So far…

- Page
  - Fixed size pages solve page allocation problem (and external fragmentation)
  - paging hardware (hierarchical, hashed and inverted page table)

8.6: Segmentation

- Memory-management scheme that supports user view of memory
- A program is a collection of segments. A segment is a logical unit such as:

  main program,

  procedure,

  function,

  method,

  object,

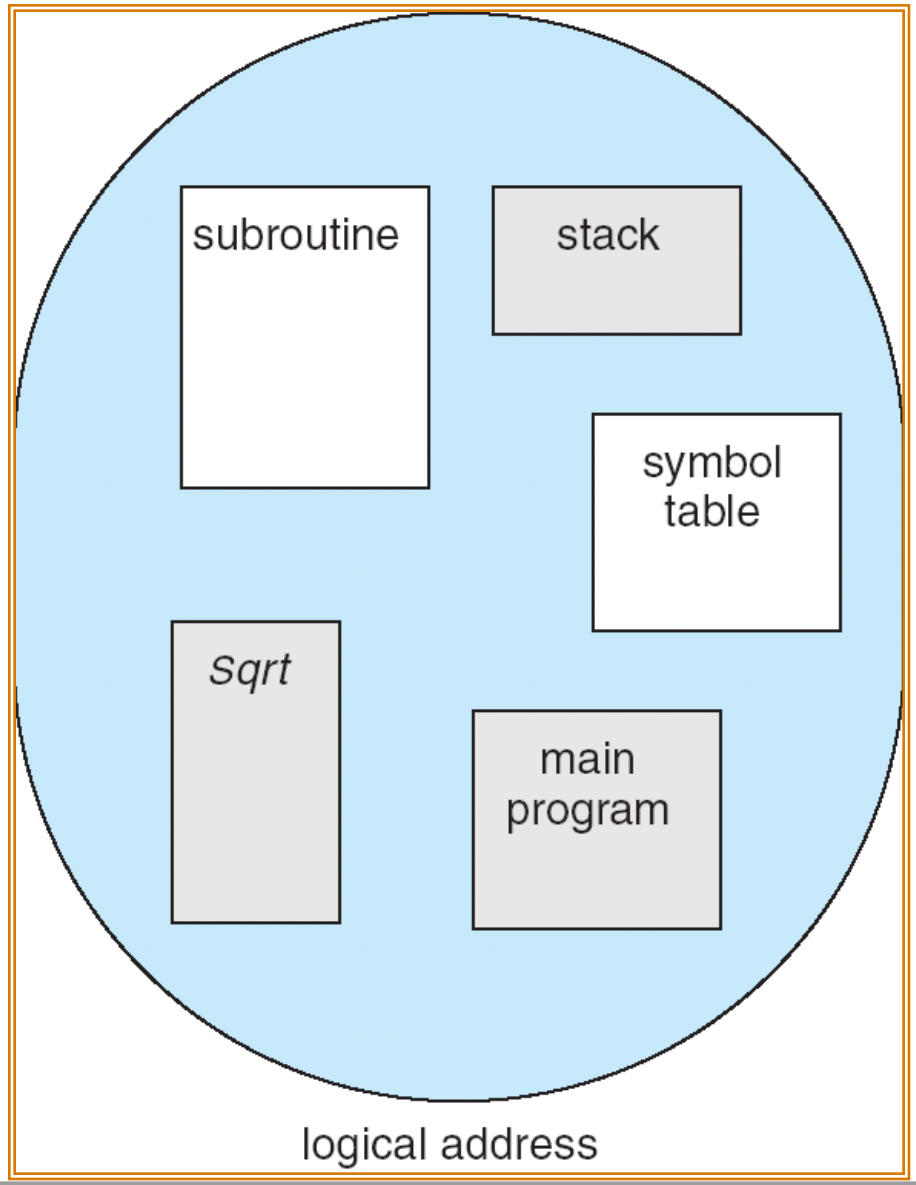
  local variables, global variables,

  common block,

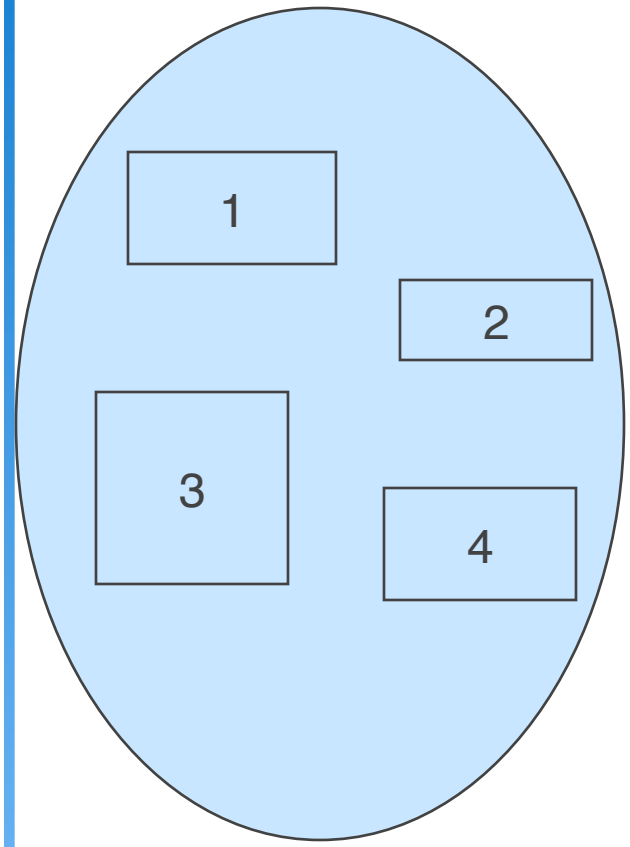
  stack,

  symbol table, arrays

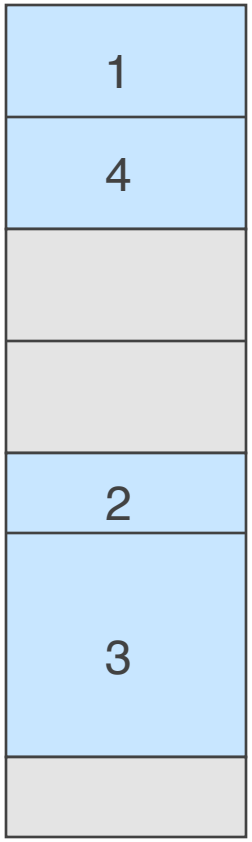
User's View of a Program



Logical View of Segmentation



user space



physical memory space

Segmentation Architecture

- Logical address consists of a two tuple:

  <segment-number, offset>,

- **Segment table** – maps two-dimensional physical addresses; each table entry has:
  - base – contains the starting physical address where the segments reside in memory
  - *limit* – specifies the length of the segment
- *Segment-table base register (STBR)* points to the segment table's location in memory
- *Segment-table length register (STLR)* indicates number of segments used by a program;

