CS342 Operating Systems

Project 3

Experiments Report

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Section-2

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Section-1

Introduction

Before starting to code our library and its functions, we researched how we can access the data of our allocated segment with mmap() and manipulate that data. We learned that we need to access and manipulate data by using bitwise operators and for initialization, allocation and freeing, we need to use these operators in different and specific methods. After deciding on these methods, we started to code the functions of the library. We double-checked every function after we wrote it and at the end, we tested them with basic and complex test cases, including threads.

Computer Specifications

We performed experiments on a laptop with Windows 10 Home, Intel i7-9750H CPU @ 2.60GHz with 4.2GHz Turbo and 16,0 GB of RAM.

We used Oracle VirtualBox VM to run the code on virtual machine with Ubuntu 20.04. I reserved 5 CPU cores and 10725MB's of RAM for the virtual machine. In the machine, we used Linux terminal to compile and run the code and VS Code to write the code.

Experiments

Other than the functionality and thread tests, we conducted 2 types of experiments: Constant allocation sizes and variable segment size, constant segment size and variable allocation sizes. For both allocating and freeing, we measured the time passed. For the latter type, we created random allocation sizes and used them in various test cases.

A) Constant allocation size, variable segment size

Segment Size: 2^{16}, Allocation sizes: 2000, 5000, 10000, 20000, 50000

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
2000 byte alloc'd in microseconds:3
bitmap after allocation

A, 0x00007f0c3f12e000, 0x400 (1024)
A, 0x00007f0c3f12e080, 0x100 (256)
A, 0x00007f0c3f12e0a0, 0x7d0 (2000)
F, 0x00007f0c3f12e19a, 0xf330 (62256)

2000 byte freed in microseconds: 1
bitmap after free operation

A, 0x00007f0c3f12e000, 0x400 (1024)
A, 0x00007f0c3f12e080, 0x100 (256)
F, 0x00007f0c3f12e0a0, 0xfb00 (64256)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
5000 byte alloc'd in microseconds:4
bitmap after allocation

A, 0x00007fe195632000, 0x400 (1024)
A, 0x00007fe195632080, 0x100 (256)
A, 0x00007fe1956320a0, 0x1390 (5008)
F, 0x00007fe195632312, 0xe770 (59248)

5000 byte freed in microseconds: 2
bitmap after free operation

A, 0x00007fe195632000, 0x400 (1024)
A, 0x00007fe195632080, 0x100 (256)
F, 0x00007fe1956320a0, 0xfb00 (64256)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
10000 byte alloc'd in microseconds:6
bitmap after allocation

A, 0x00007f38ee47c000, 0x400 (1024)
A, 0x00007f38ee47c080, 0x100 (256)
A, 0x00007f38ee47c0a0, 0x2710 (10000)
F, 0x00007f38ee47c582, 0xd3f0 (54256)

10000 byte freed in microseconds: 3
bitmap after free operation

A, 0x00007f38ee47c000, 0x400 (1024)
A, 0x00007f38ee47c080, 0x100 (256)
F, 0x00007f38ee47c0a0, 0xfb00 (64256)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
20000 byte alloc'd in microseconds:9
bitmap after allocation

A, 0x00007f1d6de76000, 0x400 (1024)
A, 0x00007f1d6de76080, 0x100 (256)
A, 0x00007f1d6de760a0, 0x4e20 (20000)
F, 0x00007f1d6de76a64, 0xace0 (44256)

20000 byte freed in microseconds: 6
bitmap after free operation

A, 0x00007f1d6de76000, 0x400 (1024)
A, 0x00007f1d6de76080, 0x100 (256)
F, 0x00007f1d6de760a0, 0xfb00 (64256)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
50000 byte alloc'd in microseconds:18
bitmap after allocation

A, 0x00007f4fda48c000, 0x400 (1024)
A, 0x00007f4fda48c080, 0x100 (256)
A, 0x00007f4fda48c0a0, 0xc350 (50000)
F, 0x00007f4fda48d90a, 0x37b0 (14256)

