Buddy and Slab Allocators

2024 Winter ECE 353: Systems Software
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Lecture 32
2.0.0

The Buddy Allocator Restricts the Problem

Typically, allocation requests are of size 2^n

- e.g. 2, 4, 8, 16, 32, ..., 4096, ...

Restrict allocations to be powers of 2 to enable a more efficient implementation

- Split blocks into 2 until you can handle the request

We want to be able to do fast searching and merging

You Can Implement the Buddy Allocator Using Multiple Lists

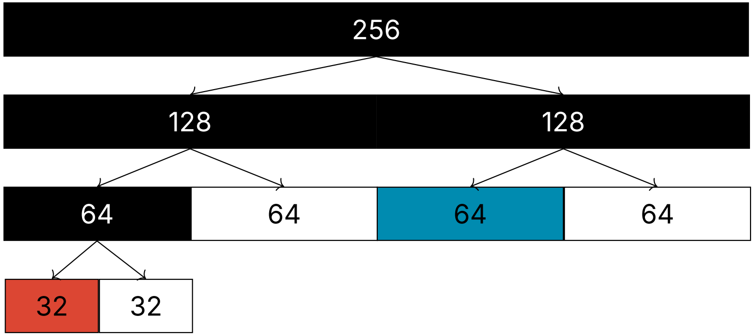
We restrict the requests to be $2^k, 0 \leq k \leq N$ (round up if needed)

Our implementation would use $N + 1$ free lists of blocks for each size

For a request of size 2^k, search the free list until we find a big enough block
- Search $k, k+1, k+2, \ldots$ until we find one
    - Recursively divide the block if needed until it's the correct size
    - Insert "buddy" blocks into free lists

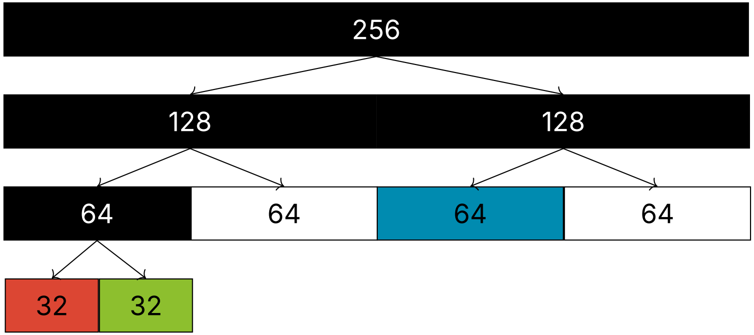
For deallocations, we coalesce the buddy blocks back together
- Recursively coalesce the blocks if needed

Using the Buddy Allocator (1)



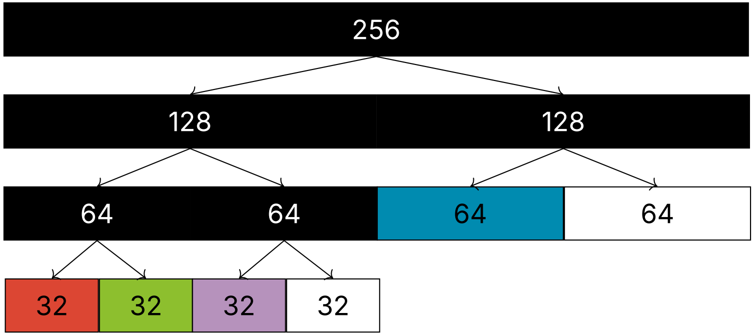
Where do we allocate a request of size 28?

Using the Buddy Allocator (2)



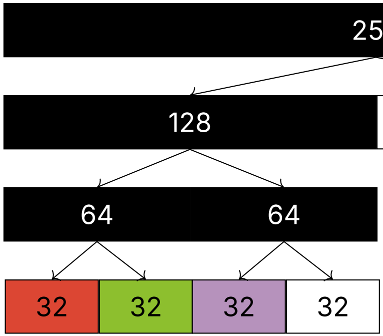
Where do we allocate a request of size 32?

Using the Buddy Allocator (3)



What happens when we free the size 64 block?

Using the Buddy Allocator (4)



Buddy Allocators are Used in Linux

- Advantages
  - Fast and simple compared to general dynamic memory allocation
  - Avoids external fragmentation by keeping free physical pages contiguous
- Disadvantages
  - There’s always internal fragmentation
    - We always round up the allocation size if it’s not a power of 2

Slab Allocators Take Advantage of Fixed Size Allocations

- Allocate objects of same size from a dedicated pool
  - All structures of the same type are the same size
- Every object type has it’s own pool with blocks of the correct size
  - This prevents internal fragmentation

Slab is a Cache of “Slots”

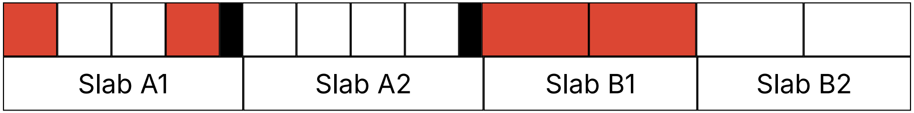
Each allocation size has a corresponding slab of slots
(one slot holds one allocation)

Instead of a linked list, we can use a bitmap
(there’s a mapping between bit and slot)
- For allocations, we set the bit and return the slot
- For deallocations, we just clear the bit

The slab can be implemented on top of the buddy allocator

Each Slab Can Be Allocated using the Buddy Allocator

Consider two object sizes: A and B



We can reduce internal fragmentation if Slabs are located adjacently

- In this example A has internal fragmentation (dark box)

Journaling Filesystem

Deleting a file on a Unix file system involves three steps:

1. Removing its directory entry.
2. Releasing the inode to the pool of free inodes.
3. Returning all disk blocks to the pool of free disk blocks.

Crashes could occur between any steps, leading to a storage leak

The journal contains operations in progress, so if a crash occurs we can recover

Even More Memory Allocations

The kernel restricts the problem for better memory allocation implementations

- Buddy allocator is a real-world restricted implementation
- Slab allocator takes advantage of fixed sized objects to reduce fragmentation