  segment number *s* is legal if *s* < STLR

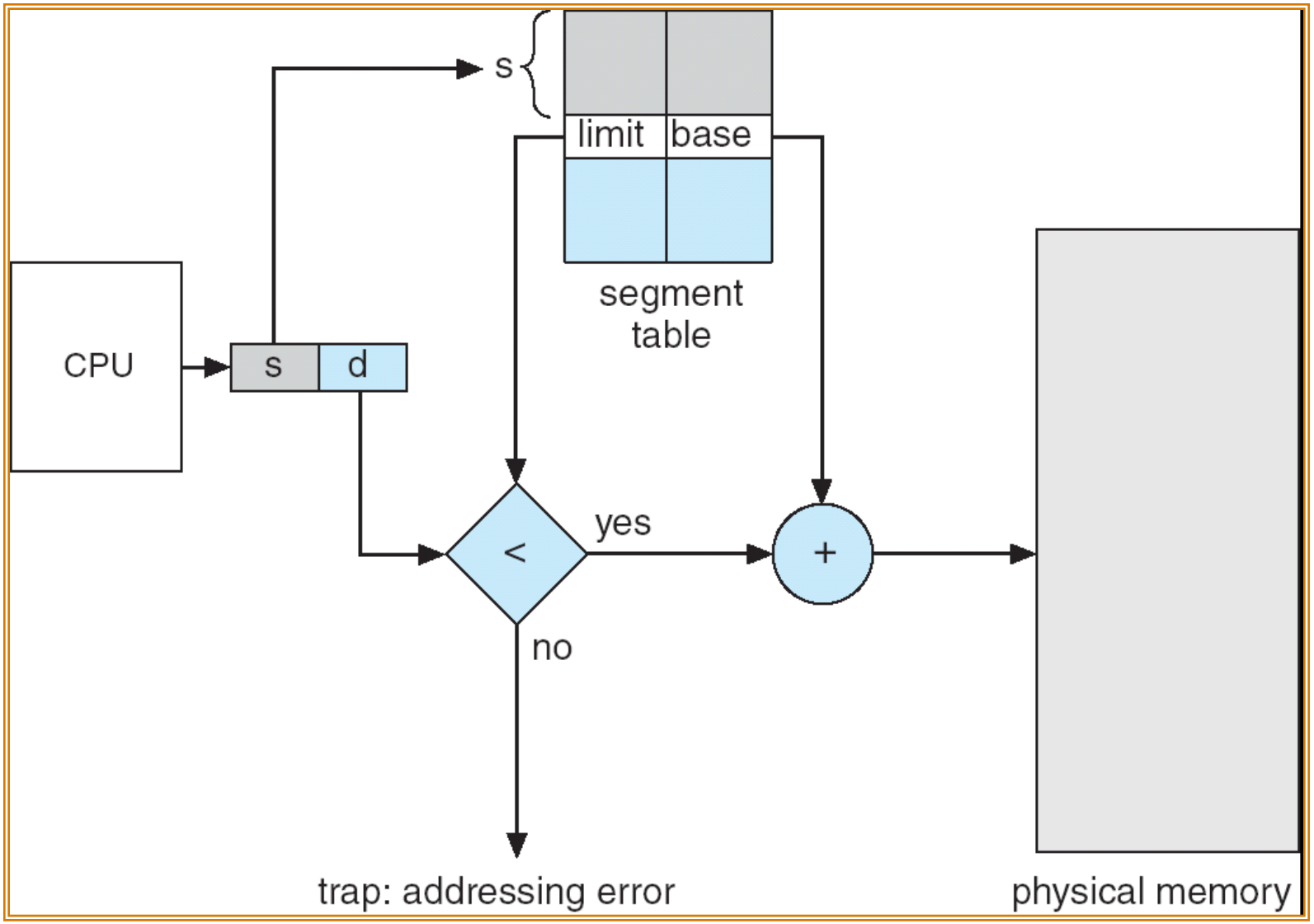
Segmentation Architecture (Cont.)

- **Relocation**.
  - dynamic
  - by segment table
- **Sharing**.
  - shared segments
  - same segment number
- **Allocation**.
  - first fit/best fit
  - external fragmentation