50000 byte freed in microseconds: 15
bitmap after free operation

A, 0x00007f4fda48c000, 0x400 (1024)
A, 0x00007f4fda48c080, 0x100 (256)
F, 0x00007f4fda48c0a0, 0xfb00 (64256)
```

Segment Size: 2^{17}, Allocation sizes: 2000, 5000, 10000, 20000, 50000

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
2000 byte alloc'd in microseconds:4
bitmap after allocation

A, 0x00007f48f5905000, 0x800 (2048)
A, 0x00007f48f5905100, 0x100 (256)
A, 0x00007f48f5905120, 0x7d0 (2000)
F, 0x00007f48f590521a, 0x1ef30 (126768)

2000 byte freed in microseconds: 1
bitmap after free operation

A, 0x00007f48f5905000, 0x800 (2048)
A, 0x00007f48f5905100, 0x100 (256)
F, 0x00007f48f5905120, 0x1f700 (128768)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
5000 byte alloc'd in microseconds:5
bitmap after allocation

A, 0x00007f2987e15000, 0x800 (2048)
A, 0x00007f2987e15100, 0x100 (256)
A, 0x00007f2987e15120, 0x1390 (5008)
F, 0x00007f2987e15392, 0x1e370 (123760)

5000 byte freed in microseconds: 2
bitmap after free operation

A, 0x00007f2987e15000, 0x800 (2048)
A, 0x00007f2987e15100, 0x100 (256)
F, 0x00007f2987e15120, 0x1f700 (128768)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
10000 byte alloc'd in microseconds:6
bitmap after allocation

A, 0x00007fd130c9f000, 0x800 (2048)
A, 0x00007fd130c9f100, 0x100 (256)
A, 0x00007fd130c9f120, 0x2710 (10000)
F, 0x00007fd130c9f602, 0x1cff0 (118768)

10000 byte freed in microseconds: 3
bitmap after free operation

A, 0x00007fd130c9f000, 0x800 (2048)
A, 0x00007fd130c9f100, 0x100 (256)
F, 0x00007fd130c9f120, 0x1f700 (128768)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
20000 byte alloc'd in microseconds:9
bitmap after allocation

A, 0x00007fda135f2000, 0x800 (2048)
A, 0x00007fda135f2100, 0x100 (256)
A, 0x00007fda135f2120, 0x4e20 (20000)
F, 0x00007fda135f2ae4, 0x1a8e0 (108768)

20000 byte freed in microseconds: 6
bitmap after free operation

A, 0x00007fda135f2000, 0x800 (2048)
A, 0x00007fda135f2100, 0x100 (256)
F, 0x00007fda135f2120, 0x1f700 (128768)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
50000 byte alloc'd in microseconds:19
bitmap after allocation

A, 0x00007fac21ded000, 0x800 (2048)
A, 0x00007fac21ded100, 0x100 (256)
A, 0x00007fac21ded120, 0xc350 (50000)
F, 0x00007fac21dee98a, 0x133b0 (78768)

50000 byte freed in microseconds: 15
bitmap after free operation

A, 0x00007fac21ded000, 0x800 (2048)
A, 0x00007fac21ded100, 0x100 (256)
F, 0x00007fac21ded120, 0x1f700 (128768)
```

Segment Size: 2^{18}, Allocation sizes: 2000, 5000, 10000, 20000, 50000

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
2000 byte alloc'd in microseconds:4
bitmap after allocation

A, 0x00007fb0433ad000, 0x1000 (4096)
A, 0x00007fb0433ad200, 0x100 (256)
A, 0x00007fb0433ad220, 0x7d0 (2000)
F, 0x00007fb0433ad31a, 0x3e730 (255792)

2000 byte freed in microseconds: 1
bitmap after free operation

A, 0x00007fb0433ad000, 0x1000 (4096)
A, 0x00007fb0433ad200, 0x100 (256)
F, 0x00007fb0433ad220, 0x3ef00 (257792)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
5000 byte alloc'd in microseconds:5
bitmap after allocation

