Operating Systems: Internals and Design Principles

Chapter 7 Memory Management

Ninth Edition

William Stallings

Memory Management Requirements

- Memory management is intended to satisfy the following requirements:
  - Relocation
  - Protection
  - Sharing
  - Logical organization
  - Physical organization

Relocation

- Programmers typically do not know in advance which other programs will be resident in main memory at the time of execution of their program
- Active processes need to be able to be swapped in and out of main memory in order to maximize processor utilization
- Specifying that a process must be placed in the same memory region when it is swapped back in would be limiting
  - May need to *relocate* the process to a different area of memory

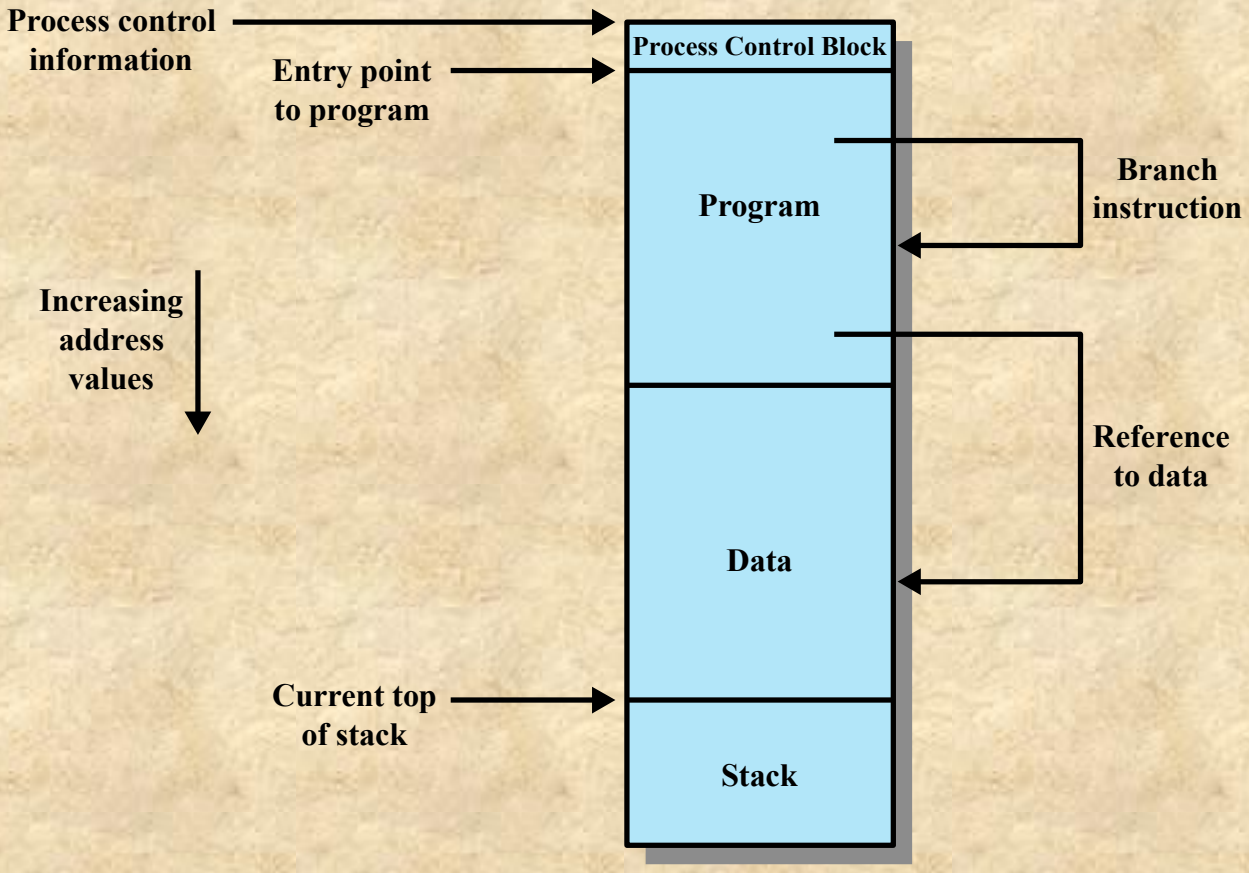


Figure 7.1 Addressing Requirements for a Process

Protection

- Processes need to acquire permission to reference memory locations for reading or writing purposes
- Location of a program in main memory is unpredictable
- Memory references generated by a process must be checked at run time
- Mechanisms that support relocation also support protection

Sharing

- Advantageous to allow each process access to the same copy of the program rather than have their own separate copy
- Memory management must allow controlled access to shared areas of memory without compromising protection
- Mechanisms used to support relocation support sharing capabilities

Logical Organization

- Memory is organized as linear

Programs are written in modules

- Modules can be written and compiled independently
- Different degrees of protection given to modules (read-only, execute-only)
- Sharing on a module level corresponds to the user's way of viewing the problem

- Segmentation is the tool that most readily satisfies requirements

Physical Organization

Cannot leave the programmer with the responsibility to manage memory

Memory available for a program plus its data may be insufficient

Overlaying allows various modules to be assigned the same region of memory but is time consuming to program

Programmer does not know how much space will be available

Memory Partitioning

- Why? To ensure the memory management requirement?
- Memory management brings processes into main memory for execution by the processor
  - Involves virtual memory
  - Based on segmentation and paging
- Partitioning
  - Used in several variations in some now-obsolete operating systems
  - Does not involve virtual memory

Fixed Partitioning

- Idea: Partition the available memory into regions with fixed boundaries.
- Each process is loaded into one of the partitions in the main memory.
- How do we select the partition size?
  - Equal size partition.
  - Unequal size partition.