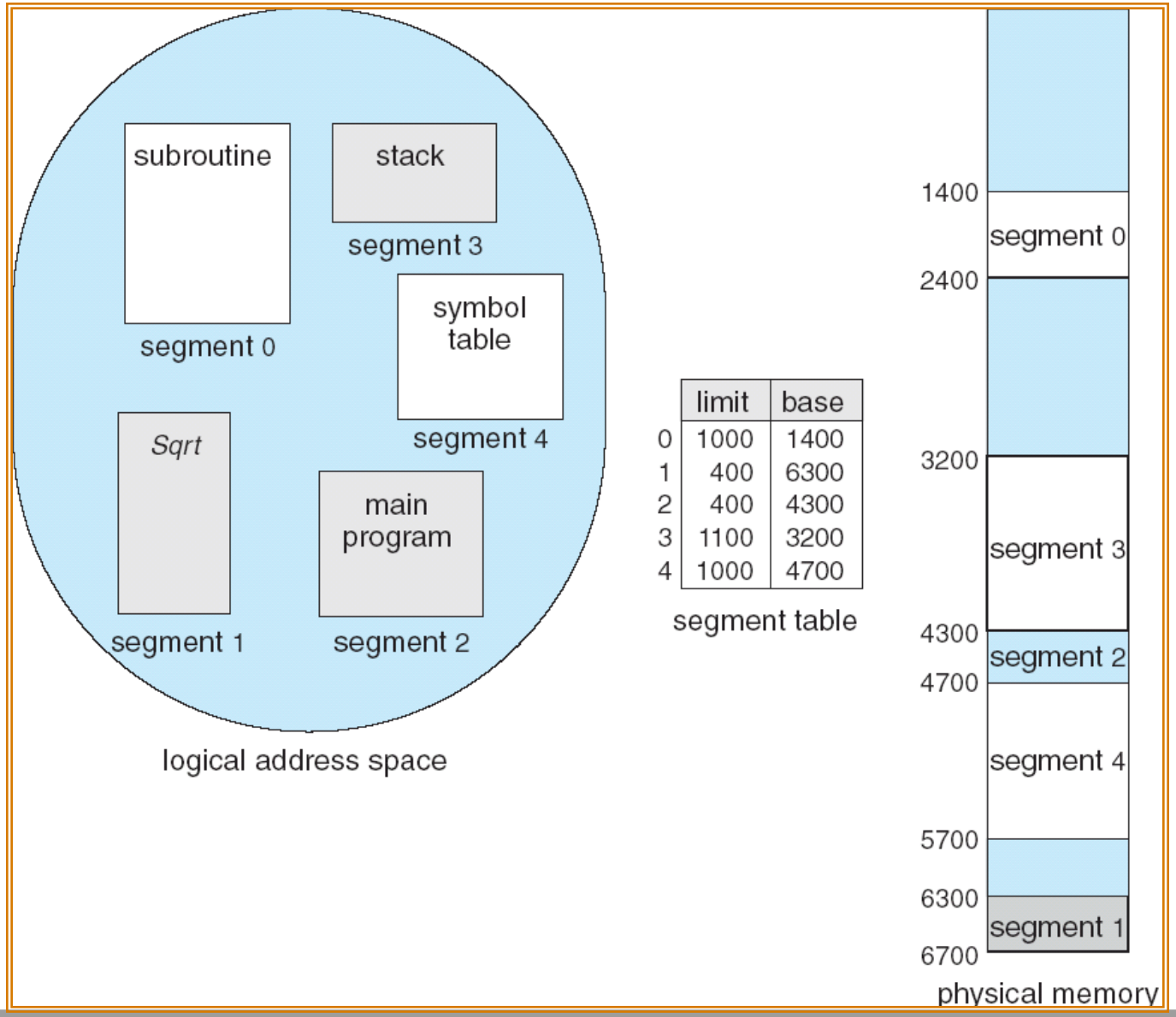
Segmentation Architecture (Cont.)

- Protection. With each entry in segment table associate:
  - validation bit = 0 ⇒ illegal segment
  - read/write/execute privileges
- Protection bits associated with segments; code sharing occurs at segment level
- Since segments vary in length, memory allocation is a dynamic storage-allocation problem
- A segmentation example is shown in the following diagram