A, 0x00007fdce3b6d000, 0x1000 (4096)
A, 0x00007fdce3b6d200, 0x100 (256)
A, 0x00007fdce3b6d220, 0x1390 (5008)
F, 0x00007fdce3b6d492, 0x3db70 (252784)

5000 byte freed in microseconds: 2
bitmap after free operation

A, 0x00007fdce3b6d000, 0x1000 (4096)
A, 0x00007fdce3b6d200, 0x100 (256)
F, 0x00007fdce3b6d220, 0x3ef00 (257792)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
10000 byte alloc'd in microseconds:7
bitmap after allocation

A, 0x00007ff116735000, 0x1000 (4096)
A, 0x00007ff116735200, 0x100 (256)
A, 0x00007ff116735220, 0x2710 (10000)
F, 0x00007ff116735702, 0x3c7f0 (247792)

10000 byte freed in microseconds: 3
bitmap after free operation

A, 0x00007ff116735000, 0x1000 (4096)
A, 0x00007ff116735200, 0x100 (256)
F, 0x00007ff116735220, 0x3ef00 (257792)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
20000 byte alloc'd in microseconds:9
bitmap after allocation

A, 0x00007f1504276000, 0x1000 (4096)
A, 0x00007f1504276200, 0x100 (256)
A, 0x00007f1504276220, 0x4e20 (20000)
F, 0x00007f1504276be4, 0x3a0e0 (237792)

20000 byte freed in microseconds: 6
bitmap after free operation

A, 0x00007f1504276000, 0x1000 (4096)
A, 0x00007f1504276200, 0x100 (256)
F, 0x00007f1504276220, 0x3ef00 (257792)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
50000 byte alloc'd in microseconds:19
bitmap after allocation

A, 0x00007fe81c5bc000, 0x1000 (4096)
A, 0x00007fe81c5bc200, 0x100 (256)
A, 0x00007fe81c5bc220, 0xc350 (50000)
F, 0x00007fe81c5bda8a, 0x32bb0 (207792)

50000 byte freed in microseconds: 15
bitmap after free operation

A, 0x00007fe81c5bc000, 0x1000 (4096)
A, 0x00007fe81c5bc200, 0x100 (256)
F, 0x00007fe81c5bc220, 0x3ef00 (257792)
```

Segment Size: 2^{19}, Allocation sizes: 2000, 5000, 10000, 20000, 50000

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
2000 byte alloc'd in microseconds:5
bitmap after allocation

A, 0x00007f9c214aa000, 0x2000 (8192)
A, 0x00007f9c214aa400, 0x100 (256)
A, 0x00007f9c214aa420, 0x7d0 (2000)
F, 0x00007f9c214aa51a, 0x7d730 (513840)

2000 byte freed in microseconds: 1
bitmap after free operation

A, 0x00007f9c214aa000, 0x2000 (8192)
A, 0x00007f9c214aa400, 0x100 (256)
F, 0x00007f9c214aa420, 0x7df00 (515840)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
5000 byte alloc'd in microseconds:6
bitmap after allocation

A, 0x00007f4fb3c56000, 0x2000 (8192)
A, 0x00007f4fb3c56400, 0x100 (256)
A, 0x00007f4fb3c56420, 0x1390 (5008)
F, 0x00007f4fb3c56692, 0x7cb70 (510832)

5000 byte freed in microseconds: 2
bitmap after free operation

A, 0x00007f4fb3c56000, 0x2000 (8192)
A, 0x00007f4fb3c56400, 0x100 (256)
F, 0x00007f4fb3c56420, 0x7df00 (515840)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
10000 byte alloc'd in microseconds:7
bitmap after allocation

A, 0x00007f559f1b5000, 0x2000 (8192)
A, 0x00007f559f1b5400, 0x100 (256)
A, 0x00007f559f1b5420, 0x2710 (10000)
F, 0x00007f559f1b5902, 0x7b7f0 (505840)

10000 byte freed in microseconds: 3
bitmap after free operation

A, 0x00007f559f1b5000, 0x2000 (8192)
A, 0x00007f559f1b5400, 0x100 (256)
F, 0x00007f559f1b5420, 0x7df00 (515840)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
20000 byte alloc'd in microseconds:10
bitmap after allocation

A, 0x00007f5d84db4000, 0x2000 (8192)
A, 0x00007f5d84db4400, 0x100 (256)
A, 0x00007f5d84db4420, 0x4e20 (20000)
F, 0x00007f5d84db4de4, 0x790e0 (495840)

20000 byte freed in microseconds: 6
bitmap after free operation

A, 0x00007f5d84db4000, 0x2000 (8192)
A, 0x00007f5d84db4400, 0x100 (256)
F, 0x00007f5d84db4420, 0x7df00 (515840)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
50000 byte alloc'd in microseconds:40
bitmap after allocation

A, 0x00007fc687c7e000, 0x2000 (8192)
A, 0x00007fc687c7e400, 0x100 (256)
A, 0x00007fc687c7e420, 0xc350 (50000)
F, 0x00007fc687c7fc8a, 0x71bb0 (465840)

50000 byte freed in microseconds: 18
bitmap after free operation

A, 0x00007fc687c7e000, 0x2000 (8192)
A, 0x00007fc687c7e400, 0x100 (256)
F, 0x00007fc687c7e420, 0x7df00 (515840)
```

