Operating Systems:
Internals and Design Principles, 6/E
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Memory Management

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Roadmap

- Basic requirements of Memory Management
- Memory Partitioning
- Basic blocks of memory management
  - Paging
  - Segmentation

Basic requirements of Memory Management

The need for memory management

- Memory is cheap today, and getting cheaper
  - But applications are demanding more and more memory, there is never enough!
- Memory Management, involves swapping blocks of data from secondary storage.
- Memory I/O is slow compared to a CPU
  - The OS must cleverly time the swapping to maximise the CPU's efficiency

Memory Management

Memory needs to be allocated to ensure a reasonable supply of ready processes to consume available processor time

Memory Management Terms

Term	Description
Frame	***Fixed***-length block of main memory.
Page	***Fixed***-length block of data in secondary memory (e.g. on disk).
Segment	***Variable-length*** block of data that resides in secondary memory.

Memory Management Requirements

- Relocation
- Protection
- Sharing
- Logical organisation
- Physical organisation

Requirements: Relocation

- The programmer does not know where the program will be placed in memory when it is executed,
  - it may be swapped to disk and return to main memory at a different location (relocated)
- Memory references must be translated to the actual physical memory address

Addressing

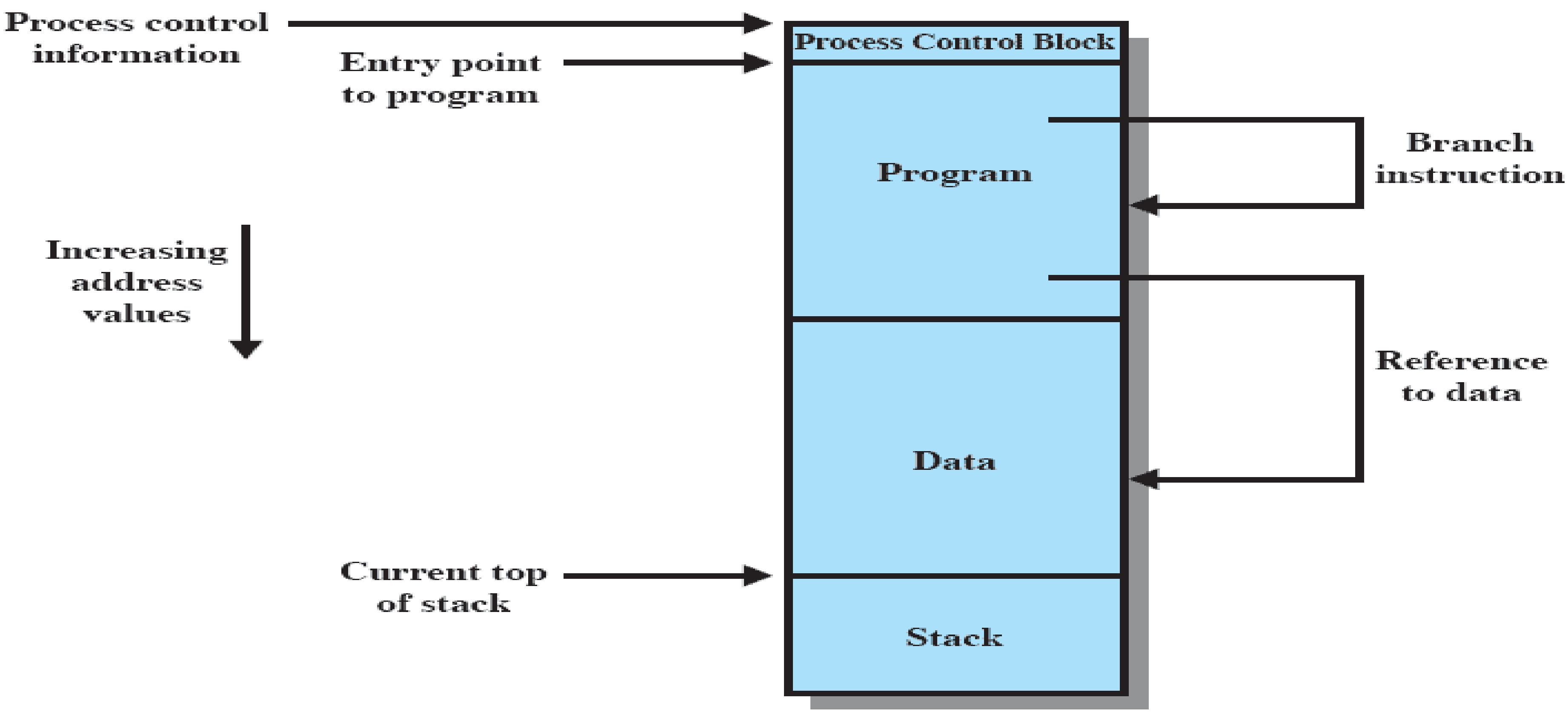


Figure 7.1 Addressing Requirements for a Process

Requirements: Protection

- Processes should not be able to reference memory locations in another process without permission
- Operating system cannot anticipate all of the memory references that a program will make
- Assess the permissibility of a memory reference (data access or branch) at the time of execution of the instruction making the reference

Requirements: Sharing

- Allow several processes to access the same portion of memory
- Better to allow each process access to the same copy of the program rather than have their own separate copy

Requirements: Logical Organization

- Memory is organized linearly (usually)
- Programs are written in modules
  - Modules can be written and compiled independently
- Different degrees of protection given to modules (read-only, execute-only)
- Share modules among processes
- Segmentation helps here

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
- Programmer does not know how much space will be available

Memory Partitioning

Types of Partitioning

- Fixed Partitioning
- Dynamic Partitioning
- Simple Paging
- Simple Segmentation
- Virtual Memory Paging
- Virtual Memory Segmentation

Fixed Partitioning

- Equal-size partitions
  - Any process whose size is less than or equal to the partition size can be loaded into an available partition
- The operating system can swap a process out of a partition
  - If none are in a ready or running state