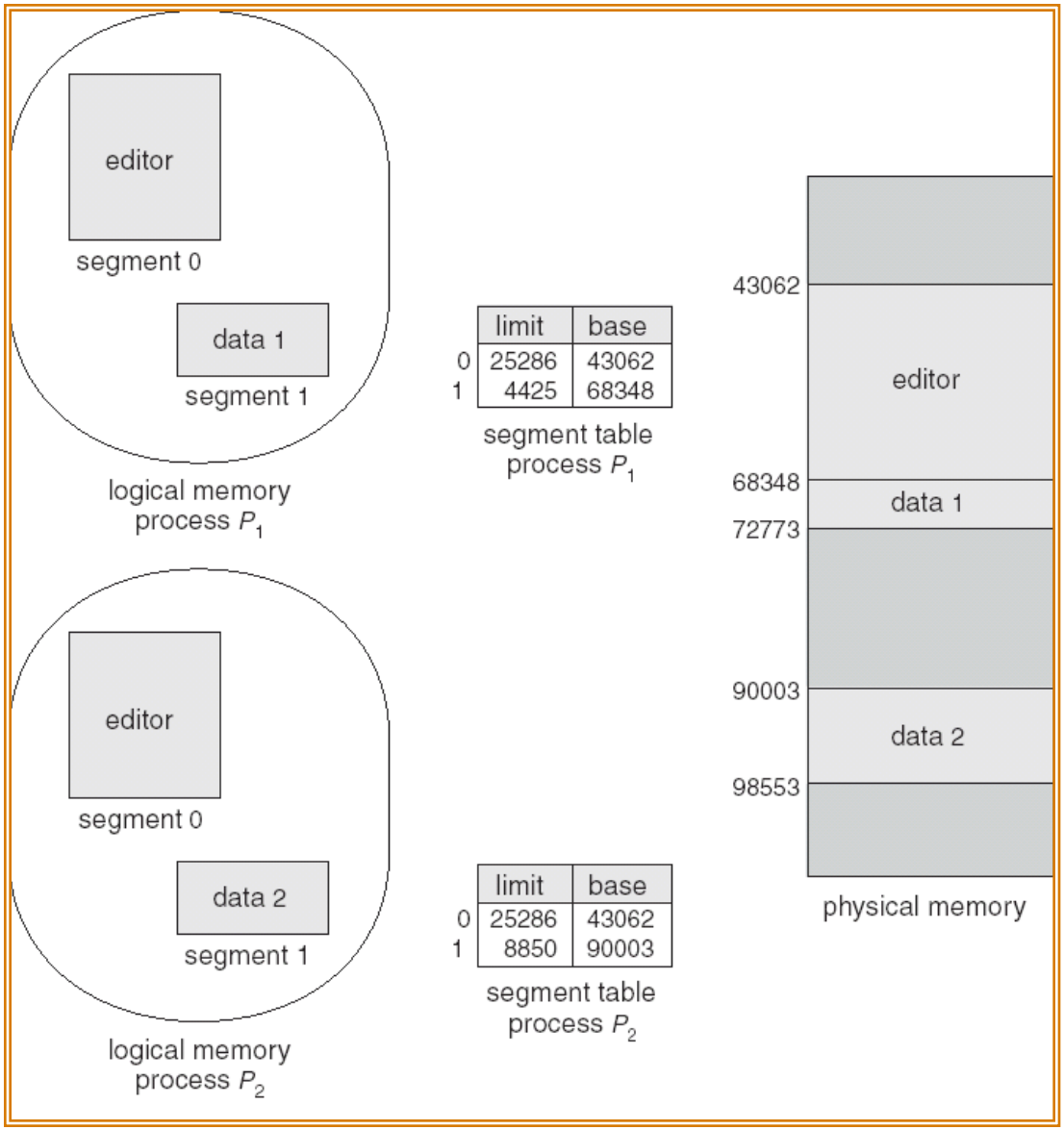
Address Translation Architecture



Example of Segmentation



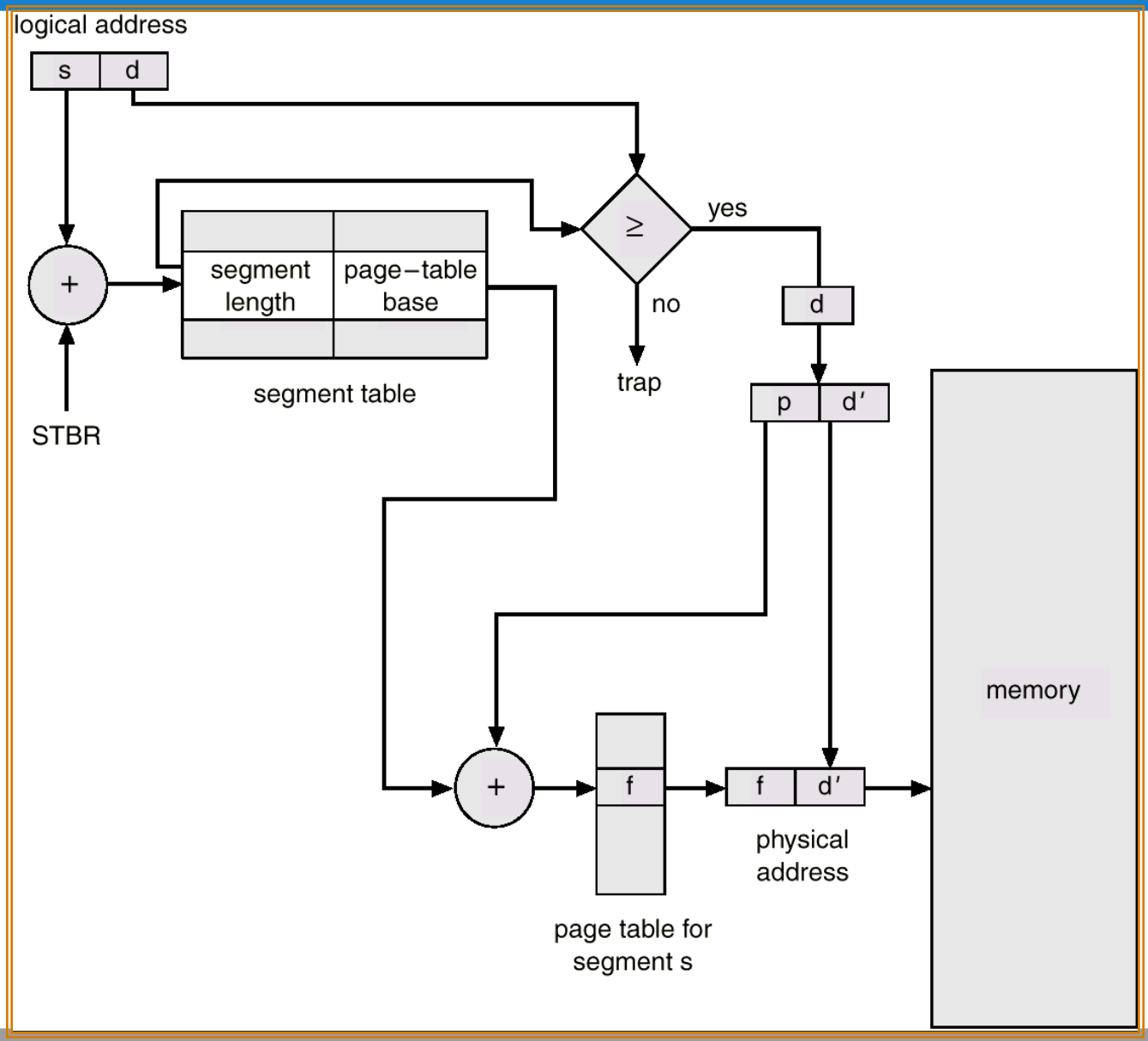
Sharing of Segments