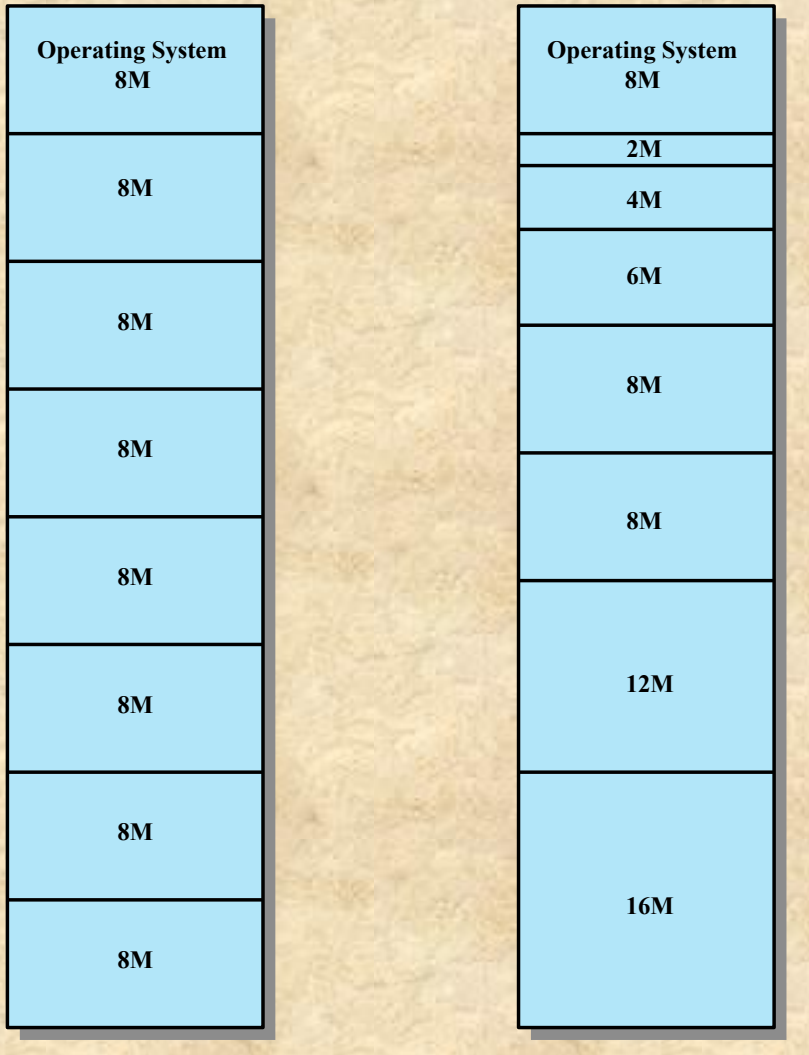


Figure 7.2 Example of Fixed Partitioning of a 64-Mbyte Memory

Fixed partitions

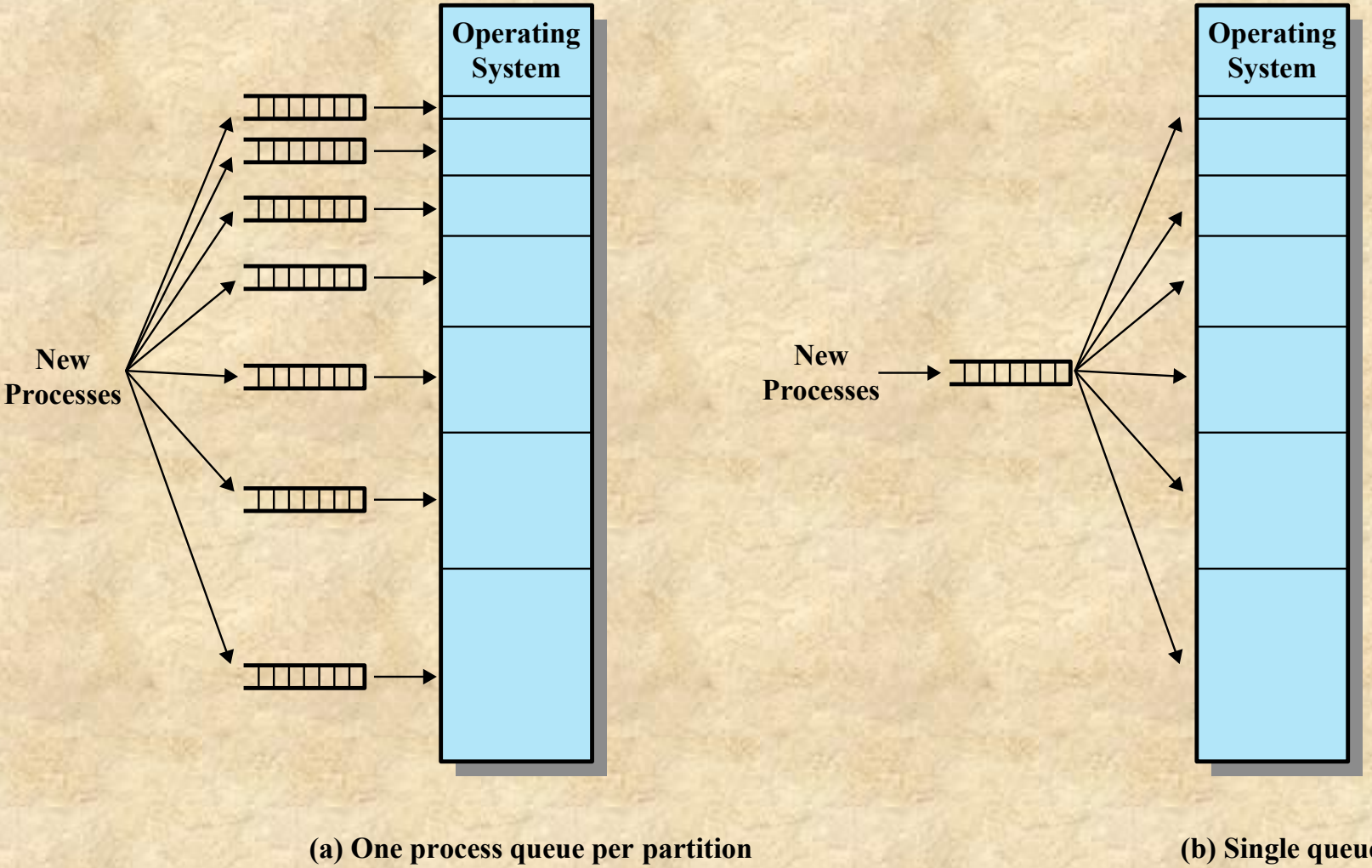
- Placement Strategy for equal size partitioning?
- Any process whose size is less than or equal to the partition size can be loaded into available partition.
- If partitions are full, and no process is ready or running state, the OS can swap a process out of any partition and load in another process.

