Operating Systems

Free Space Management

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Another solution: use better algorithms to find available memory space

With variable-sized segments, what are the most suitable algorithms to manage free space?

The problem of free-space management

When using segmentation with variable-sized segments

When allocating memory on the heap in user space

- malloc(size) and free(ptr)

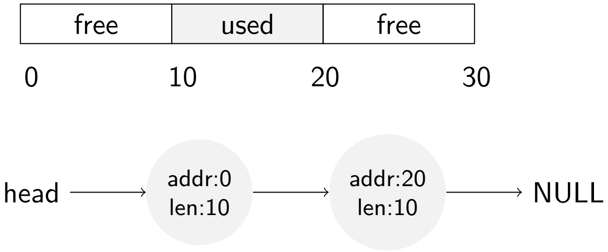
When allocating kernel memory

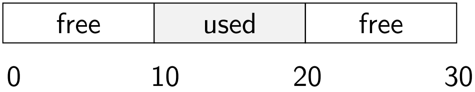
Objective: minimize external fragmentation

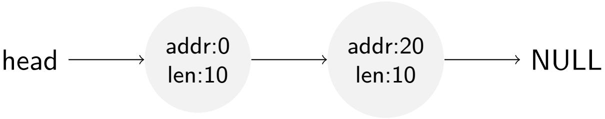
- may introduce internal fragmentation

Basic idea: Use a linked list to manage free chunks of memory

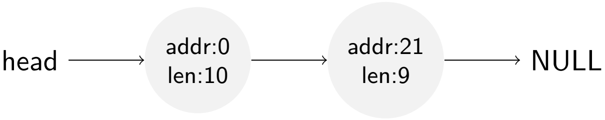
Low-level mechanism: Splitting



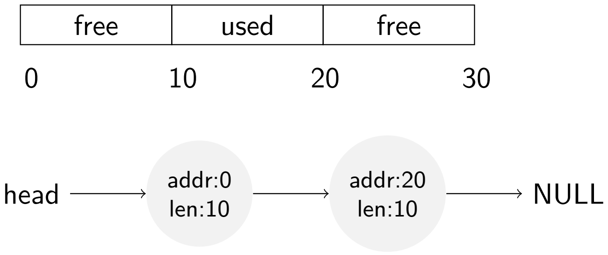




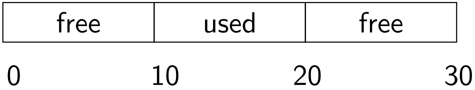
Request: one byte of memory

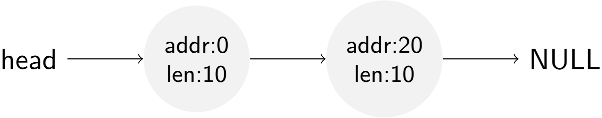


Low-level mechanism: Coalescing

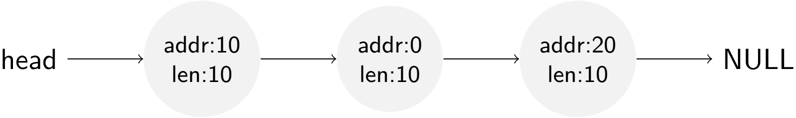


Low-level mechanism: Coalescing

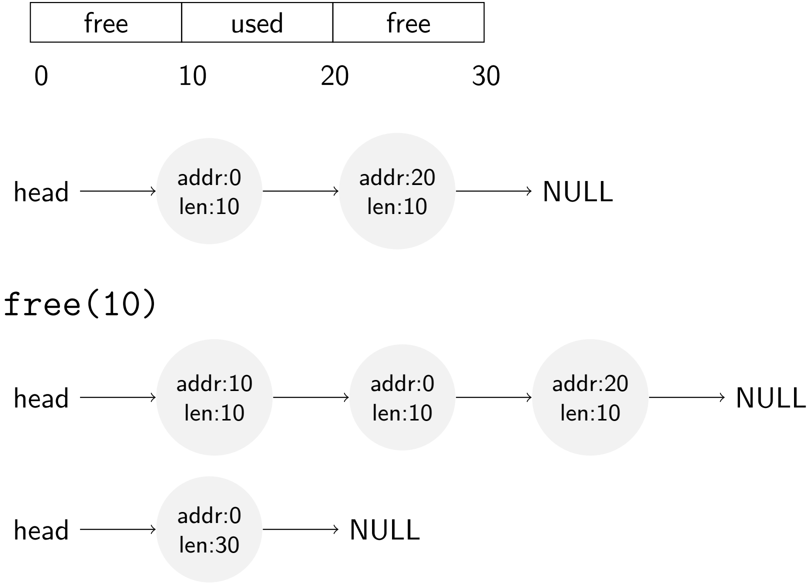




`free(10)`

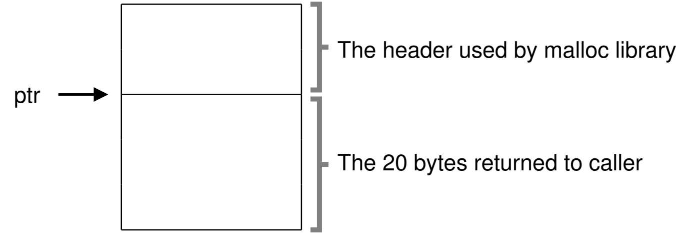


Low-level mechanism: Coalescing

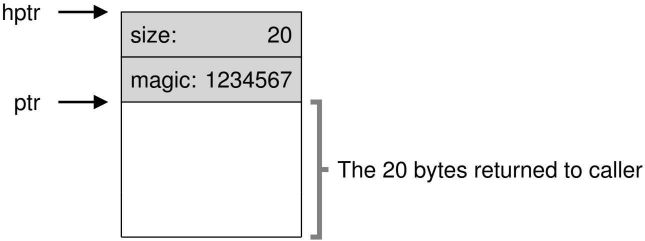