Segmentation with Paging – MULTICS

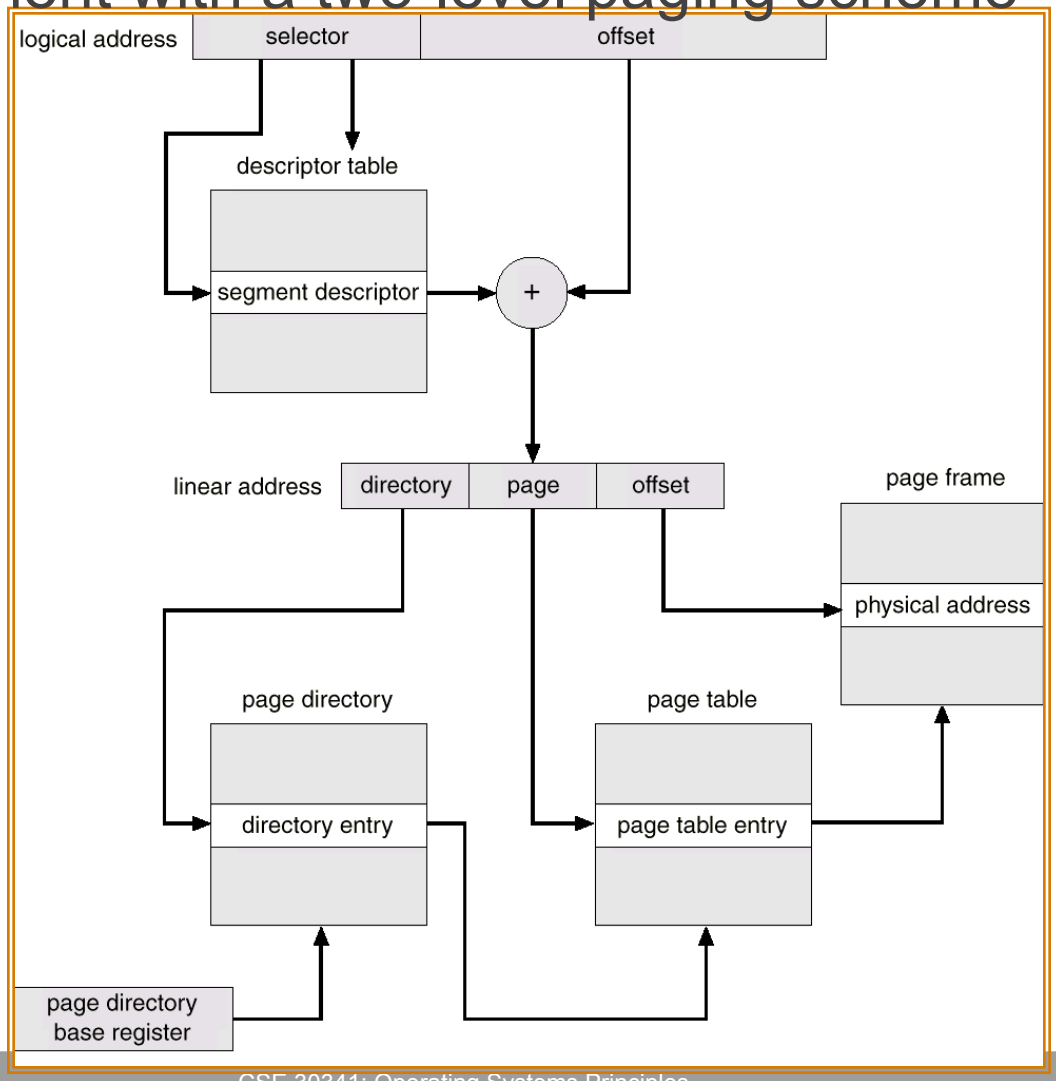
- The MULTICS system solved problems of external fragmentation and lengthy search times by paging the segments
- Solution differs from pure segmentation in that the segment-table entry contains not the base address of the segment, but rather the base address of a page table for this segment

