Section 17
Implicit List Heap Allocator

CS 107A, Autumn 2021
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Don’t forget to start recording

Bird's Eye View

Day	Week 9 Monday	Tuesday	Wednesday	Thursday	Friday	Week 10 Monday	Tuesday	Wednesday
CS 107A		Section: Implicit List Heap Allocators		Section: Explicit List Heap Allocators			Section: Beyond CS 107	
CS 107	Lecture: Optimization		Lab: Code and Memory Optimization		Lecture: Additional Topics	Lecture: Wrap-up		No Lab
CS 107 assignments	assign5 due, assign6 out							assign6 due Friday

assign6: Heap Allocator

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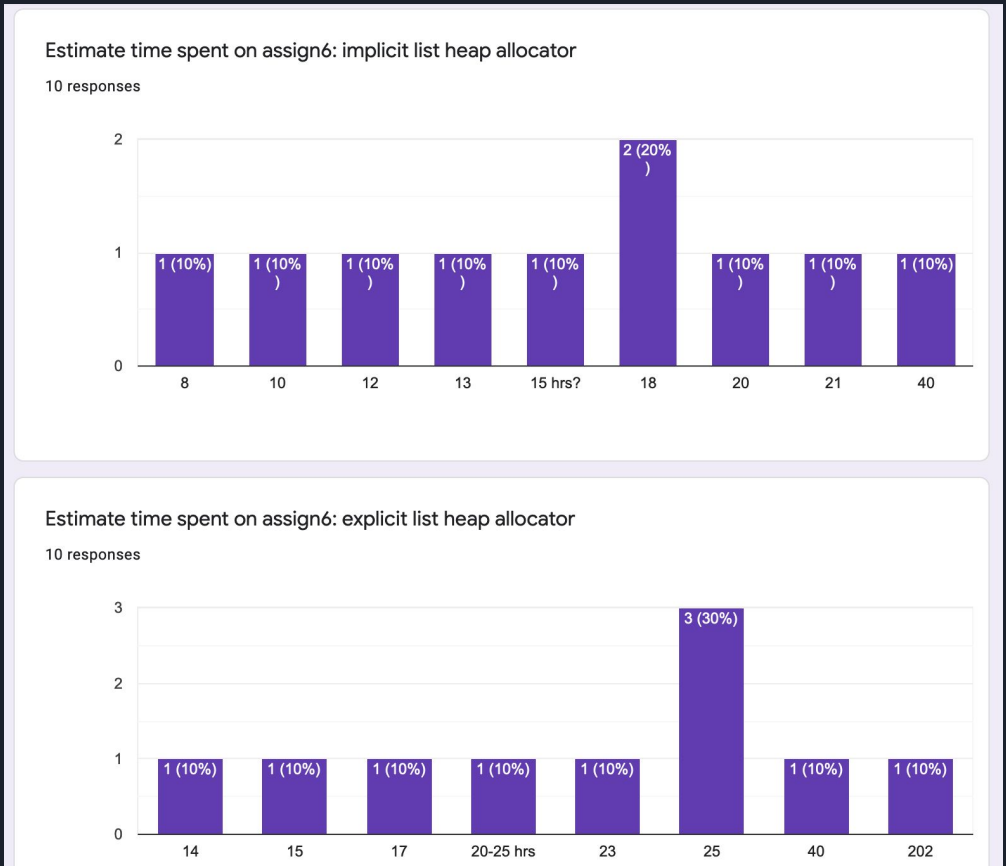


Announcements

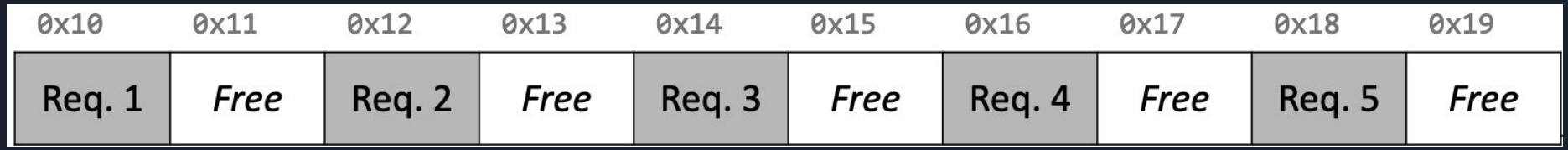
- Feedback on weekend OH
- Please start heap allocator early, it's big
- Heap Allocator Office Hours
  - Friday (?)
  - No OH next week, Slack remains ~asynchronous~
  - Aim to finish implicit heap allocator this week