Segment Size: 2^{20}, Allocation sizes: 2000, 5000, 10000, 20000, 50000

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
2000 byte alloc'd in microseconds:5
bitmap after allocation

A, 0x00007efd223da000, 0x4000 (16384)
A, 0x00007efd223da800, 0x100 (256)
A, 0x00007efd223da820, 0x7d0 (2000)
F, 0x00007efd223da91a, 0xfb730 (1029936)

2000 byte freed in microseconds: 1
bitmap after free operation

A, 0x00007efd223da000, 0x4000 (16384)
A, 0x00007efd223da800, 0x100 (256)
F, 0x00007efd223da820, 0xfbf00 (1031936)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
5000 byte alloc'd in microseconds:6
bitmap after allocation

A, 0x00007fc669faa000, 0x4000 (16384)
A, 0x00007fc669faa800, 0x100 (256)
A, 0x00007fc669faa820, 0x1390 (5008)
F, 0x00007fc669faaa92, 0xfab70 (1026928)

5000 byte freed in microseconds: 1
bitmap after free operation

A, 0x00007fc669faa000, 0x4000 (16384)
A, 0x00007fc669faa800, 0x100 (256)
F, 0x00007fc669faa820, 0xfbf00 (1031936)
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
10000 byte alloc'd in microseconds:8
bitmap after allocation

A, 0x00007ff993c78000, 0x4000 (16384)
A, 0x00007ff993c78800, 0x100 (256)
A, 0x00007ff993c78820, 0x2710 (10000)
F, 0x00007ff993c78d02, 0xf97f0 (1021936)

10000 byte freed in microseconds: 3
bitmap after free operation

A, 0x00007ff993c78000, 0x4000 (16384)
A, 0x00007ff993c78800, 0x100 (256)
F, 0x00007ff993c78820, 0xfbf00 (1031936)
```

```
20000 byte alloc'd in microseconds:11
bitmap after allocation

A, 0x00007fbe1f568000, 0x4000 (16384)
A, 0x00007fbe1f568800, 0x100 (256)
A, 0x00007fbe1f568820, 0x4e20 (20000)
F, 0x00007fbe1f5691e4, 0xf70e0 (1011936)

20000 byte freed in microseconds: 6
bitmap after free operation

A, 0x00007fbe1f568000, 0x4000 (16384)
A, 0x00007fbe1f568800, 0x100 (256)
F, 0x00007fbe1f568820, 0xfbf00 (1031936)
```

```
50000 byte alloc'd in microseconds:20
bitmap after allocation

A, 0x00007f00a1f25000, 0x4000 (16384)
A, 0x00007f00a1f25800, 0x100 (256)
A, 0x00007f00a1f25820, 0xc350 (50000)
F, 0x00007f00a1f2708a, 0xefbb0 (981936)