MULTICS Address Translation Scheme



8.7: Intel 30386 Address Translation

- segmentation with paging for memory management with a two-level paging scheme



Linux on Intel 80x86

- Uses minimal segmentation to keep memory management implementation more portable
- Uses 6 segments:
  - Kernel code
  - Kernel data
  - User code (shared by all user processes, using logical addresses)
  - User data (likewise shared)
  - Task-state (per-process hardware context)
  - LDT
- Uses 2 protection levels:
  - Kernel mode
  - User mode

Chapter 9: Virtual memory

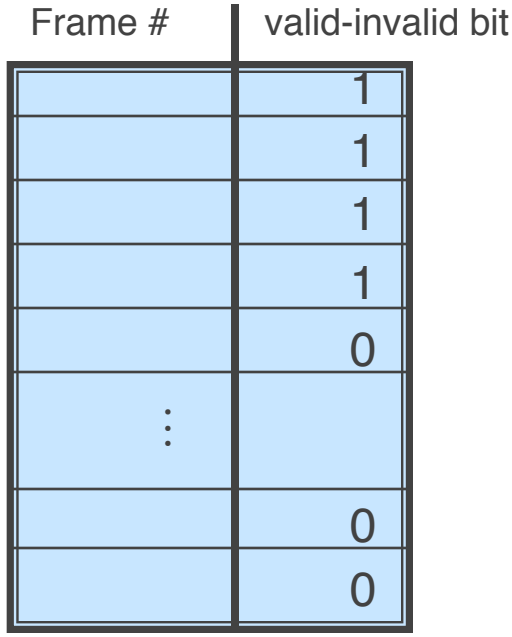
- Virtual memory – separation of user logical memory from physical memory.
  - Only part of the program needs to be in memory for execution.
  - Logical address space can therefore be much larger than physical address space.
  - Allows address spaces to be shared by several processes.
  - Allows for more efficient process creation.
- Virtual memory can be implemented via:
  - Demand paging
  - Demand segmentation

Demand Paging

- Bring a page into memory only when it is needed
  - Less I/O needed if not all pages are needed
  - Less memory needed
  - Faster response
  - More users
- Page is needed ⇒ reference to it
  - invalid reference ⇒ abort
  - not-in-memory ⇒ bring to memory