Agenda

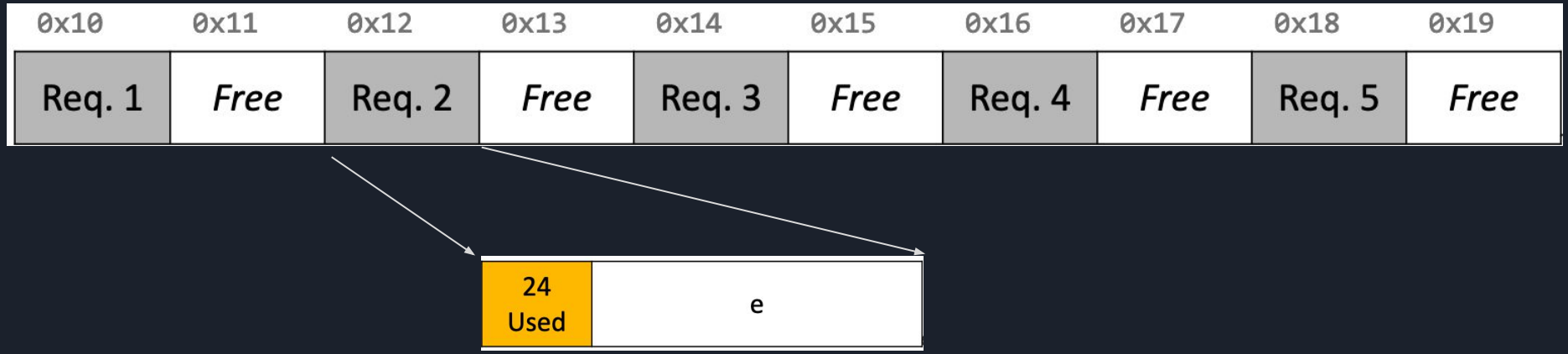
- Implicit List Terminology
- Headers
- Blocks
- Implicit List

Implicit List Terminology

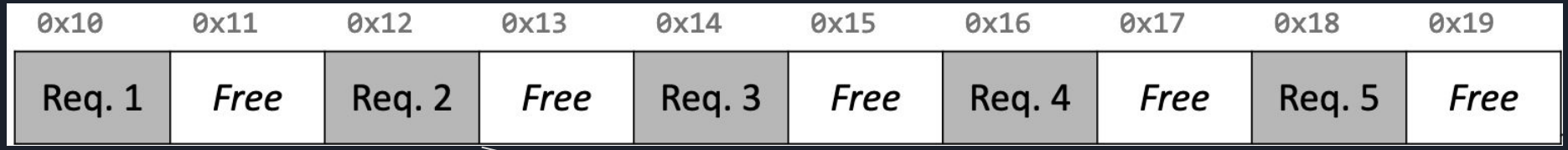
The heap is made up of an implicit list of blocks



Each block consists of a header and a payload

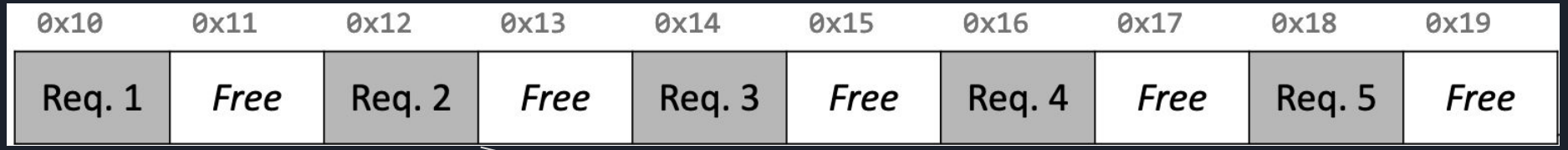


Each header consists of the size and the allocated bit



0bxxxxxxxxx 0bxxxxxxxxx 0bxxxxxxxxx 0bxxxxxxxxx
0bxxxxxxxxx 0bxxxxxxxxx 0bxxxxxxxxx 0bxxxxxx00a

Implicit List operations work at 3 levels



Work within the implicit list

Work within a block

0bxxxxxxxxx 0bxxxxxxxxx 0bxxxxxxxxx 0bxxxxxxxxx
0bxxxxxxxxx 0bxxxxxxxxx 0bxxxxxxxxx 0bxxxxx00a

Work within a header

Headers

Headers

- Required by the handout:
  - 8 bytes, and must be able to hold any size `malloc` takes in
    - So what type should a header be?