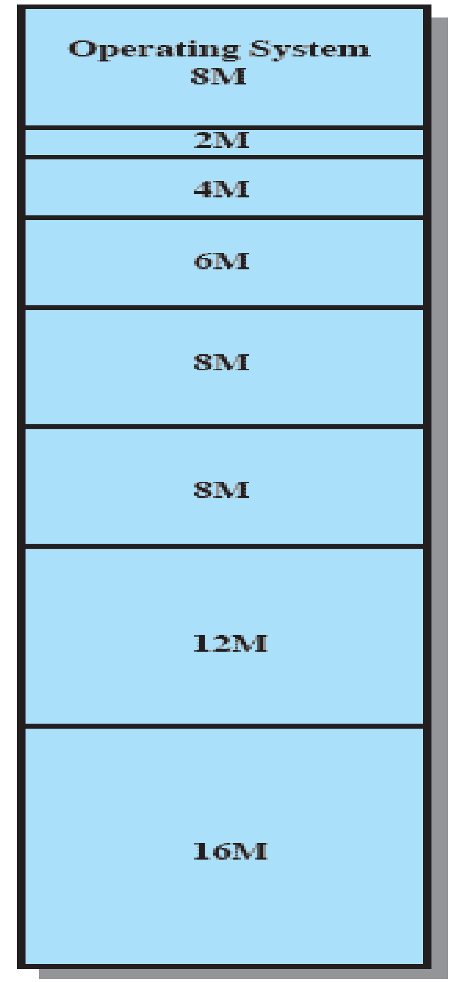
(a) Equal-size partitions

Fixed Partitioning Problems

- A program may not fit in a partition.
  - The programmer must design the program with overlays
- Main memory use is inefficient.
  - Any program, no matter how small, occupies an entire partition.
  - This is results in *internal fragmentation.*

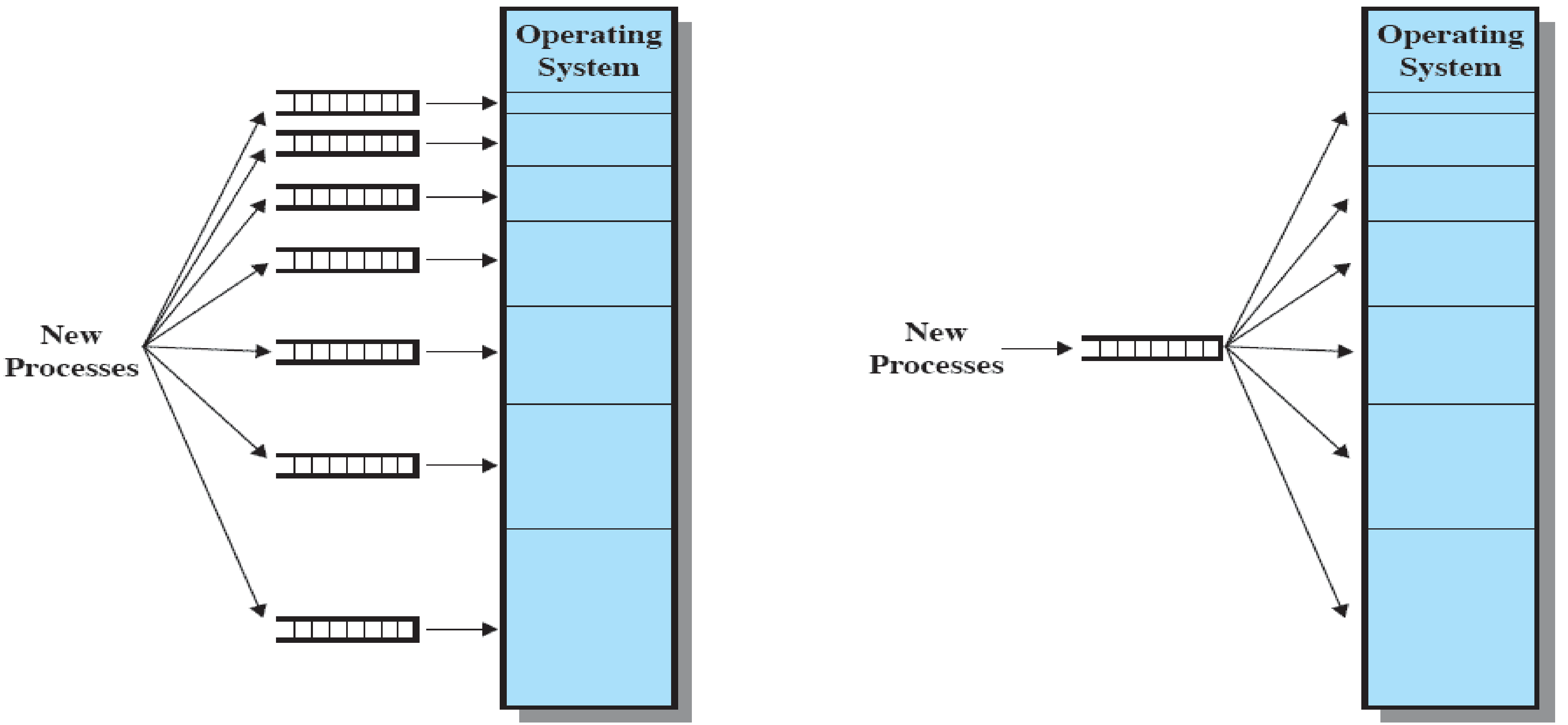
Solution – Unequal Size Partitions

- Lessens both problems
  - but doesn't solve completely
  - Programs up to 16M can be accommodated without overlay
  - Smaller programs can be placed in smaller partitions, reducing internal fragmentation