The list which maintains the free blocks also needs main memory, so how do we allcate free space to it?

Heap allocator uses a header to store size etc.

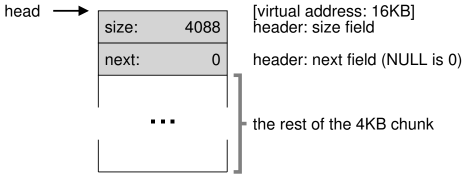


An Allocated Region Plus Header

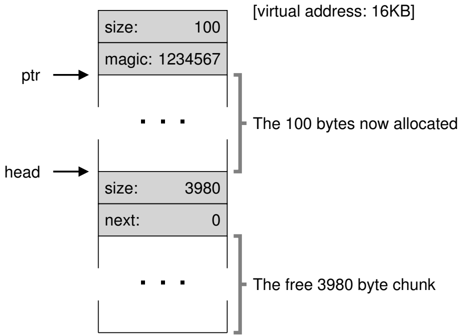


Specific Contents Of The Header

The free list is embedded in the free space

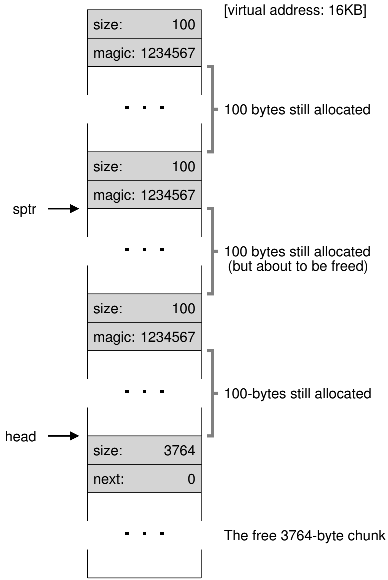


A Heap With One Free Chunk



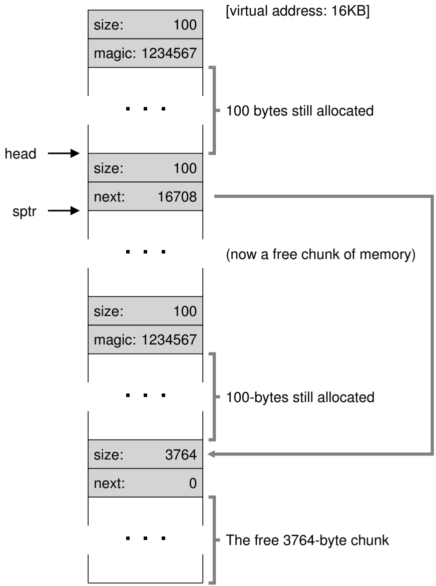
A Heap: After One Allocation

Free space with three chunks allocated



Free Space With Three Chunks Allocated

Free(): From three chunks down to two



Free Space With Two Chunks Allocated

Basic strategies

Search the free list for a hole with size $>=$ requested size

First Fit and Next Fit: Start from the beginning of the list or the current node

- Stop searching as soon as we find a free hole that's big enough

Best Fit: Find the smallest hole that will fit by searching the entire list

- Produces the smallest leftover hole — reduced wasted space

Worst Fit: Find the largest hole by searching the entire list

Simulations have shown: **First Fit** and **Best Fit** are better, but **First Fit** is simpler and faster

How to allocate free space for kernel dynamically?

