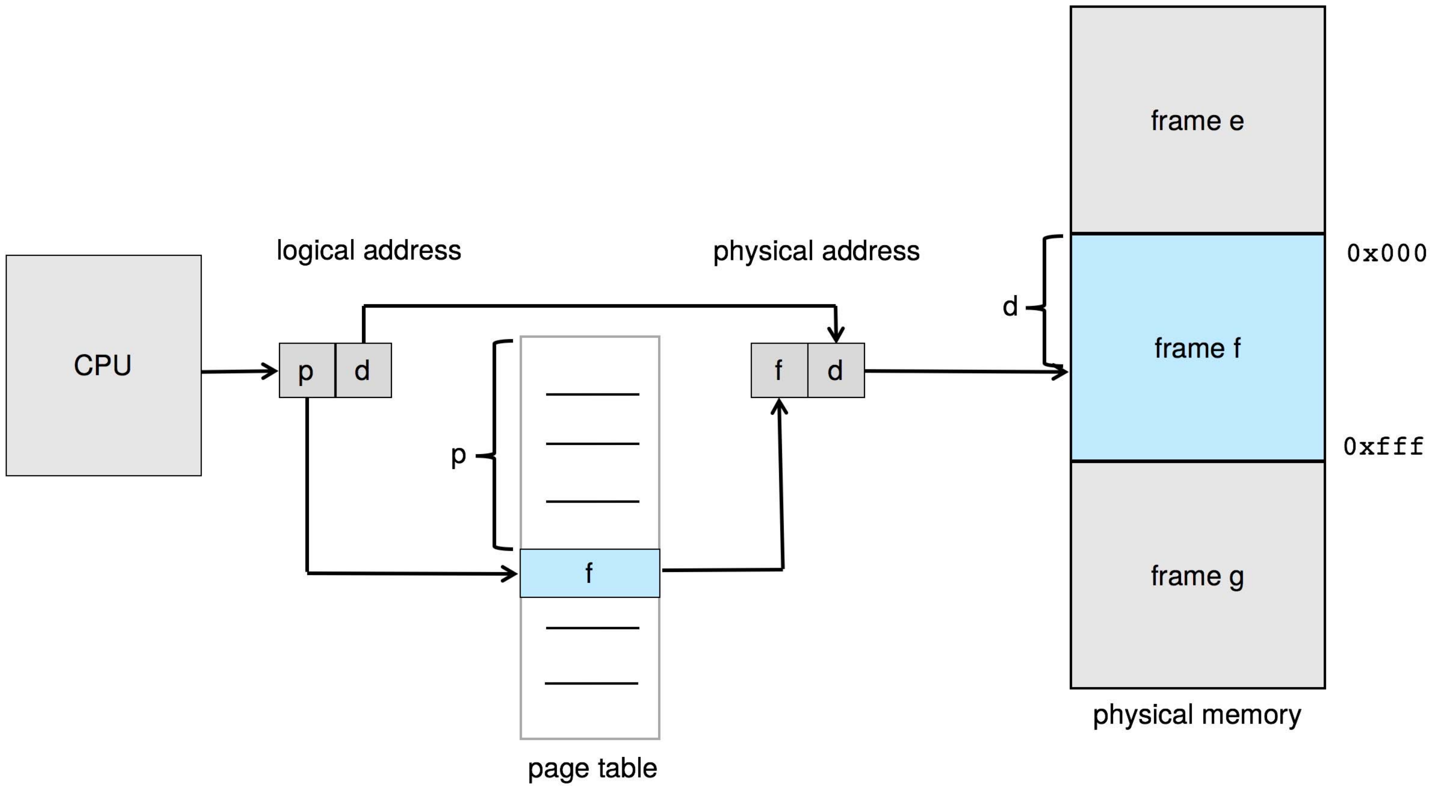
Address Translation Scheme

- 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

page number	page offset
p	d
m -n	n

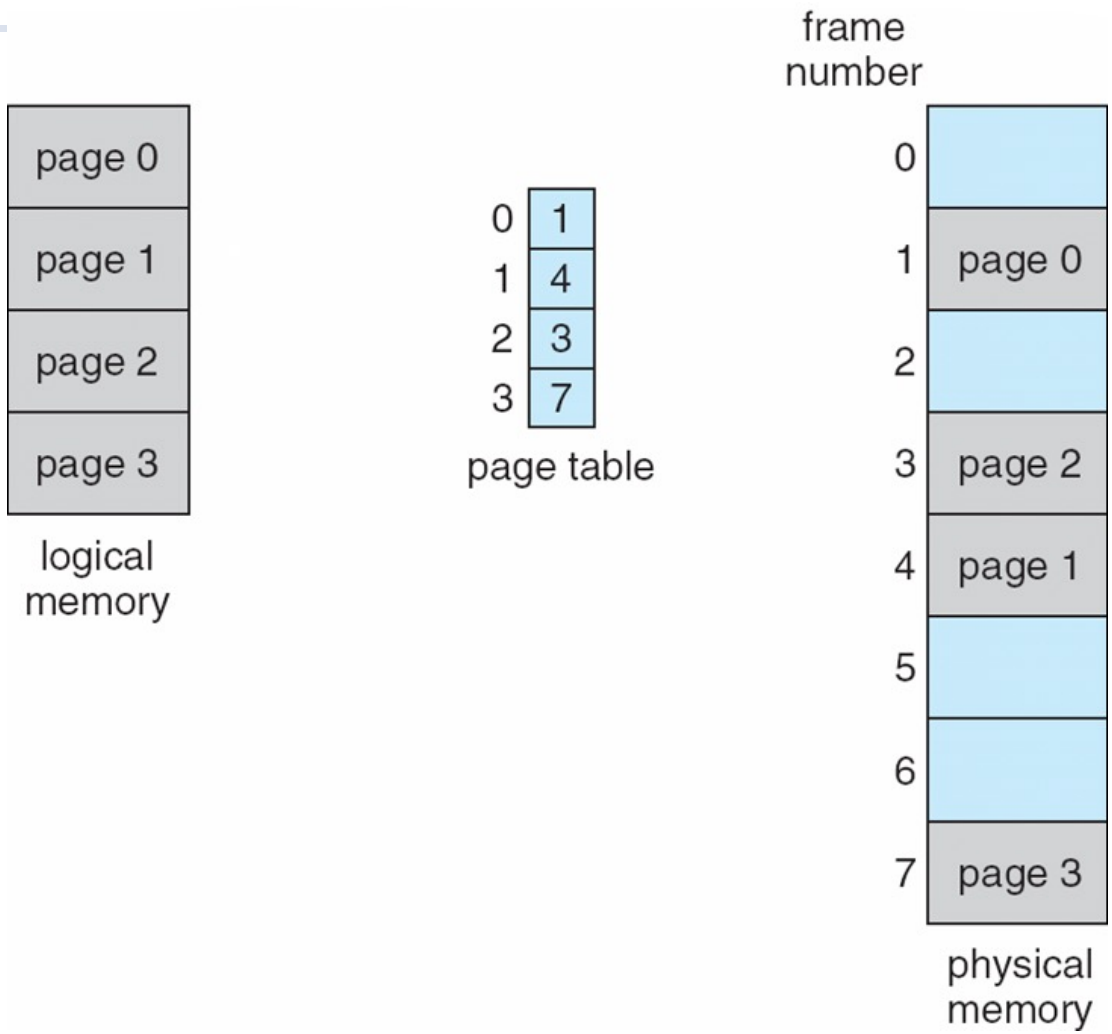
  - For given logical address space 2^m and page size 2^n

Paging Hardware



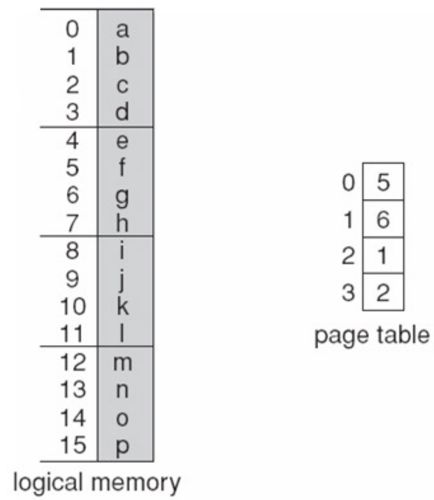
The logical address is generated by the CPU and sent to the MMU unit, where it is divided into two parts

Paging Model of Logical and Physical Memory



Paging Example

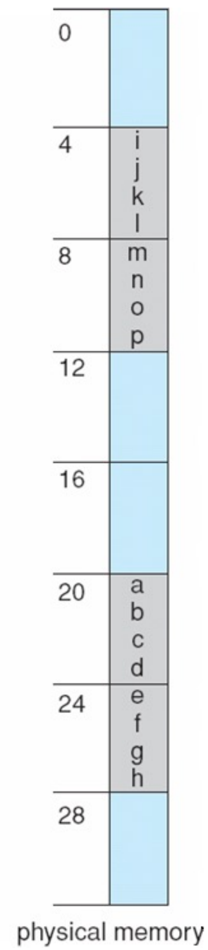
- Logical address: n = 2 and m = 4. Using a page size of 4 bytes and a physical memory of 32 bytes (equivalent to 8 pages)



How does Logical address 13 map to?