50000 byte freed in microseconds: 15
bitmap after free operation

A, 0x00007f00a1f25000, 0x4000 (16384)
A, 0x00007f00a1f25800, 0x100 (256)
F, 0x00007f00a1f25820, 0xfbf00 (1031936)
```

B) Constant segment size, variable allocation size

5 random allocation between 5000 and 15000

Segment size is 64KB

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
sum of total size desired to be allocated : 47832
8540 byte allocation request successfully done
13612 byte allocation request successfully done
10141 byte allocation request successfully done
6431 byte allocation request successfully done
9108 byte allocation request successfully done

total allocaton time of 5 random amounts between 5000 and 15000 bytes in microseconds: 52
blocks after allocation:
A, 0x00007ff4811ec000, 0x400 (1024)
A, 0x00007ff4811ec080, 0x100 (256)
A, 0x00007ff4811ec0a0, 0x2160 (8544)
A, 0x00007ff4811ec4cc, 0x3530 (13616)
A, 0x00007ff4811ecb72, 0x27a0 (10144)
A, 0x00007ff4811ed066, 0x1920 (6432)
A, 0x00007ff4811ed38a, 0x23a0 (9120)
F, 0x00007ff4811ed7fe, 0x4010 (16400)
internal fragmentation amount: 24
All allocations are free in microseconds: 15
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
sum of total size desired to be allocated : 50962
12738 byte allocation request successfully done
8887 byte allocation request successfully done
13784 byte allocation request successfully done
9925 byte allocation request successfully done
5628 byte allocation request successfully done

total allocaton time of 5 random amounts between 5000 and 15000 bytes in microseconds: 60
blocks after allocation:
A, 0x00007fe8bfbca000, 0x400 (1024)
A, 0x00007fe8bfbca080, 0x100 (256)
A, 0x00007fe8bfbca0a0, 0x31d0 (12752)
A, 0x00007fe8bfbca6da, 0x22c0 (8896)
A, 0x00007fe8bfbcab32, 0x35e0 (13792)
A, 0x00007fe8bfbcb1ee, 0x26d0 (9936)
A, 0x00007fe8bfbcb6c8, 0x1600 (5632)
F, 0x00007fe8bfbcb988, 0x33c0 (13248)
internal fragmentation amount: 46
All allocations are free in microseconds: 16
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
sum of total size desired to be allocated : 52956
8623 byte allocation request successfully done
10715 byte allocation request successfully done
12505 byte allocation request successfully done
14036 byte allocation request successfully done
7077 byte allocation request successfully done

total allocaton time of 5 random amounts between 5000 and 15000 bytes in microseconds: 71
blocks after allocation:
A, 0x00007f5bba4de000, 0x400 (1024)
A, 0x00007f5bba4de080, 0x100 (256)
A, 0x00007f5bba4de0a0, 0x21b0 (8624)
A, 0x00007f5bba4de4d6, 0x29e0 (10720)
A, 0x00007f5bba4dea12, 0x30e0 (12512)
A, 0x00007f5bba4df02e, 0x36e0 (14048)
A, 0x00007f5bba4df70a, 0x1bb0 (7088)
F, 0x00007f5bba4dfa80, 0x2c00 (11264)
internal fragmentation amount: 36
All allocations are free in microseconds: 17
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
sum of total size desired to be allocated : 43094
8851 byte allocation request successfully done
10151 byte allocation request successfully done
6783 byte allocation request successfully done
9040 byte allocation request successfully done
8269 byte allocation request successfully done

total allocaton time of 5 random amounts between 5000 and 15000 bytes in microseconds: 47
blocks after allocation:
A, 0x00007fac70794000, 0x400 (1024)
A, 0x00007fac70794080, 0x100 (256)
A, 0x00007fac707940a0, 0x22a0 (8864)
A, 0x00007fac707944f4, 0x27b0 (10160)
A, 0x00007fac707949ea, 0x1a80 (6784)
A, 0x00007fac70794d3a, 0x2350 (9040)
A, 0x00007fac707951a4, 0x2050 (8272)
F, 0x00007fac707955ae, 0x5290 (21136)
internal fragmentation amount: 26
All allocations are free in microseconds: 13
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
sum of total size desired to be allocated : 39627
9244 byte allocation request successfully done
5653 byte allocation request successfully done
7217 byte allocation request successfully done
7117 byte allocation request successfully done
10396 byte allocation request successfully done

total allocaton time of 5 random amounts between 5000 and 15000 bytes in microseconds: 47
blocks after allocation:
A, 0x00007f0e79936000, 0x400 (1024)
A, 0x00007f0e79936080, 0x100 (256)
A, 0x00007f0e799360a0, 0x2420 (9248)
A, 0x00007f0e79936524, 0x1620 (5664)
A, 0x00007f0e799367e8, 0x1c40 (7232)
A, 0x00007f0e79936b70, 0x1bd0 (7120)
A, 0x00007f0e79936eea, 0x28a0 (10400)
F, 0x00007f0e799373fe, 0x6010 (24592)
internal fragmentation amount: 37
All allocations are free in microseconds: 12
```