(b) Unequal-size partitions

Fixed Partitioning – Unequal Size



(a) One process queue per partition

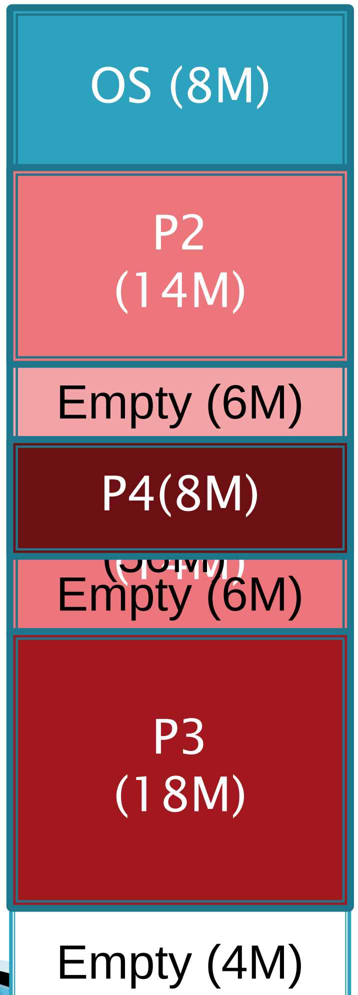
(b) Single queue

Figure 7.3 Memory Assignment for Fixed Partitioning

Dynamic Partitioning

- Partitions are of variable length and number
- Process is allocated exactly as much memory as required

Dynamic Partitioning Example



- *External Fragmentation*
- Memory external to all processes is fragmented
- Can resolve using *compaction*
  - OS moves processes so that they are contiguous
  - Time consuming and wastes CPU time

Dynamic Partitioning

- Operating system must decide which free block to allocate to a process
- Best-fit algorithm
  - Chooses the block that is closest in size to the request
  - Worst performance overall
  - Since smallest block is found for process, the smallest amount of fragmentation is left
  - Memory compaction must be done more often

Dynamic Partitioning

- First-fit algorithm
  - Scans memory form the beginning and chooses the first available block that is large enough
  - Fastest
  - May have many process loaded in the front end of memory that must be searched over when trying to find a free block

Dynamic Partitioning

- Next-fit
  - Scans memory from the location of the last placement
  - More often allocate a block of memory at the end of memory where the largest block is found
  - The largest block of memory is broken up into smaller blocks
  - Compaction is required to obtain a large block at the end of memory

Allocation

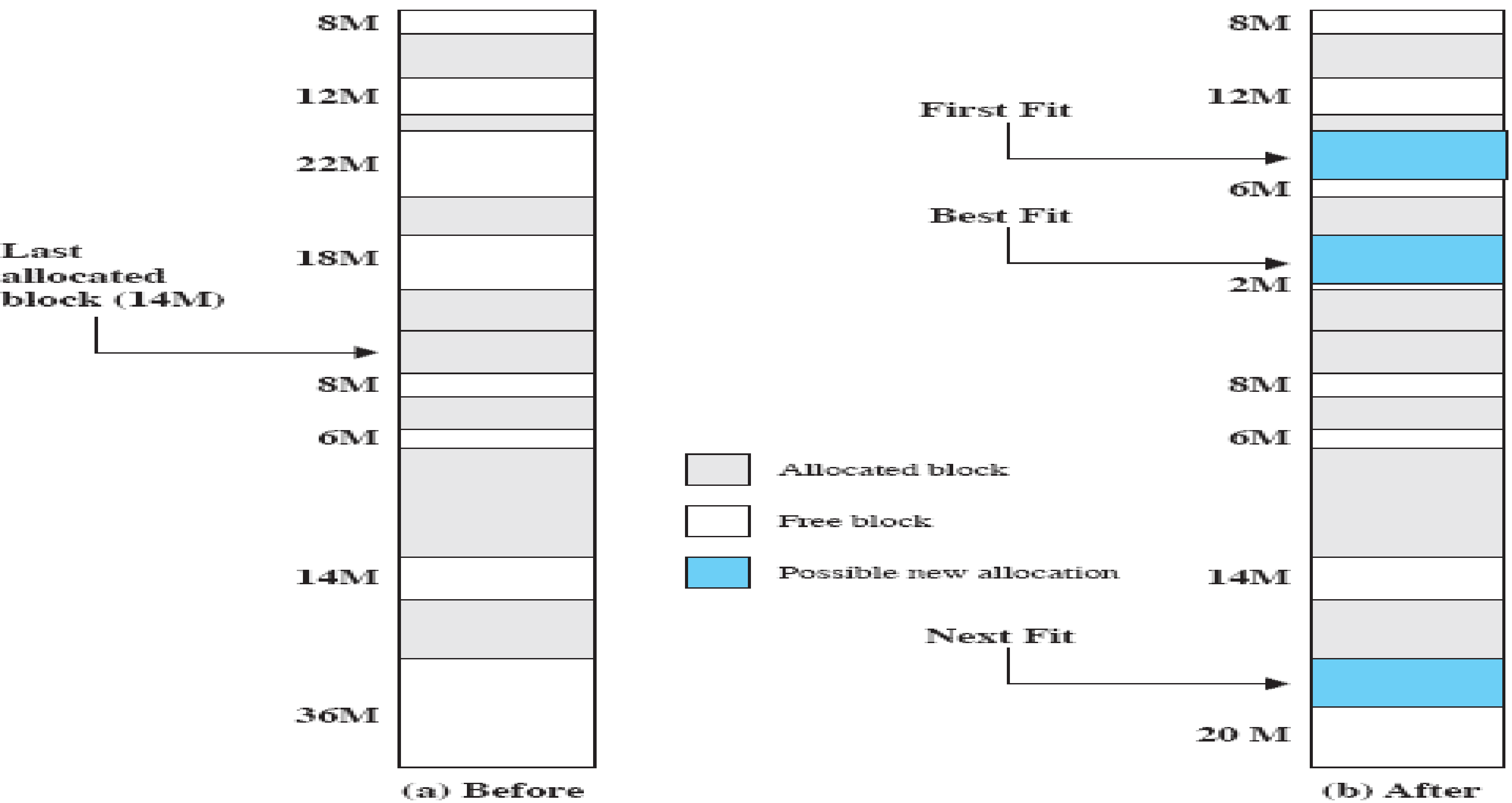


Figure 7.5 Example Memory Configuration before and after Allocation of 16-Mbyte Block