Logical address 0 is page 0, offset 0. Indexing into the page table, we find that page 0 is in frame 5. Thus, logical address 0 maps to physical address 20 [= (5 × 4) + 0].

Logical address 3 (page 0, offset 3) maps to physical address 23 [= (5 × 4) + 3].

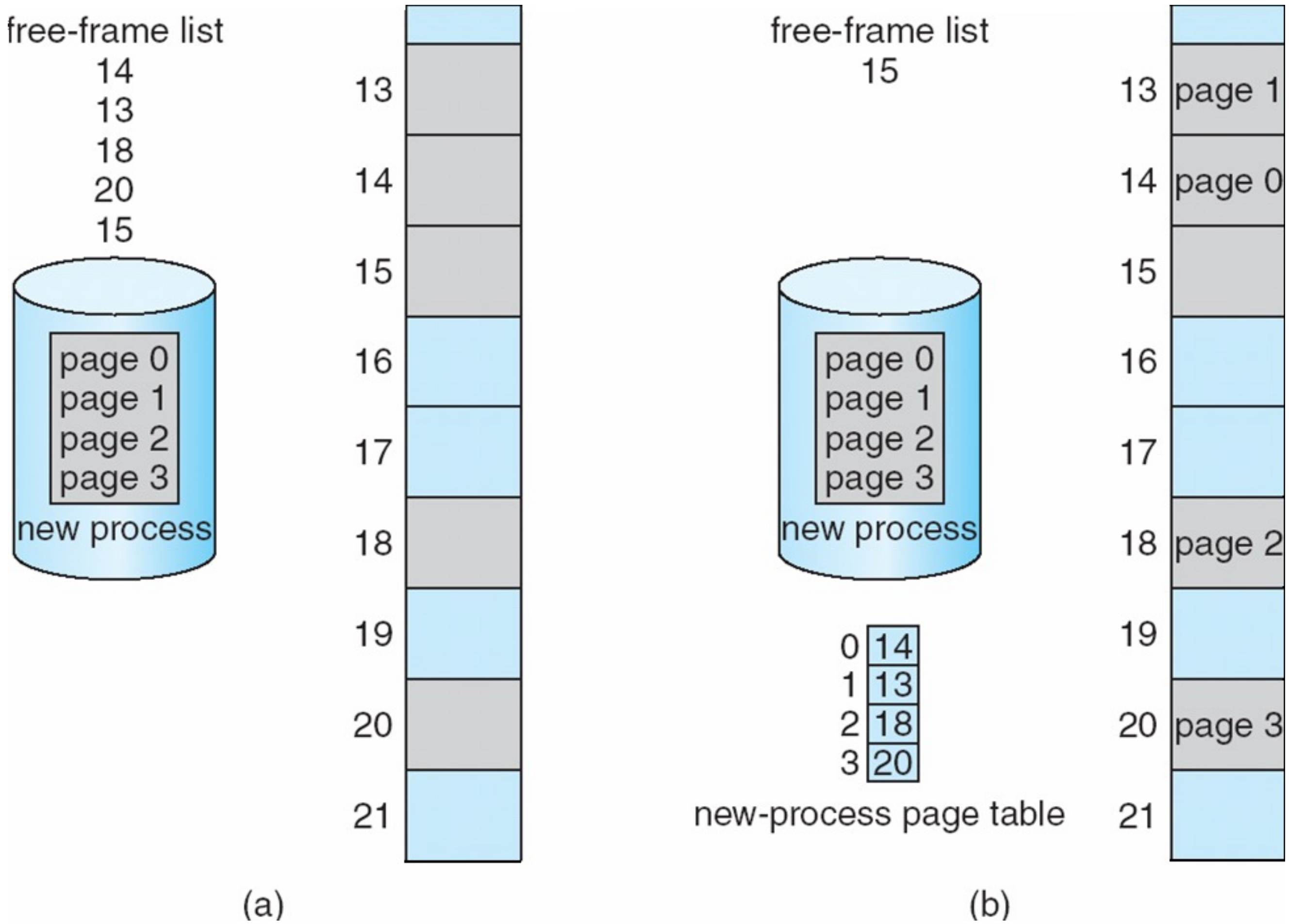


Logical address 4 is page 1, offset 0; according to the page table, page 1 is mapped to frame 6. Thus, logical address 4 maps to physical address 24 [= (6 × 4) + 0].

Example: calculating internal fragmentation

- Page size = 2,048 bytes
- Process size = 72,766 bytes
- 35 pages + 1,086 bytes (36 frames)
- 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 different page sizes – 8 KB and 4 MB

Free Frames



Before allocation

After allocation