First 5 random allocation performed, 2 of them are freed, 2 new random allocation performed and all of them are freed.

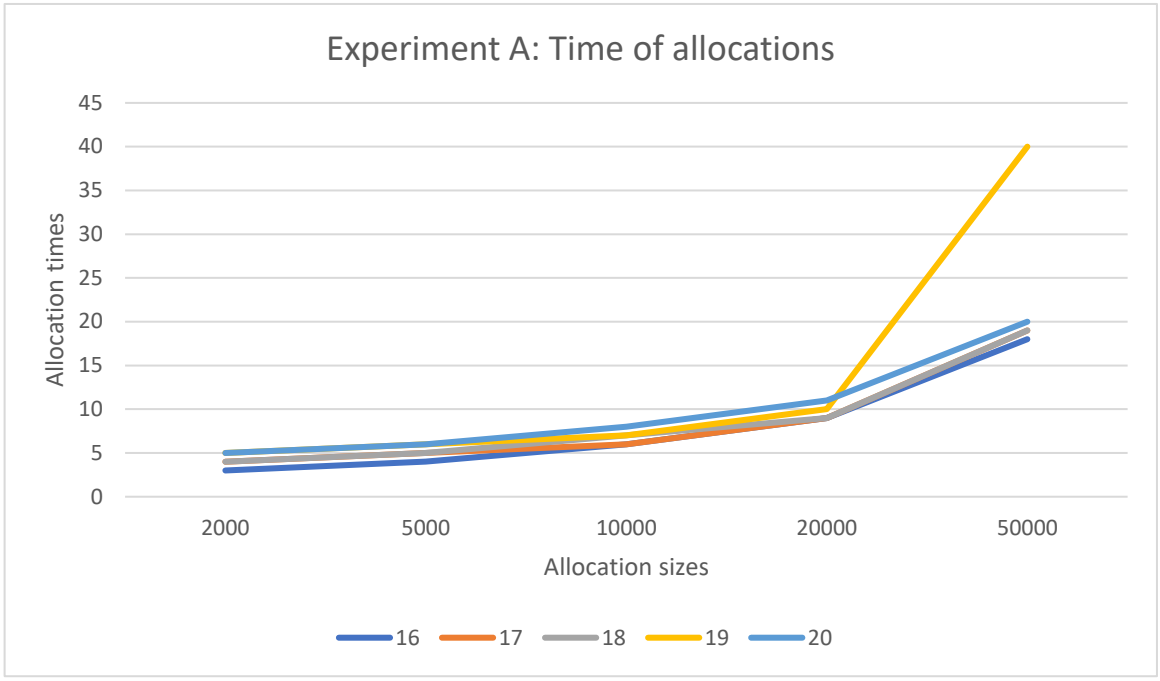
```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
sum of total size desired to be allocated : 55200
6963 byte allocation request successfully done
12693 byte allocation request successfully done
14253 byte allocation request successfully done
13003 byte allocation request successfully done
8288 byte allocation request successfully done
total allocaton time of 5 random amounts between 5000 and 15000 bytes in microseconds: 57
blocks after allocation:
A, 0x00007f159dc88000, 0x400 (1024)
A, 0x00007f159dc88080, 0x100 (256)
A, 0x00007f159dc880a0, 0x1b40 (6976)
A, 0x00007f159dc88408, 0x31a0 (12704)
A, 0x00007f159dc88a3c, 0x37b0 (14256)
A, 0x00007f159dc89132, 0x32d0 (13008)
A, 0x00007f159dc8978c, 0x2060 (8288)
F, 0x00007f159dc89b98, 0x2340 (9024)
internal fragmentation amount: 32
p2 and p4 are freed in microseconds: 8
blocks after freeing p2 and p4:
A, 0x00007f159dc88000, 0x400 (1024)
A, 0x00007f159dc88080, 0x100 (256)