Buddy System

- Entire space available is treated as a single block
- Request arrives of less than block size
- Block splits into two equal size blocks (buddies)
  - Process continues until smallest block greater than or equal to the request is generated

Example of Buddy System

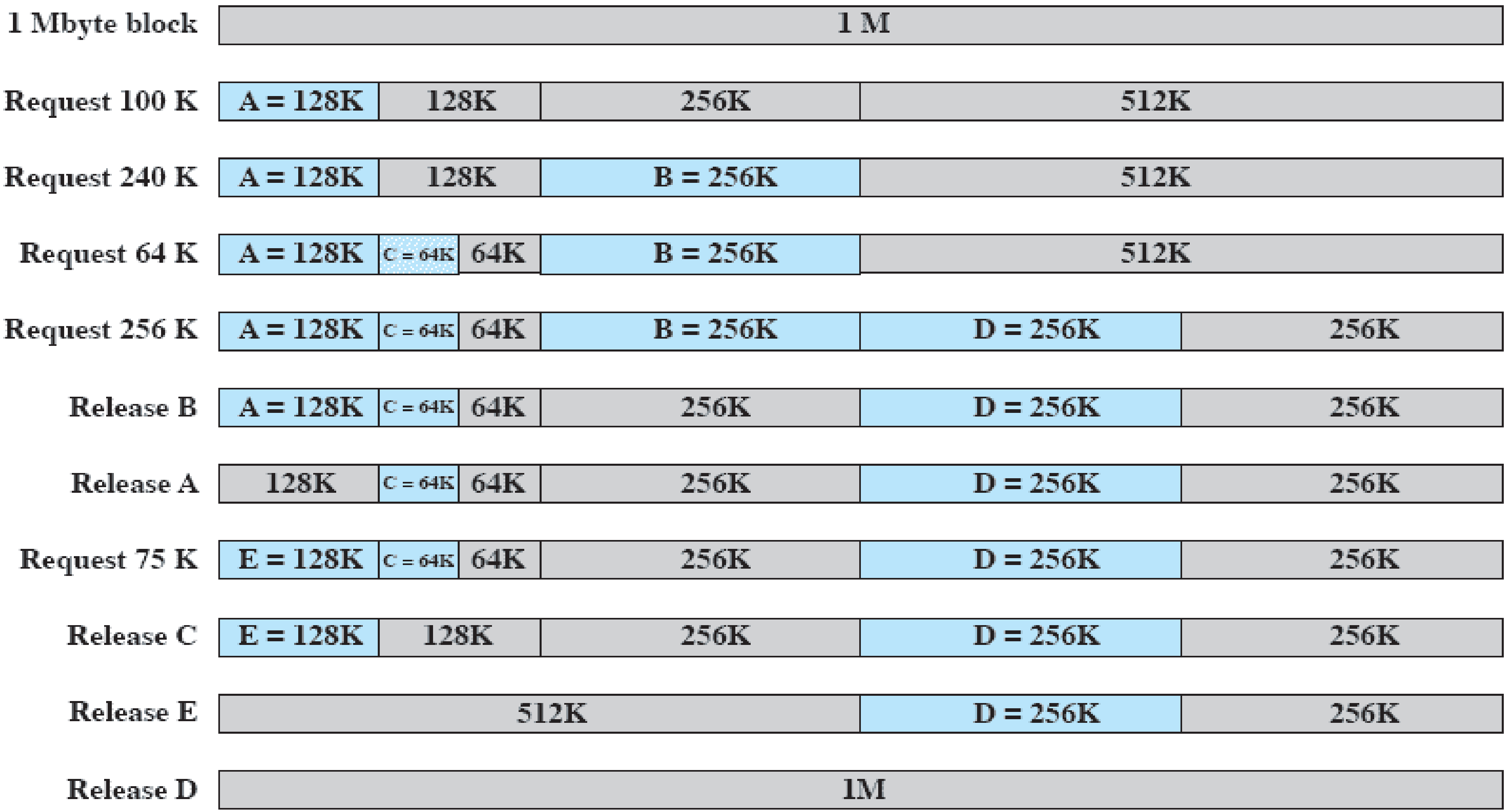


Figure 7.6 Example of Buddy System

Tree Representation of Buddy System

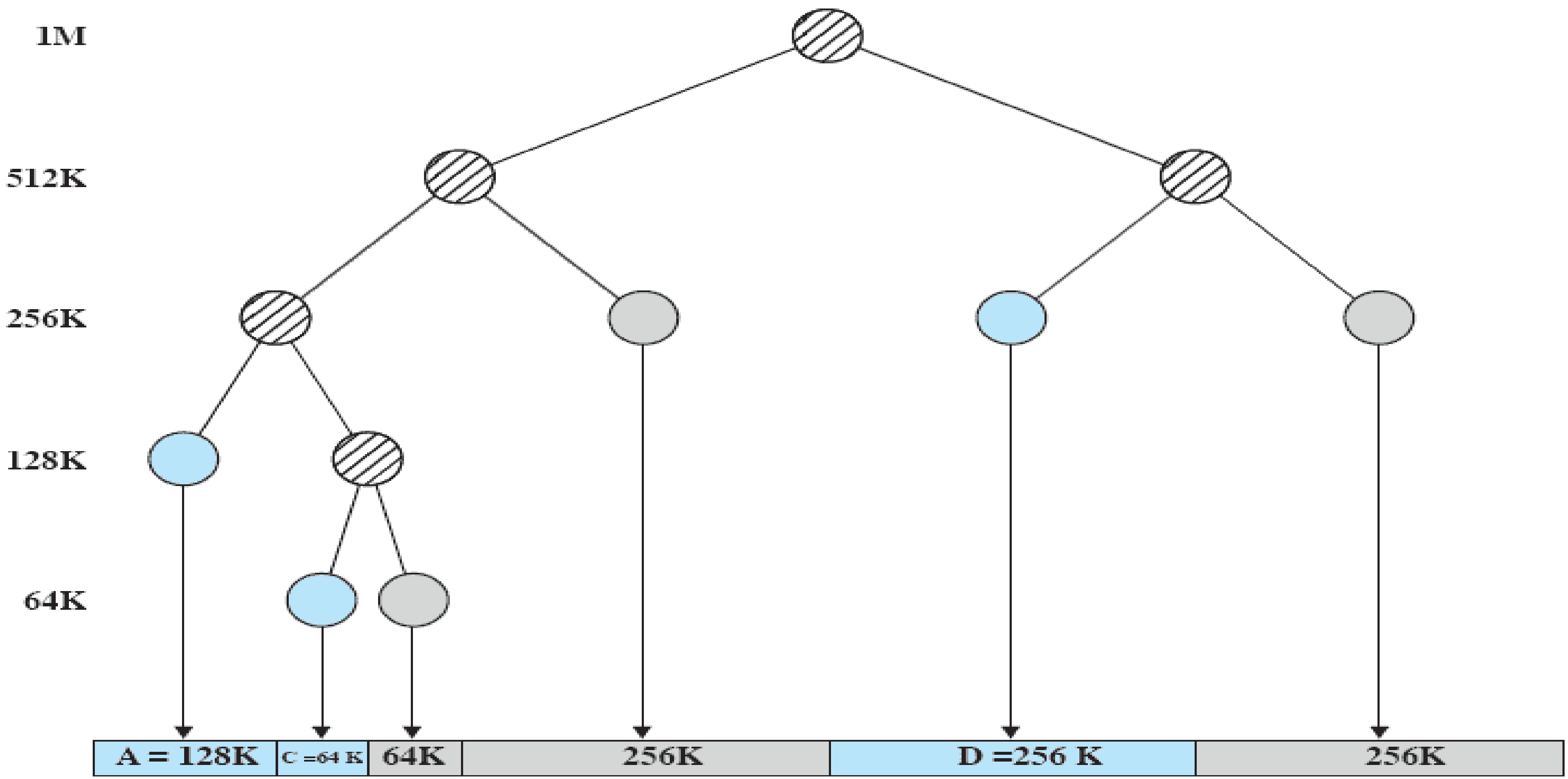


Figure 7.7 Tree Representation of Buddy System

Relocation

- When program loaded into memory the actual (absolute) memory locations are determined
- A process may occupy different partitions which means different absolute memory locations during execution