Disadvantages

- The number of partitions specified at system generation time limits the number of active processes in the system
- Small jobs will not utilize partition space efficiently. (**Internal fragmentation**)

Fixed size partitioning…

- Unequal size partitioning
- We partition the main memory into set of unequal size partitions.
- What are the placement options?
  - A queue for each partition
  - One queue for each partition (why?)
- Advantages?
  - Minimizes the memory wastage
- Disadvantages
  - Some internal fragmentation



(a) One process queue per partition

(b) Single queue

Figure 7.3 Memory Assignment for Fixed Partitioning

Disadvantages

- A program may be too big to fit in a partition
  - Program needs to be designed with the use of overlays
- Main memory utilization is inefficient
  - Any program, regardless of size, occupies an entire partition
  - ***Internal fragmentation***
- The number of partitions specified at system generation time limits the number of active (not suspended) processes in the system.

Dynamic Partitioning

- Partitions are of variable length and number
- Process is allocated exactly as much memory as it requires
- This technique was used by IBM's mainframe operating system, OS/MVT

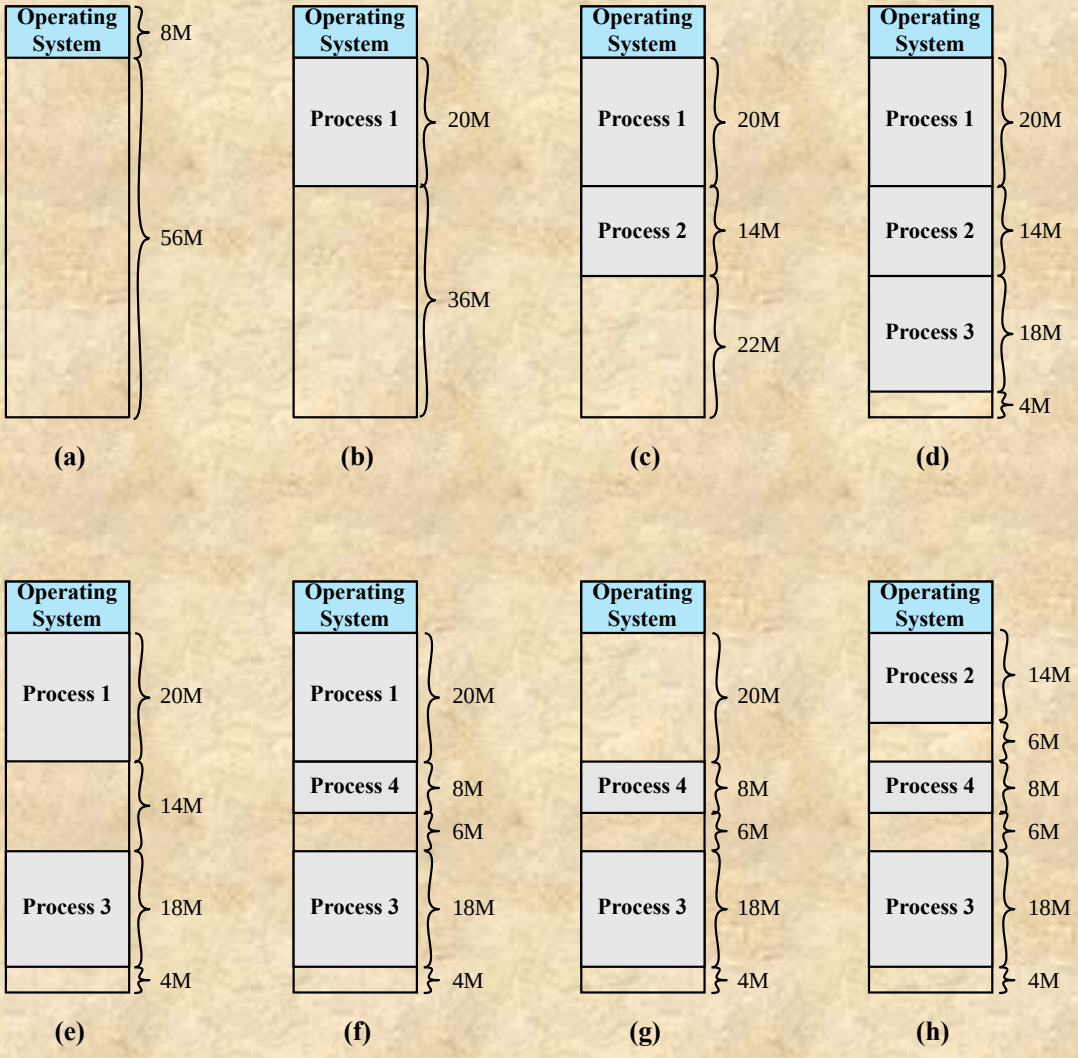


Figure 7.4 The Effect of Dynamic Partitioning

Dynamic Partitioning

External Fragmentation

- Memory becomes more and more fragmented
- Memory utilization declines

Compaction

- Technique for overcoming external fragmentation
- OS shifts processes so that they are contiguous
- Free memory is together in one block
- Time consuming and wastes CPU time

Placement Algorithms

Best-fit	First-fit	Next-fit
• Chooses the block that is closest in size to the request	• Begins to scan memory from the beginning and chooses the first available block that is large enough	• Begins to scan memory from the location of the last placement and chooses the next available block that is large enough