A, 0x00007f159dc880a0, 0x1b40 (6976)
F, 0x00007f159dc88408, 0x31a0 (12704)
A, 0x00007f159dc88a3c, 0x37b0 (14256)
F, 0x00007f159dc89132, 0x32d0 (13008)
A, 0x00007f159dc8978c, 0x2060 (8288)
F, 0x00007f159dc89b98, 0x2340 (9024)
12102 byte allocation request successfully done
5433 byte allocation request successfully done
total reallocaton time of 2 new random amounts between 5000 and 15000 bytes for p2 and p4 in microseconds: 14
blocks after reallocation of p2 and p4:
A, 0x00007f159dc88000, 0x400 (1024)
A, 0x00007f159dc88080, 0x100 (256)
A, 0x00007f159dc880a0, 0x1b40 (6976)
A, 0x00007f159dc88408, 0x2f50 (12112)
F, 0x00007f159dc889f2, 0x250 (592)
A, 0x00007f159dc88a3c, 0x37b0 (14256)
A, 0x00007f159dc89132, 0x1540 (5440)
F, 0x00007f159dc893da, 0x1d90 (7568)
A, 0x00007f159dc8978c, 0x2060 (8288)
F, 0x00007f159dc89b98, 0x2340 (9024)
All allocations are freed in microseconds: 14
blocks after freeing:
A, 0x00007f159dc88000, 0x400 (1024)
A, 0x00007f159dc88080, 0x100 (256)
F, 0x00007f159dc880a0, 0xfb00 (64256)
internal fragmentation amount after reallocation and freeing: 49
```