  - Swapping
  - Compaction

Addresses

- Logical
  - Address is a reference to a memory location independent of the current assignment of data to memory.
- Relative
  - Address is example of logical address.
  - Address expressed as a location relative to some known point usually a processor register.
- Physical or Absolute
  - Address is actual location in main memory.

Relocation

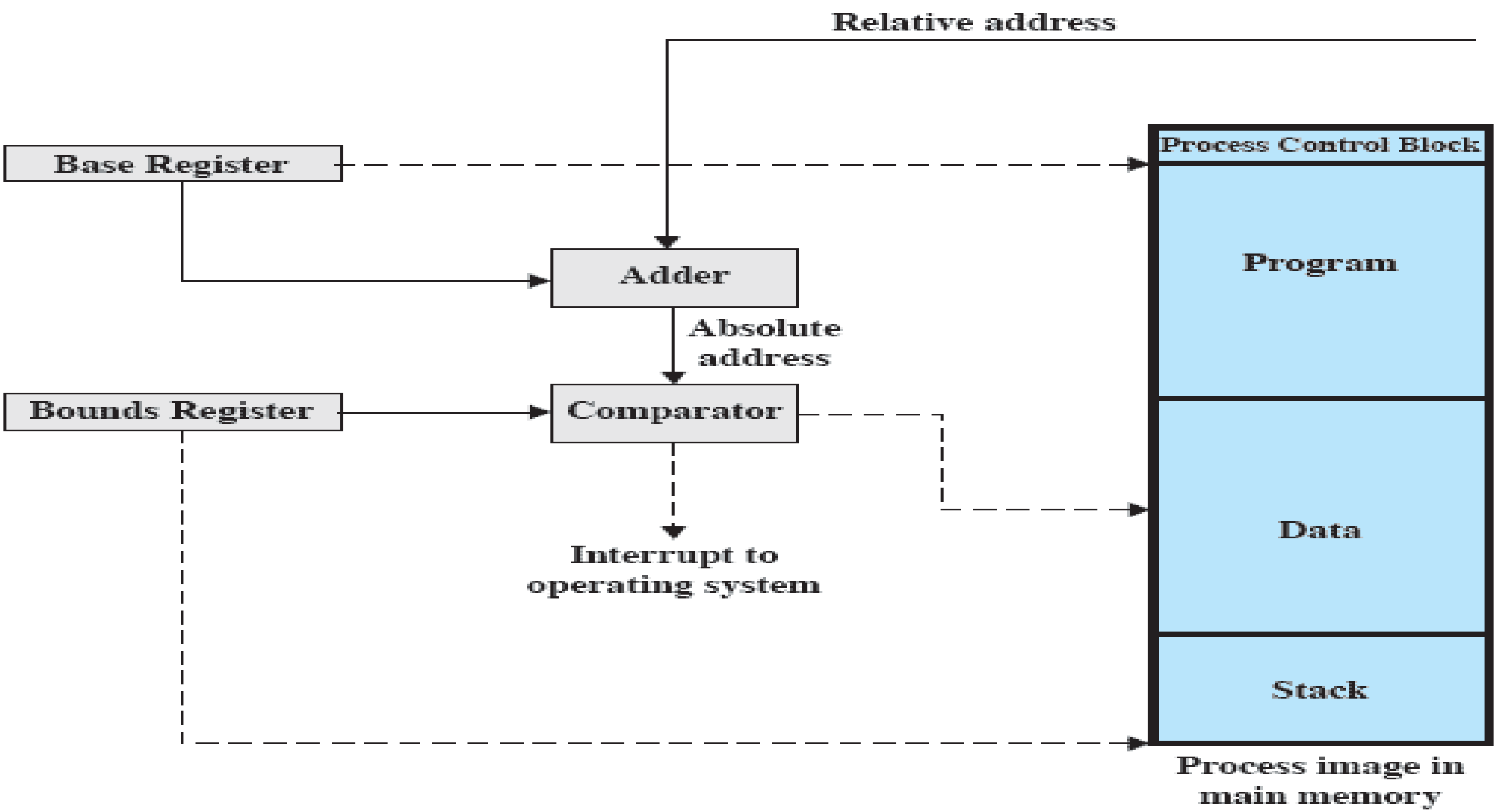


Figure 7.8 Hardware Support for Relocation

Registers Used during Execution

- Base register
  - Starting address for the process
- Bounds register
  - Ending location of the process
- These values are set when the process is loaded or when the process is swapped in