Valid-Invalid Bit

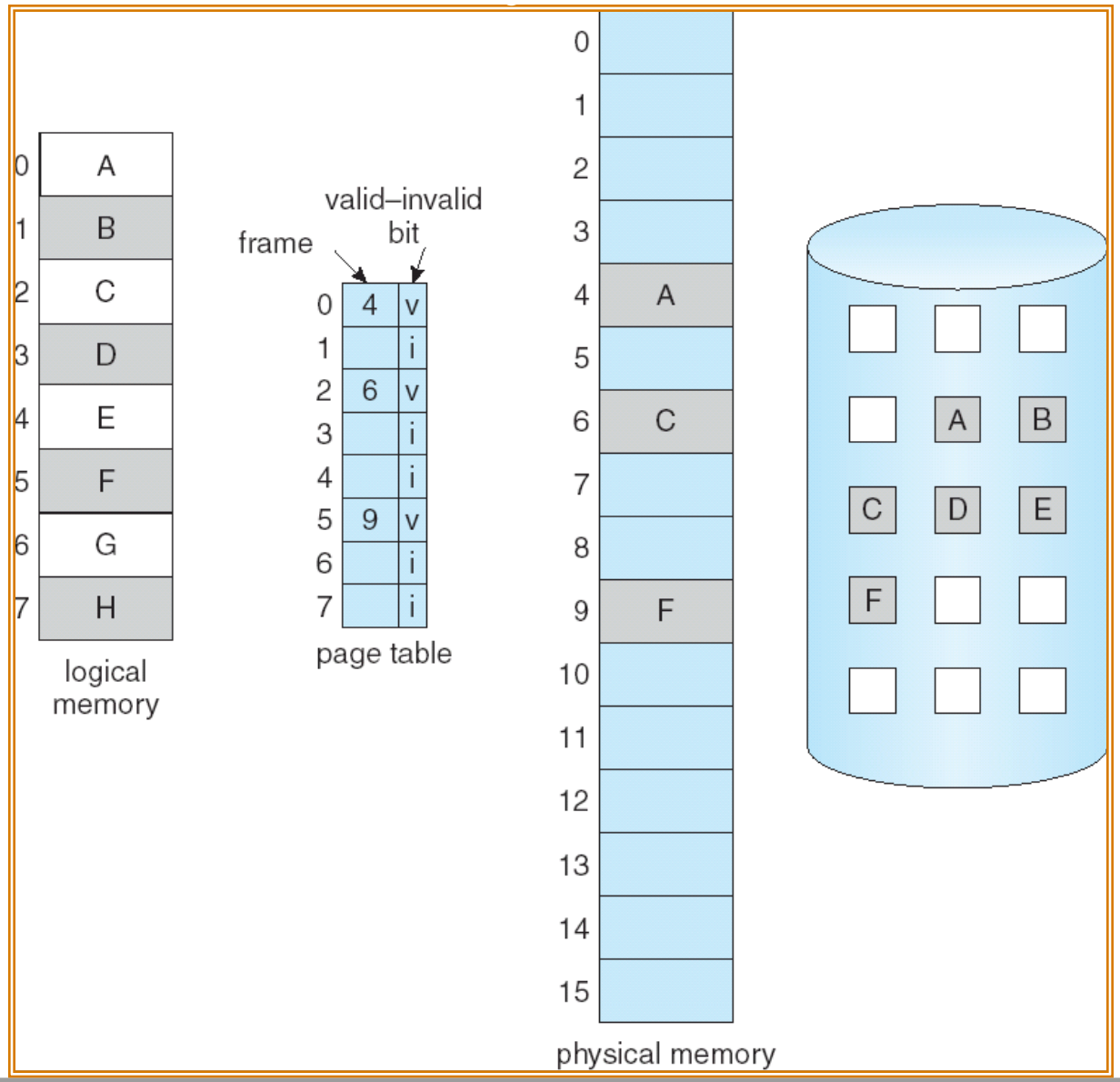
- With each page table entry a valid–invalid bit is associated (1 ⇒ in-memory, 0 ⇒ not-in-memory)
- Initially valid–invalid but is set to 0 on all entries
- Example of a page table snapshot:



page table

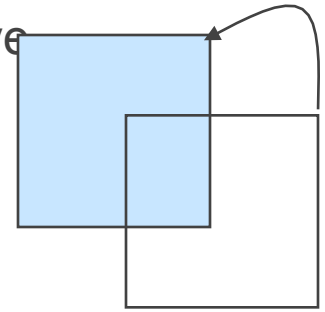
- During address translation, if valid–invalid bit in page table entry is 0 ⇒ page fault

Page Table When Some Pages Are Not in Main Memory



Page Fault

- If there is ever a reference to a page, first reference will trap to OS ⇒ page fault
- OS looks at another table to decide:
  - Invalid reference ⇒ abort.
  - Just not in memory.
- Get empty frame.
- Swap page into frame.
- Reset tables, validation bit = 1.
- Restart instruction: Least Recently Used
  - block move



  - auto increment/decrement location

Steps in Handling a Page Fault