How to allocate free space for kernel dynamically?

Different from memory allocation for user-mode process

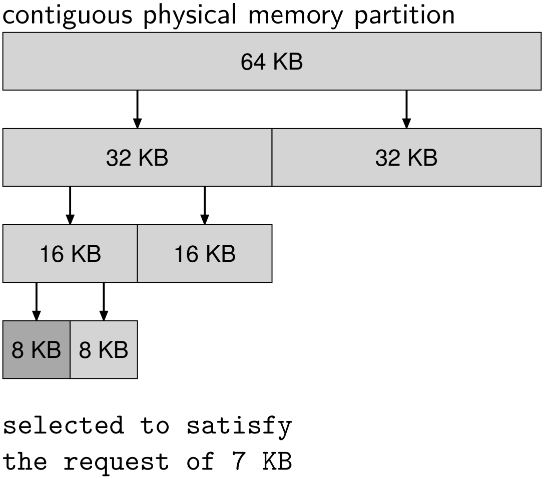
- multiple kernel structrues with different sizes
- contiguous area for device access

A new idea: Buddy Allocation

Buddy Memory Allocation: allocates sizes in powers of 2 (4 KB, 8 KB, 16 KB, etc.)

- requests in odd sizes are satisfied by rounding up to the next power of 2
- every time a request comes in, existing memory will be recursively divided into two "buddies" till the requested size is satisfied with the smallest "buddy"

Example: Request for 7 KB from 64 KB



Advantage of Buddy Memory Allocation

Coalescing —

- When an allocated partition of memory is released, it can be easily coalesced (recursively, if needed) with adjacent free partitions to a partition doubling in size.
- In the example, ultimately we end up with the original 64 KB partition

Drawbacks of Buddy Memory Allocation

If we are unfortunate, there will be a large amount of space wasted within the partition

- This unused space within a partition is **internal fragmentation**
- For example, a 33 KB request will need to be satisfied using a 64 KB partition

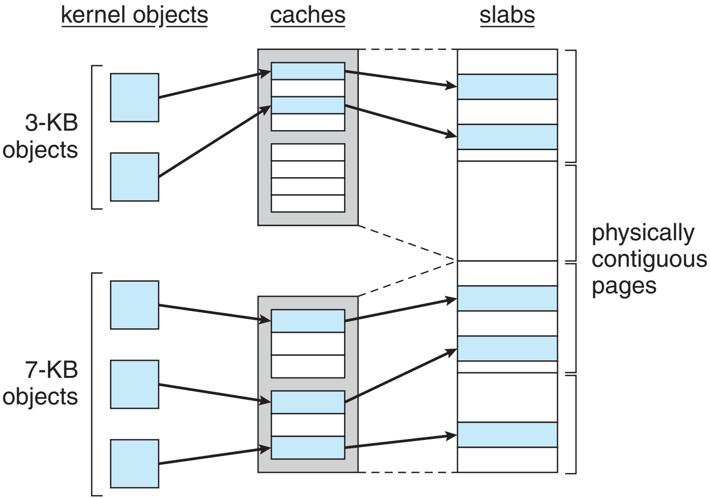
Any ideas that are even better?

Linux 2.0: Buddy memory allocation

Solaris 2.4 and Linux 2.2: **Slab allocation**

- Designed by Jeff Bonwick ("100x" engineer)
- Uses caches/slabs to store kernel objects of **precise** sizes
- An object in a slab can be marked as *free* or *used*
- A slab may be in one of three possible states: full, empty, partial
- The slab allocator first attempts to satisfy the request with a free object in a *partial* slab
- If none exist, a free object is assigned from an *empty* slab
- If no empty slabs are available, a new slab is allocated from physical memory by a general allocator

Slab allocation



Another problem with segmentation: a segment needs to fit into the physical memory