Registers Used during Execution

- The value of the base register is added to a relative address to produce an absolute address
- The resulting address is compared with the value in the bounds register
- If the address is not within bounds, an interrupt is generated to the operating system

Basic blocks of memory management

Paging
Segmentation

Paging

- Partition memory into small equal fixed-size chunks and divide each process into the same size chunks
- The chunks of a process are called ***pages***
- The chunks of memory are called ***frames***

Paging

- Operating system maintains a page table for each process
  - Contains the frame location for each page in the process
  - Memory address consist of a page number and offset within the page

Page Table

Processes and Frames

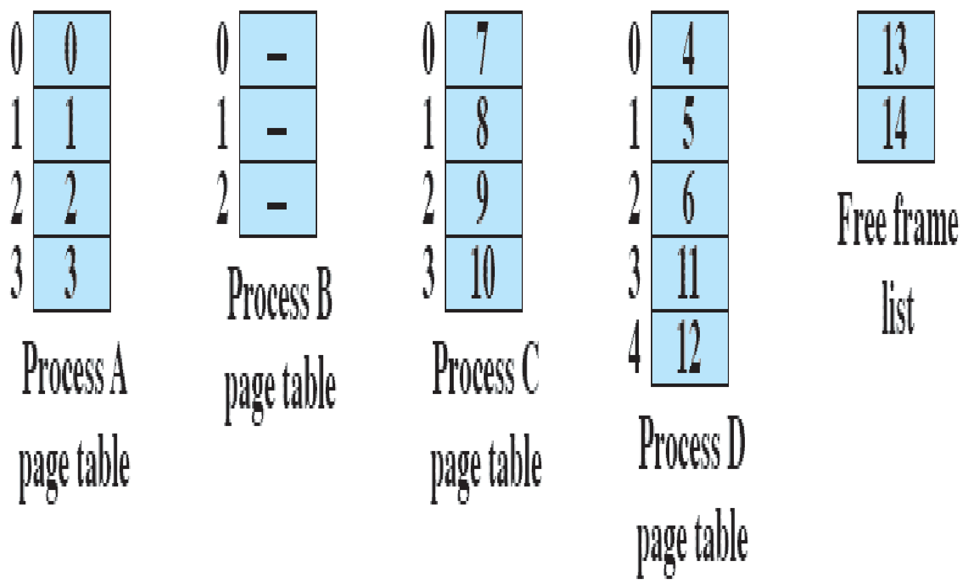
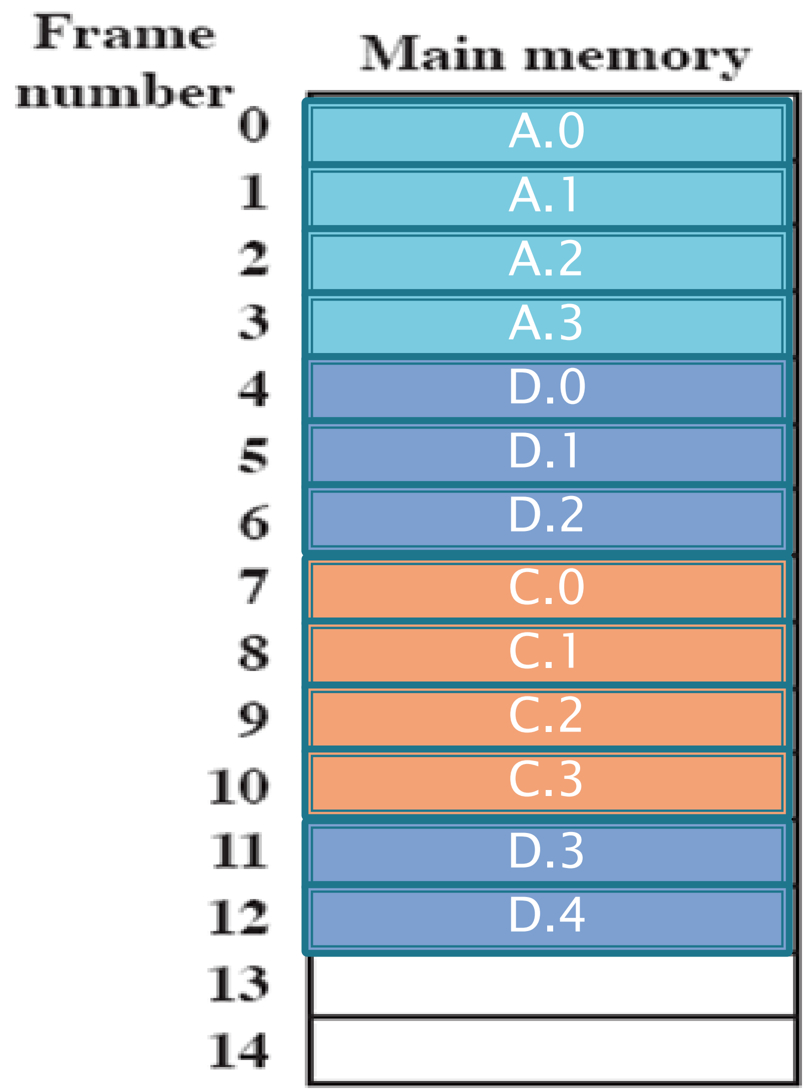


Figure 7.10 Data Structures for the Example of Figure 7.9 at Time Epoch (f)