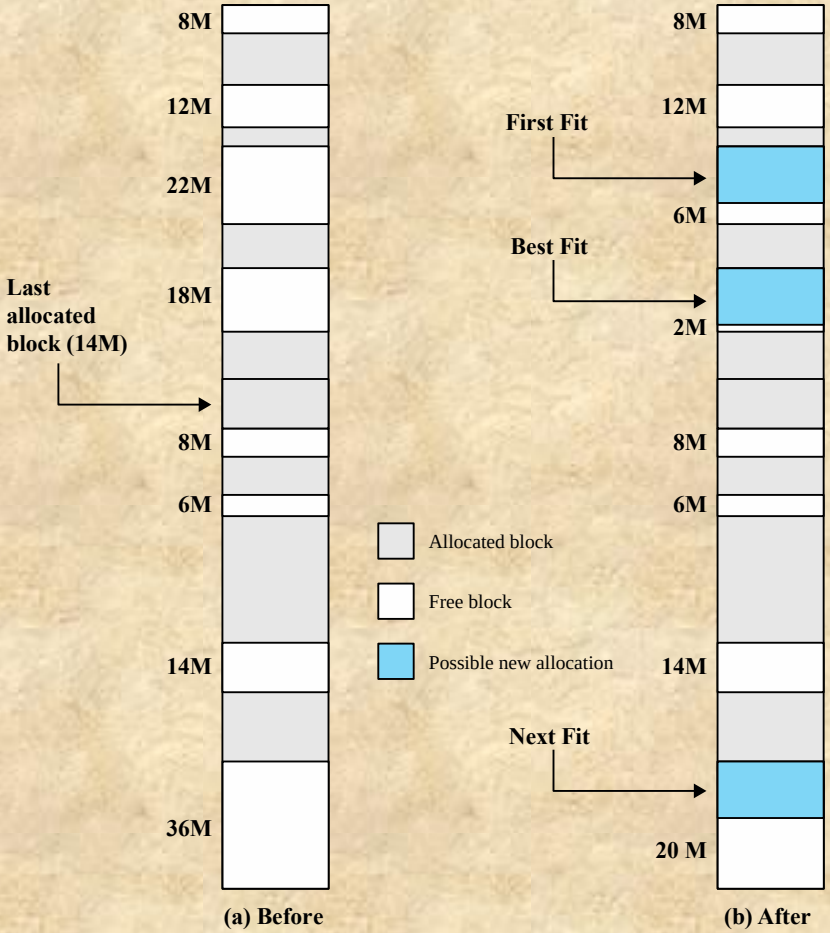


Figure 7.5 Example Memory Configuration before and after Allocation of 16-Mbyte Block

Memory deallocation

- When the partitions are not used anymore, it should be released
- Fixed partition?
  - Reset the free/busy status
- Dynamic Partitions?
  - Need to combine free areas.
  - How? What could be the scenarios that we have to deal?

Relocation

- A process may occupy different partitions
  - The process may be swapped out
  - When swapped back in, it may be assigned to a different partition than the last time
  - Dynamic partitioning, fixed partitioning*
  - Compaction
  - The locations referenced by a process are not fixed
  - They will change each time a process is swapped in or shifted

Addresses

Logical

- Reference to a memory location independent of the current assignment of data to memory

Relative

- A particular example of logical address, in which the address is expressed as a location relative to some known point

Physical or Absolute

- Actual location in main memory

Relative Addressing

- Memory reference in a loaded process are relative to the origin of the program.
- Hardware mechanism to translate relative addresses to physical addresses.
- Bounds register: ending location of the program
- Base register: starting address of the running program