Headers

- Required by the handout:
  - 8 bytes, and must be able to hold any size `malloc` takes in
  - `typedef size_t header_t;`

Headers

- Required by the handout:
  - 8 bytes, and must be able to hold any size `malloc` takes in
  - `typedef size_t header_t;`
  - Sizes must be a multiple of 8 (use the `ALIGNMENT` constant)
  - An “allocated bit” must be stored within as well
  - Wait, we have to hold 64 bits for the size, and also 1 bit for whether it’s allocated - do we need 65 bits?

Some size_t numbers that are multiples of 8

0	0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00000000
8	0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00001000
16	0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00010000
24	0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00011000

Some size_t numbers that are multiples of 8

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16	0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00010000
24	0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00000000 0b00011000

Use the LSB as the allocated bit

- Arbitrarily decide that 0 = FREE, 1 = ALLOC (you can reverse this if you like, as long as you always follow the rule!)

25

```
0b00000000 0b00000000 0b00000000 0b00000000
0b00000000 0b00000000 0b00000000 0b00011001
```

- This has an actual value of 25. This value is meaningless.
- We know that when we extract out the size, the LSB should be 0.
- We can extract the actual size by zeroing out the LSB.
- We can extract the allocated bit by reading only the LSB.

24

```
0b00000000 0b00000000 0b00000000 0b00000000
0b00000000 0b00000000 0b00000000 0b00011000
```

1

```
(allocated bit = ALLOC)
```

Header-level Operations

- Write:
  - `bool is_free(header_t *header);` (group)
  - `void set_alloc(header_t *header);` (group)
  - `size_t get_size(header_t *header);` (partner)
- You may assume:
  - `typedef size_t header_t;`
  - the constants `FREE` and `ALLOC` are defined (one of them is 1, the other is 0)

Blocks

Pointers within a Block

header pointer (same as block pointer)

payload pointer (only used to return to user - you will never write to the payload for the implicit list!)

next block pointer

Block-level Operations

- Write:
  - `void *header2payload(header_t *header);` (group)
  - `header_t *payload2header(void *payload);` (partner)
  - `header_t *next_block(header_t *header);` (partner)
  - Is it possible to write `prev_block`?
- You may assume:
  - The existence of the header-level functions we wrote earlier (don't examine the values of headers all over again!)

Implicit List

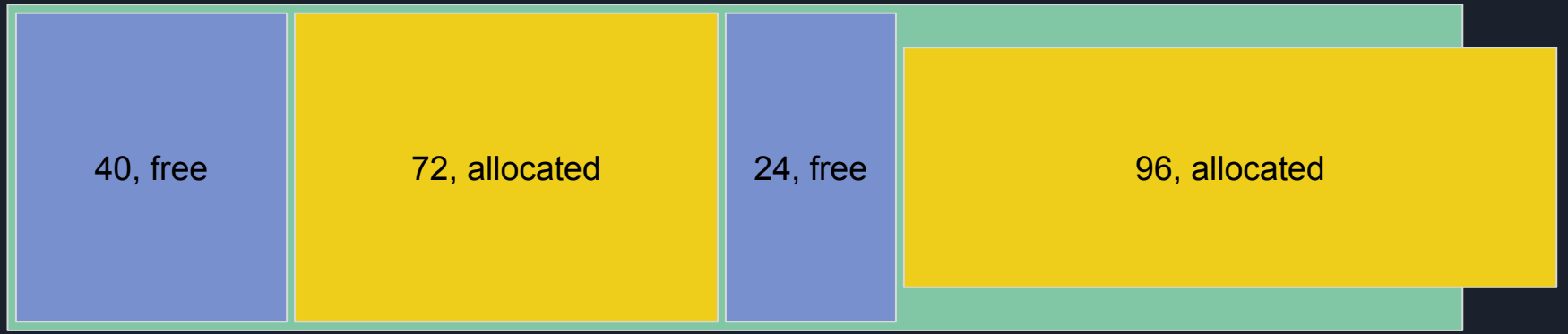
The implicit list must fit the entire heap exactly

Note: at the very beginning, the heap is just one big giant free block

This is after we've done some `mallocs` and `frees`

Overlaps NOT allowed! (header pointer + size must point to next block)

The last block must take up exactly the heap remainder (last block pointer + size must be end of heap)



Don’t treat these slides as a list of validity characteristics, by the way. Sizes must be a multiple of 8, too, for example.

`next_block`, which we already wrote, helps us iterate through blocks

Implicit list-level Operations

- Write:
  - `size_t count_blocks(header_t *start);` (group)
  - `header_t *find_block_of_64(header_t *start);` (group)
- You may assume:
  - The existence of the block-level functions we wrote earlier (don't parse pointers all over again!)