Segmentation

- A program can be subdivided into segments
  - Segments may vary in length
  - There is a maximum segment length
- Addressing consist of two parts
  - a segment number and
  - an offset
- Segmentation is similar to dynamic partitioning

Logical Addresses

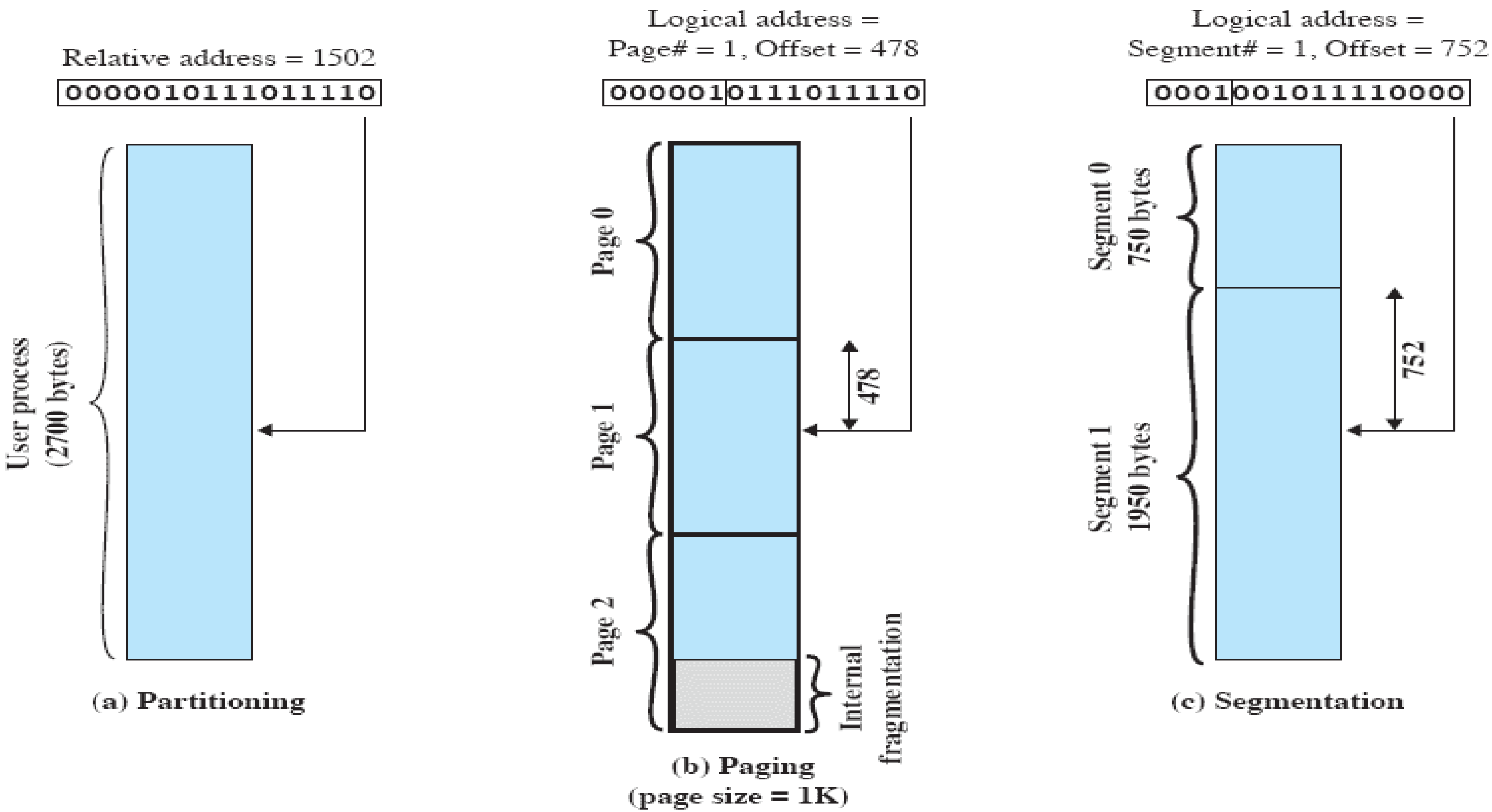
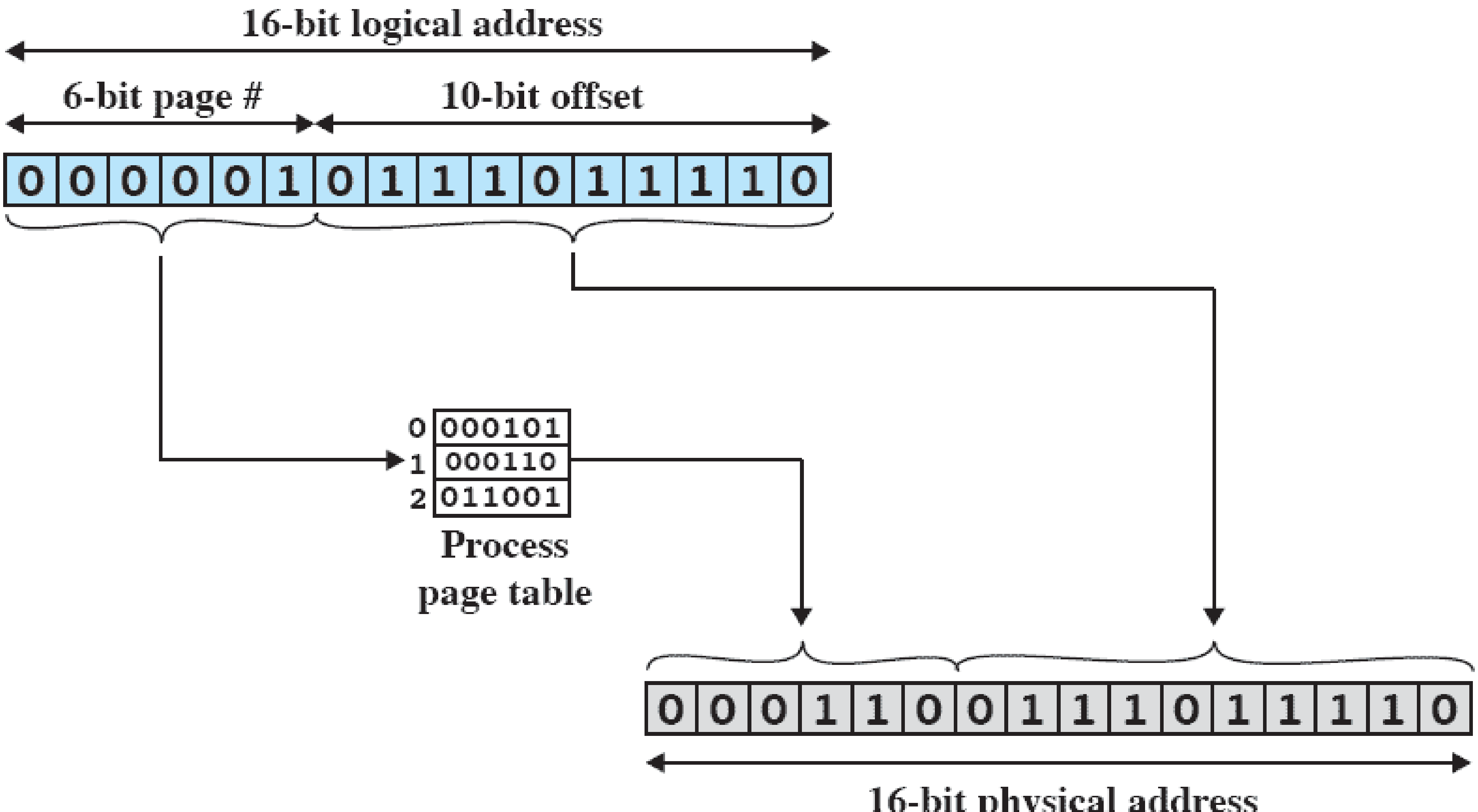