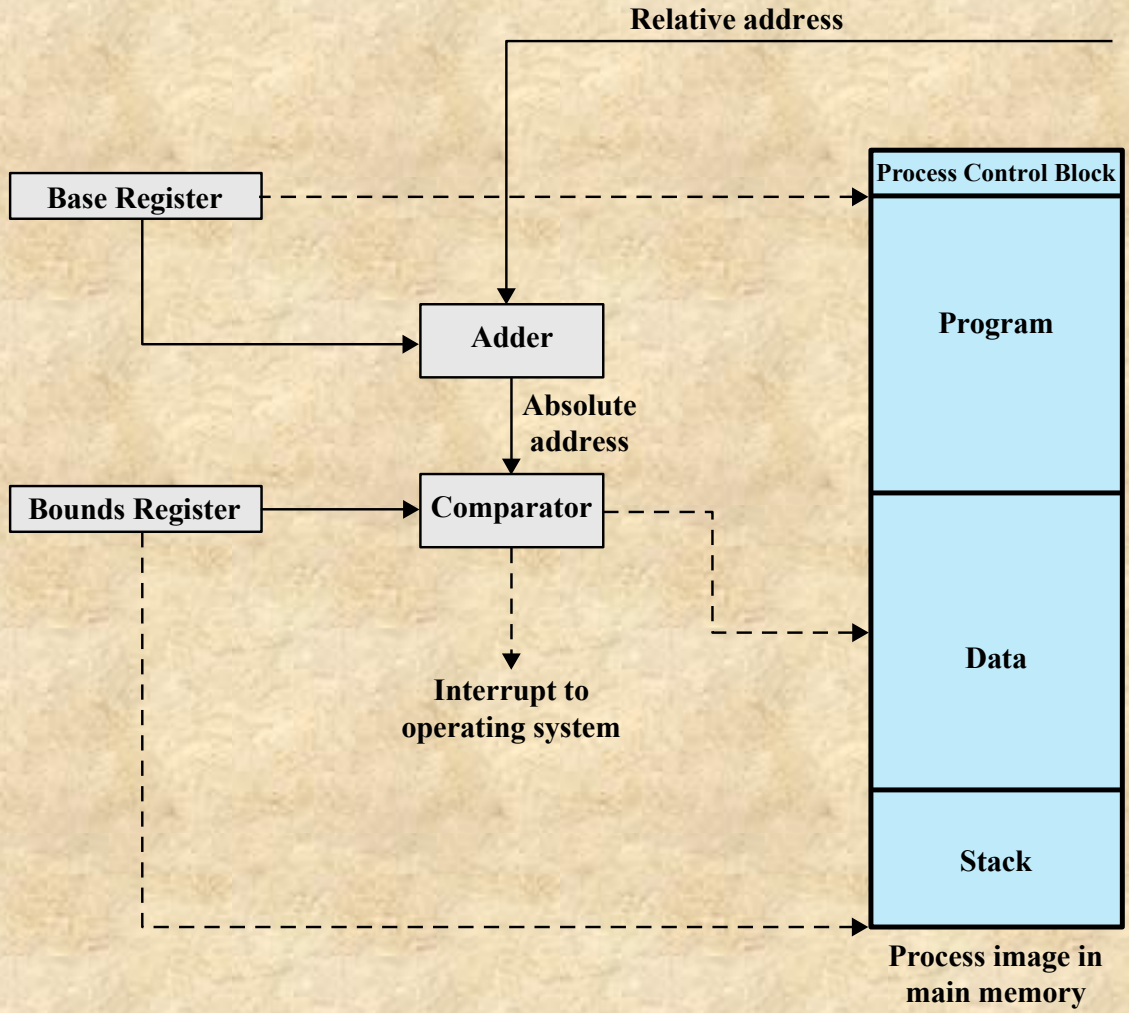


Figure 7.8 Hardware Support for Relocation

Paging

- Partition memory into equal fixed-size chunks that are relatively small
- Process is also divided into small fixed-size chunks of the same size

Pages	Frames
• Chunks of a process	• Available chunks of memory

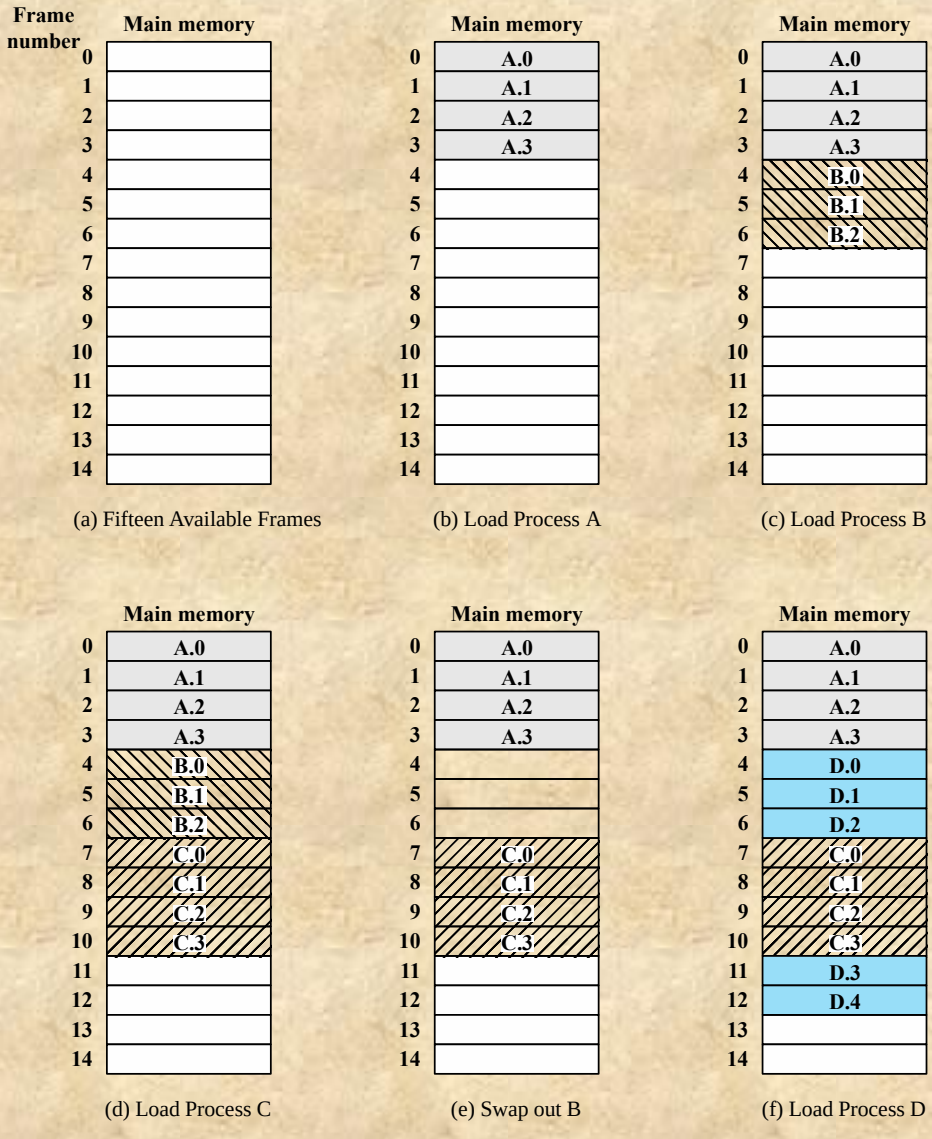


Figure 7.9 Assignment of Process Pages to Free Frames

Page Table

- Maintained by operating system for each process
- Contains the frame location for each page in the process
- Processor must know how to access for the current process
- Used by processor to produce a physical address

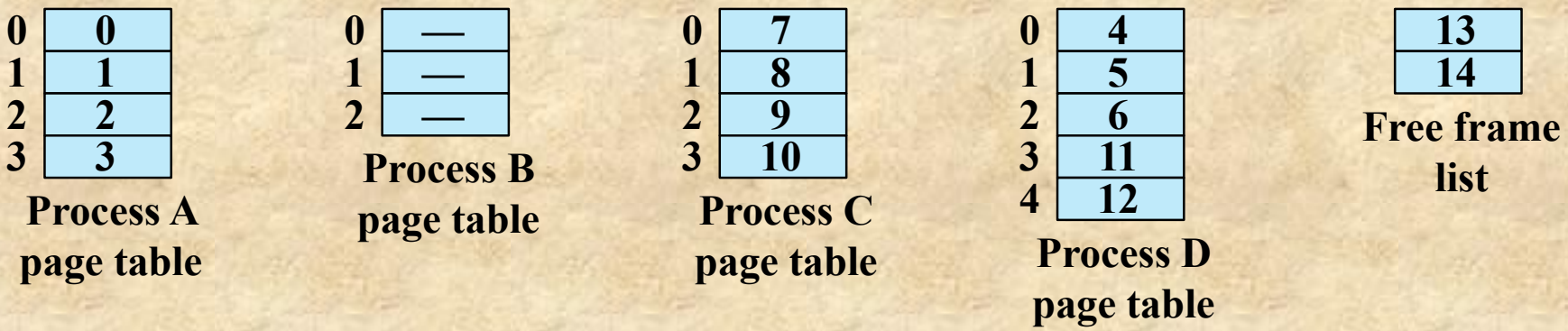


Figure 7.10 Data Structures for the Example of Figure 7.9 at Time Epoch (f)

