Dynamic Memory Allocation

- Memory Allocation: where?
- Fragmentation
  - external vs. internal
- Implementation Approaches
  - Naïve vs. Buddy System

Dynamic Memory Allocation – when?

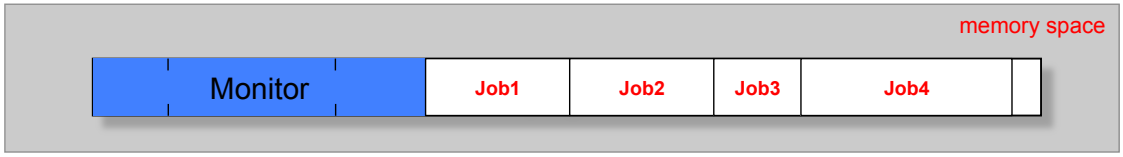
When does new memory get allocated in the kernel?

- New process gets created (fork())
- New program gets loaded into memory (execve())
- Process stack grows
  - What about thread stacks?
- Process expands heap (malloc())
- Process "creates" (attaches to) shared memory segment (shmat())
- Map a file to memory (mmap())

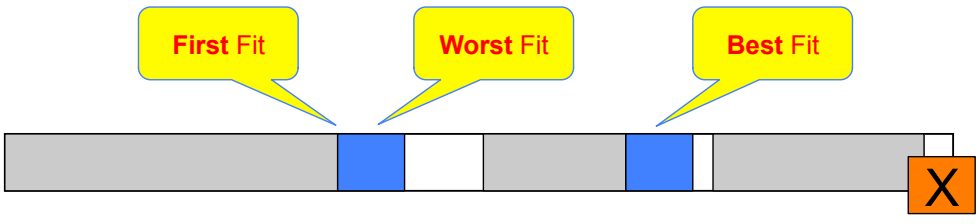
Note: These memory segments "belong to" the user!

For internal memory management OS uses Slab Allocator.

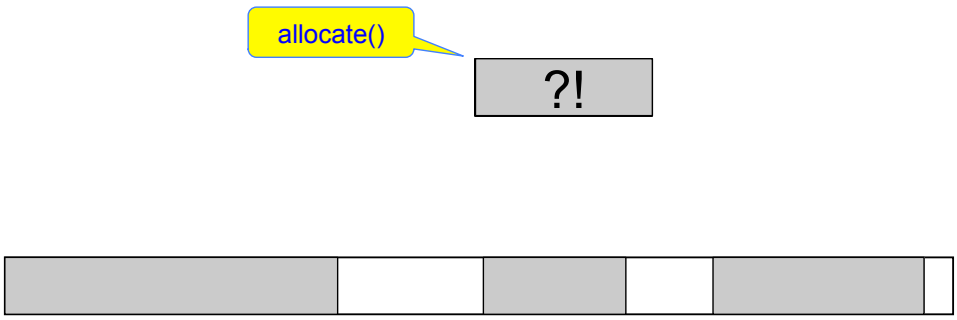
Memory Allocation



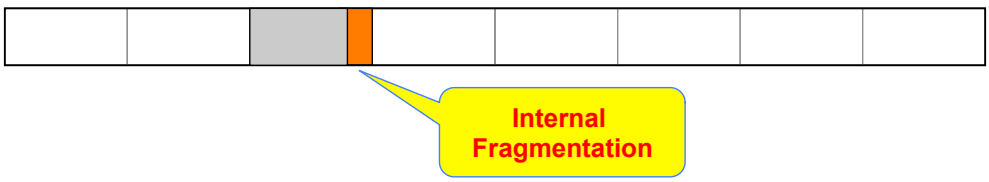
Memory Allocation



(External) Fragmentation

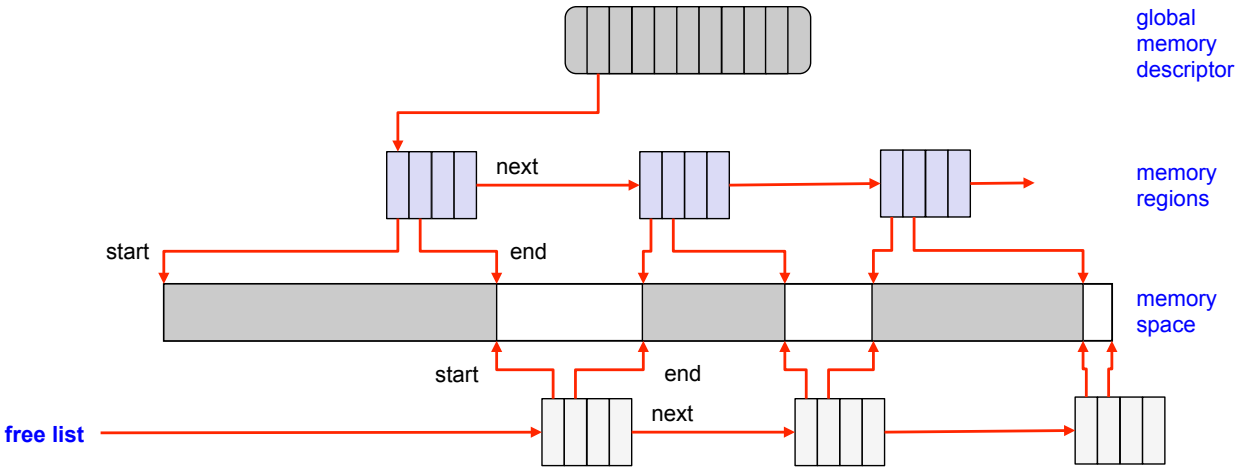


(Internal) Fragmentation



(Internal) Fragmentation

Memory Allocation: Data Structures



(Binary) Buddy System Allocation

Harry Markowitz
1927-
1990 Nobel Memorial Prize in Economics (nobelprize.org)

Maintain multiple free lists, one for each power-of-2 size.

Allocation:
- Increase size of request to next power of 2*.
- Look up segment in free lists.
- If exists, allocate.
- If none exists, split next larger segment in half, put first half (the "buddy") on free list, and return second half.

De-Allocation:
- Return segment to free list.
- Check if buddy is free. If so, coalesce.

References: Donald Knuth: The Art of Computer Programming Volume 1: Fundamental Algorithms. Second Edition (Reading, Massachusetts: Addison-Wesley, 1997), pp. 435-455. ISBN 0-201-89683-4

Allocation at Different Levels

explicit user-level allocation:
- `malloc(size)`
  - allocate virtually contiguous sequence of bytes at user level

user-level library

user level

byte-sized allocations:
- `kmalloc(size, gfp_mask)`
  - allocate physically contiguous sequence of bytes
- `vmalloc(size, gfp_mask)`
  - allocate virtually contiguous sequence of bytes

Slab Allocator (+ caching)

`alloc_pages()` and `__get_free_pages()`
- allocate frames or pages, at low level
- useful to allocate contiguous frames/pages.

Buddy System!

kernel level

Summary: Dynamic Memory Allocation

- Memory Allocation
- Internal and External Fragmentation
- Implementation Approaches
- Free Lists
- Buddy System