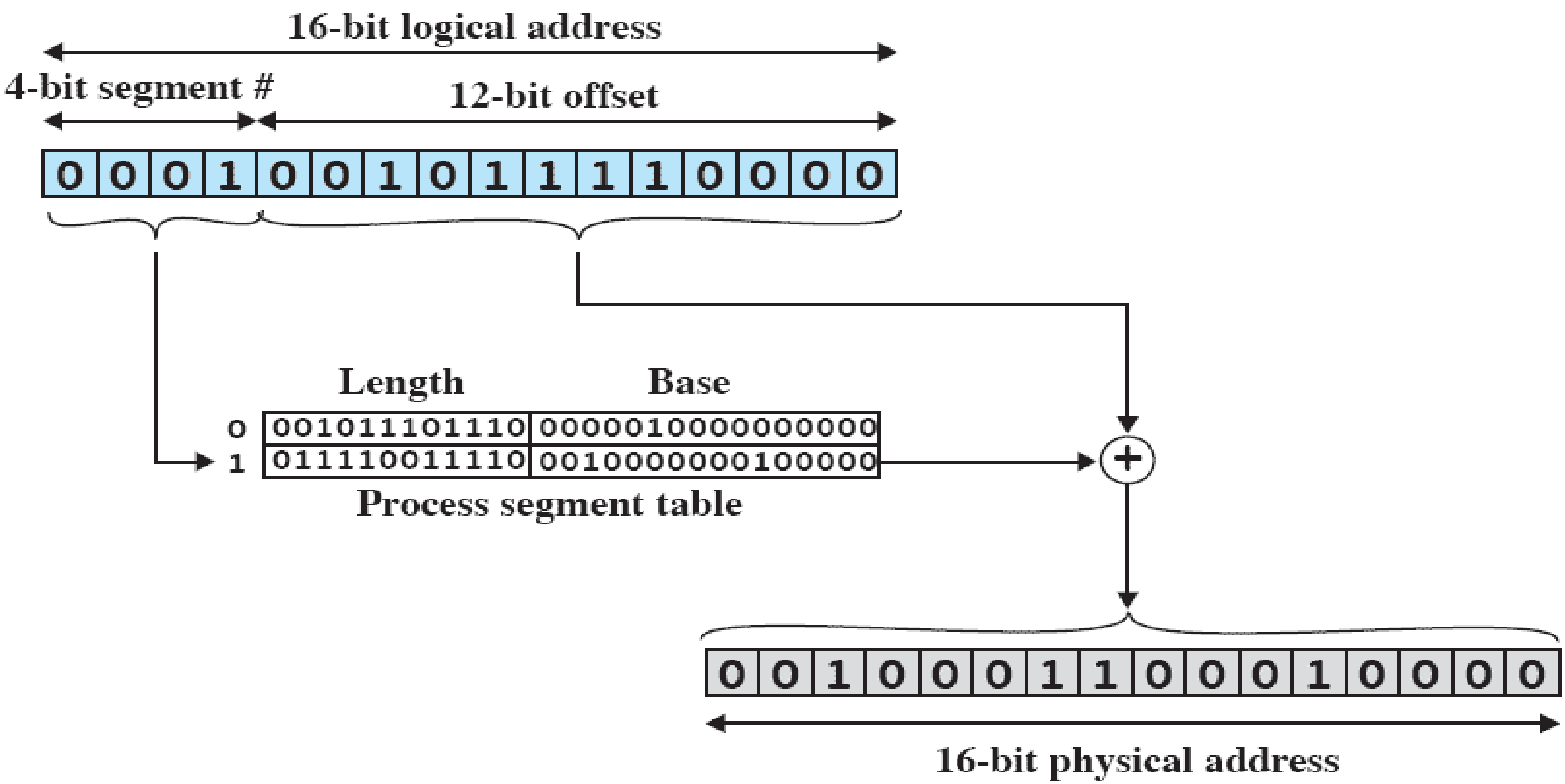
Figure 7.11 Logical Addresses

Paging



(a) Paging

Segmentation



(b) Segmentation

Figure 7.12 Examples of Logical-to-Physical Address Translation