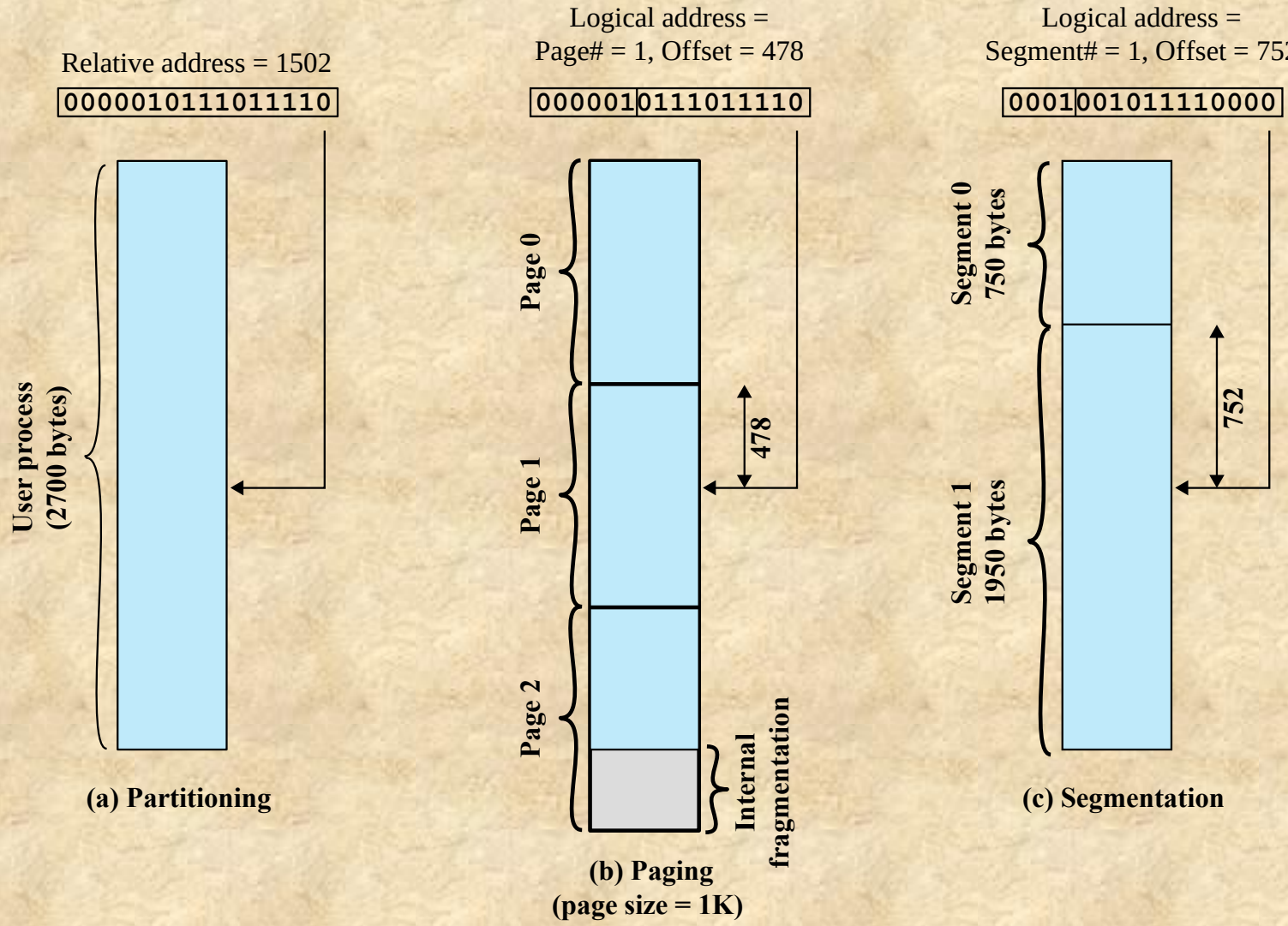


Figure 7.11 Logical Addresses

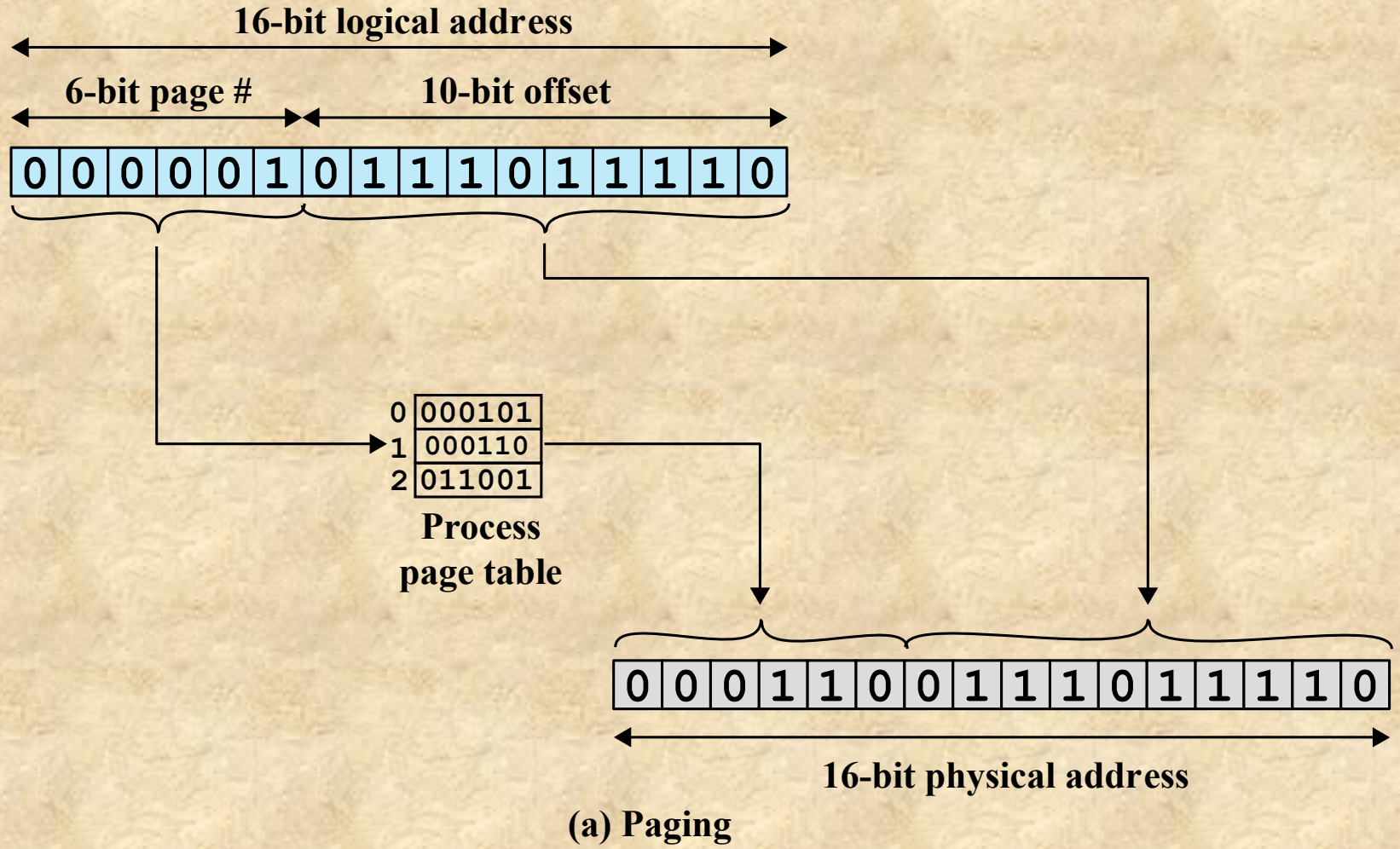


Figure 7.12 Examples of Logical-to-Physical Address Translation

Segmentation

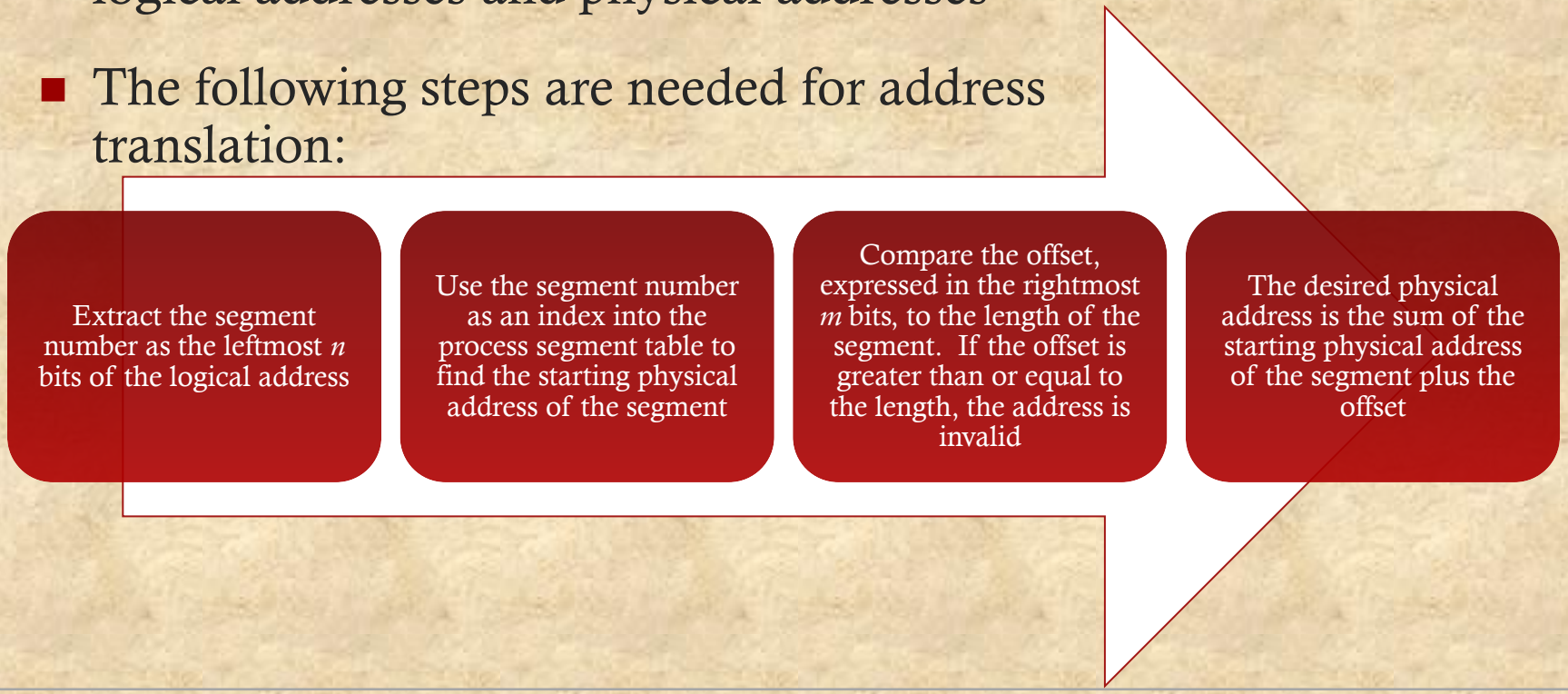
- A program can be subdivided into segments
  - May vary in length
  - There is a maximum length
- Addressing consists of two parts:
  - Segment number
  - An offset
- Similar to dynamic partitioning
- Eliminates internal fragmentation

Segmentation

- Usually visible
- Provided as a convenience for organizing programs and data
- Typically, the programmer will assign programs and data to different segments
- For purposes of modular programming the program or data may be further broken down into multiple segments
  - The principal inconvenience of this service is that the programmer must be aware of the maximum segment size limitation

