My Malloc Library

Learning Objectives

Upon completion of this assignment, you should be able:

1. Manipulate C pointers to traverse a process' address space
2. Use pointer arithmetic to adjust pointer references
3. Use casting to dereference memory storage as different types
4. Manually adjust the process heap

New mechanisms you will see and use include:

- C: enum, type casting, pointer arithmetic, fprintf(), stdout, stderr
- system calls: sbrk()

Function Specifications

NAME

```
my_malloc(), my_free(),coalesce_freelist(), free_list_begin()
```

SYNOPSIS

```
#include "my_malloc.h"

void * my_malloc(size_t size);
void my_free(void *ptr);

void coalesce_free_list(void);
FreeListNode * free_list_begin( void );

typedef struct freelistnode {
    struct freelistnode *flink;
    size_t size;
} * FreeListNode;
```

DESCRIPTION

my_malloc()
: allocates `size` bytes of memory

my_free()
: deallocates memory allocation pointed to by `ptr`, previously allocated by my_malloc().

coalesce_free_list()
: merges adjacent chunks on the free list into single larger chunks.

free_list_begin()
: retrieves the first node of the free list

RETURN VALUES AND ERRORS

On success, `my_malloc()` returns an 8-byte aligned pointer to the allocated memory.
On failure, `my_malloc()` returns `NULL` and sets `myerrno` to `MYENOMEM`.

`my_free()` returns nothing.
On failure, when called with a non-malloc'd pointer, `my_free()` sets `myerrno` to `MYEBADFREEPTR`.

`free_list_begin()` returns a pointer to the first free list node or NULL if the free list is empty.

Implementation Details

Memory Allocation

We refer to the entire memory block of memory used to satisfy an allocation request as the "chunk" – the chunk will be bigger than the extent of memory we expect the user to access. The *minimum chunk size* should be the size of the struct freelistnode plus any padding needed to make the chunk size a multiple of 8.

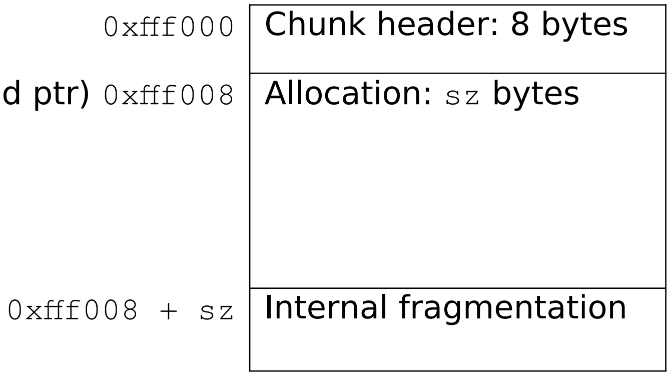
Chunks

Allocated chunks returned by `my_malloc()` will be inflated by:

1. chunk header: 8 bytes
2. internal fragmentation:
    a. any padding necessary to make the chunk size a multiple of 8
    b. potential wastage from using an oversized chunk

Chunk header

Use the 8 bytes just before the address returned by `my_malloc()` for your bookkeeping chunk header. Use the first four bytes for the total chunk size (including header and padding) and the second 4-bytes to designate that the chunk was allocated by `my_malloc()`.



An Example Allocated Chunk

Allocating a chunk

`my_malloc()` first searches the free list for a usable chunk. If no usable chunk is found, call `sbrk()`[1] to extend the heap segment. `my_malloc()` returns a pointer referencing 8 bytes into the chunk, i.e. after the chunk header.

Chunk splitting

Oversized chunks (i.e. larger than needed for the request) must be split into two unless the remainder would be smaller than the *minimum chunk size*. In the former case, the remainder should be added to the free list. In the latter case, `my_malloc()` will return an oversized chunk that suffers small internal fragmentation.

Memory Deallocation

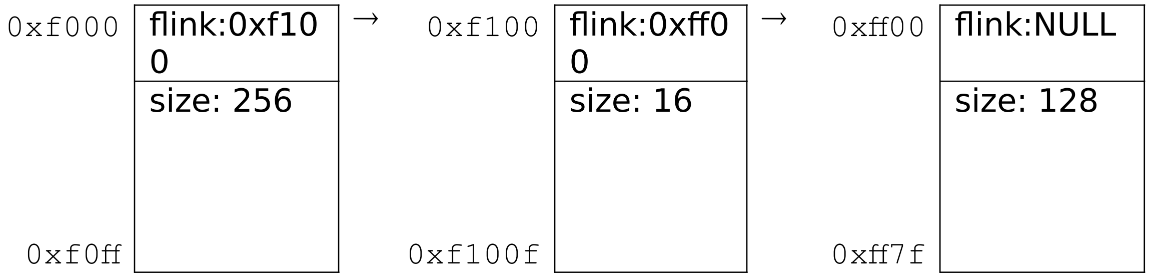
`my_free()` places freed or deallocated chunks of memory onto a free list.

Free List Management

Use `struct freelistnode` in `my_malloc.h` to implement a singly-linked free list to manage free chunks. To add a chunk to the free list, embed a `struct freelistnode` at the beginning of the very same memory chunk[2]. If `ptr` is the address of the chunk:

```
    FreeListNode node;
    node = (FreeListNode)ptr;
```

Then properly set `node->size` and `node->flink` and insert `node` into the free list. `flink` should be NULL for the last node in the list.



Example Free List

Chunk coalescing

Chunk coalescing is only done when `coalesce_free_list()` is called explicitly:

`my_free()` does not coalesce adjacent memory chunks during or after chunk insertion!

[1] For this exercise, we use the simpler yet deprecated sbrk() not the more complex, POSIX-compliant mmap.

[2] This is why minimum chunk size must be the size of struct freelistnode.

Requirements and Constraints

1. You may use no static variables and **one** global variable for the first free list node.
2. Always call sbrk(8192)[3] except if `my_malloc()` requests more than 8,192 bytes, then call `sbrk()` with the minimum size needed to accommodate the chunk.
3. Assume that other library routines also may make calls to sbrk().
4. Besides sbrk(), you may not use **any** other library or system calls.
5. You may not use more than 8 bookkeeping bytes.
6. Your free list should always be sorted in ascending order by chunk address.
7. Use a *first fit* strategy to search the free list, i.e. return the first usable chunk found.

Submission

FOLLOW THESE INSTRUCTIONS PRECISELY

Requisite files:

- Sources: `my_malloc.c` and any auxiliary files needed to implement the functions in `my_malloc.h`
- README: you may submit an optional README file with comments, feedback, known issues, etc.

Place your completed files in your cs551/lab1 directory.

my_malloc.h

```
//the size of the header for heap allocated memory chunks
#define CHUNKHEADERSIZE 8

//error signaling
typedef enum {MYNOERROR, MYENOMEM, MYBADFREEPTR } MyErrorNo;
MyErrorNo myerrno=MYNOERROR;

//my_malloc: returns a pointer to a chunk of heap allocated memory
void *my_malloc(size_t size);

//my_free: reclaims the previously allocated chunk referenced by ptr
void my_free(void *ptr);

//struct freelistnode: node for linked list of 'free' chunks
typedef struct freelistnode {
   struct freelistnode *flink; //pointer to next free chunk node
   size_t size; //size of current chunk
} * FreeListNode;

//free_list_begin(): returns pointer to first chunk in free list
FreeListNode free_list_begin(void);

//coalesce_free_list(): merge adjacent chunks on the free list
```

[3] You may call `sbrk(0)` to identify the heap’s current end.

```
void coalesce_free_list(void);
```