Address Translation

- Another consequence of unequal size segments is that there is no simple relationship between logical addresses and physical addresses
- The following steps are needed for address translation:



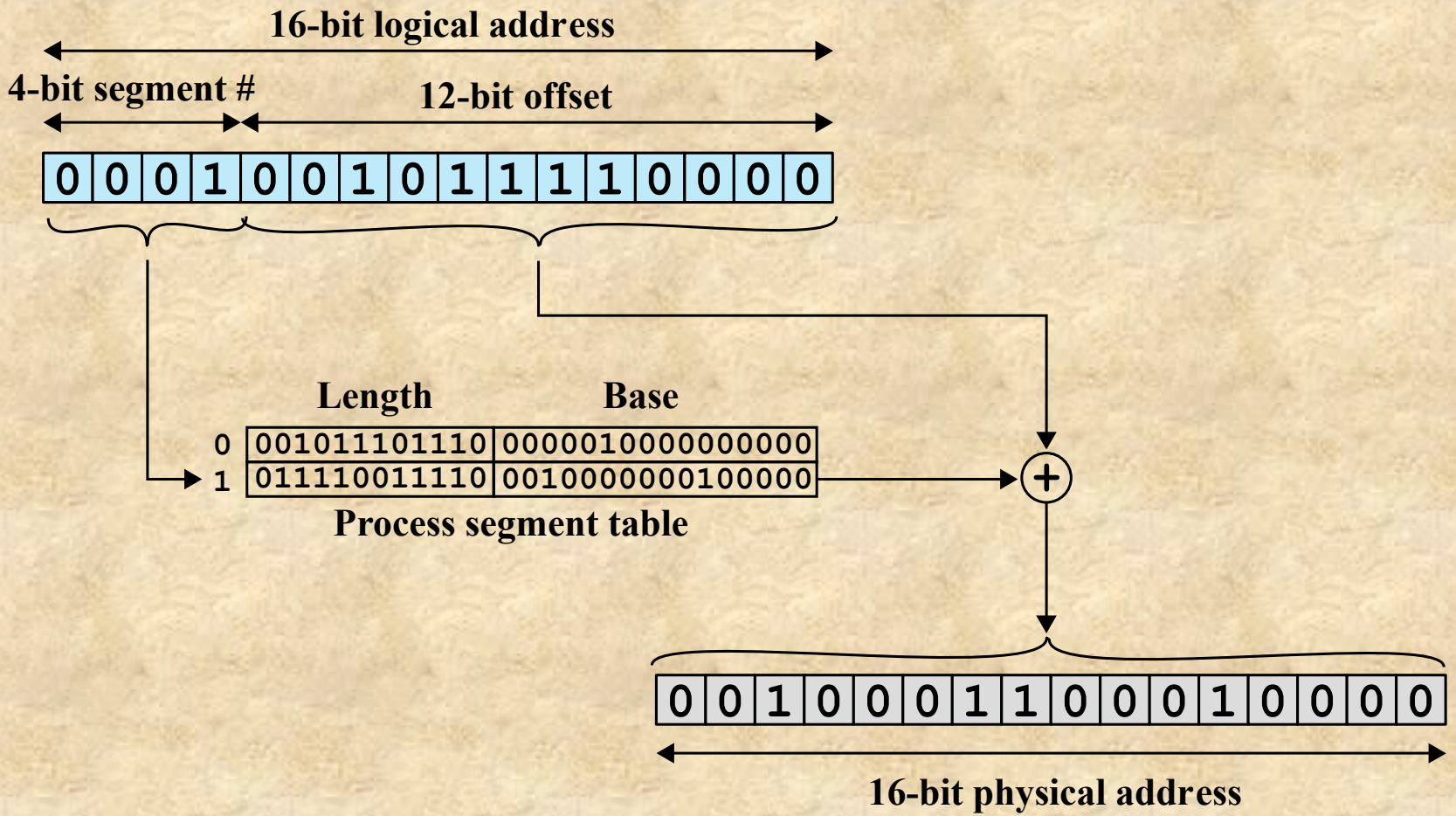


Figure 7.12 Examples of Logical-to-Physical Address Translation

Table 7.2

Memory Management Techniques

Technique	Description	Strengths	Weaknesses
Fixed Partitioning	Main memory is divided into a number of static partitions at system generation time. A process may be loaded into a partition of equal or greater size.	Simple to implement; little operating system overhead.	Inefficient use of memory due to internal fragmentation; maximum number of active processes is fixed.
Dynamic Partitioning	Partitions are created dynamically, so that each process is loaded into a partition of exactly the same size as that process.	No internal fragmentation; more efficient use of main memory.	Inefficient use of processor due to the need for compaction to counter external fragmentation.
Simple Paging	Main memory is divided into a number of equal-size frames. Each process is divided into a number of equal-size pages of the same length as frames. A process is loaded by loading all of its pages into available, not necessarily contiguous, frames.	No external fragmentation.	A small amount of internal fragmentation.
Simple Segmentation	Each process is divided into a number of segments. A process is loaded by loading all of its segments into dynamic partitions that need not be contiguous.	No internal fragmentation; improved memory utilization and reduced overhead compared to dynamic partitioning.	External fragmentation.
Virtual Memory Paging	As with simple paging, except that it is not necessary to load all of the pages of a process. Nonresident pages that are needed are brought in later automatically.	No external fragmentation; higher degree of multiprogramming; large virtual address space.	Overhead of complex memory management.
Virtual Memory Segmentation	As with simple segmentation, except that it is not necessary to load all of the segments of a process. Nonresident segments that are needed are brought in later automatically.	No internal fragmentation, higher degree of multiprogramming; large virtual address space; protection and sharing support.	Overhead of complex memory management.

(Table is on page 317 in textbook)

Summary

- Memory management requirements
  - Relocation
  - Protection
  - Sharing
  - Logical organization
  - Physical organization
- Paging
- Memory partitioning
  - Fixed partitioning
  - Dynamic partitioning
  - Buddy system*
  - Relocation
- Segmentation