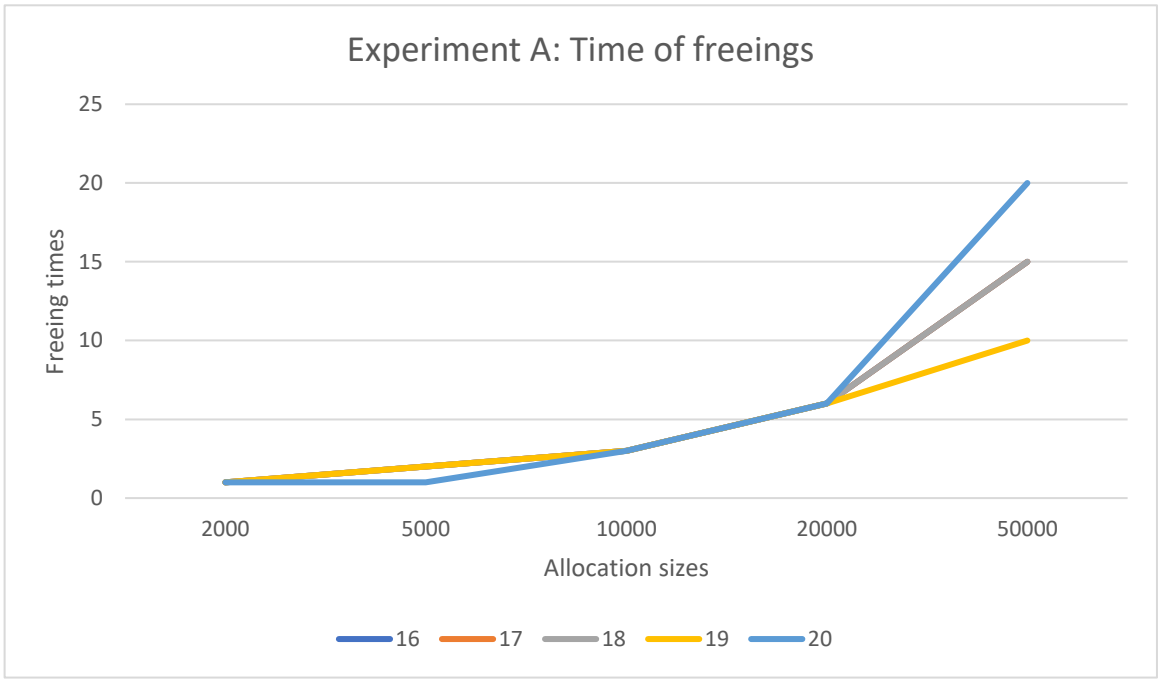
```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
sum of total size desired to be allocated : 46004
7338 byte allocation request successfully done
10780 byte allocation request successfully done
5244 byte allocation request successfully done
13679 byte allocation request successfully done
8963 byte allocation request successfully done
total allocaton time of 5 random amounts between 5000 and 15000 bytes in microseconds: 51
blocks after allocation:
A, 0x00007f0f401bf000, 0x400 (1024)
A, 0x00007f0f401bf080, 0x100 (256)
A, 0x00007f0f401bf0a0, 0x1cb0 (7344)
A, 0x00007f0f401bf436, 0x2a20 (10784)
A, 0x00007f0f401bf97a, 0x1480 (5248)
A, 0x00007f0f401bfc0a, 0x3570 (13680)
A, 0x00007f0f401c02b8, 0x2310 (8976)
F, 0x00007f0f401c071a, 0x4730 (18224)
internal fragmentation amount: 28
p2 and p4 are freed in microseconds: 7
blocks after freeing p2 and p4:
A, 0x00007f0f401bf000, 0x400 (1024)
A, 0x00007f0f401bf080, 0x100 (256)
A, 0x00007f0f401bf0a0, 0x1cb0 (7344)
F, 0x00007f0f401bf436, 0x2a20 (10784)
A, 0x00007f0f401bf97a, 0x1480 (5248)
F, 0x00007f0f401bfc0a, 0x3570 (13680)
A, 0x00007f0f401c02b8, 0x2310 (8976)
F, 0x00007f0f401c071a, 0x4730 (18224)
9347 byte allocation request successfully done
12730 byte allocation request successfully done
total reallocaton time of 2 new random amounts between 5000 and 15000 bytes for p2 and p4 in microseconds: 14
blocks after reallocation of p2 and p4:
A, 0x00007f0f401bf000, 0x400 (1024)
A, 0x00007f0f401bf080, 0x100 (256)
A, 0x00007f0f401bf0a0, 0x1cb0 (7344)
A, 0x00007f0f401bf436, 0x2490 (9360)
F, 0x00007f0f401bf8c8, 0x590 (1424)
A, 0x00007f0f401bf97a, 0x1480 (5248)
A, 0x00007f0f401bfc0a, 0x31c0 (12736)
F, 0x00007f0f401c0242, 0x3b0 (944)
A, 0x00007f0f401c02b8, 0x2310 (8976)
F, 0x00007f0f401c071a, 0x4730 (18224)
All allocations are freed in microseconds: 13
blocks after freeing:
A, 0x00007f0f401bf000, 0x400 (1024)
A, 0x00007f0f401bf080, 0x100 (256)
F, 0x00007f0f401bf0a0, 0xfb00 (64256)
internal fragmentation amount after reallocation and freeing: 47
```

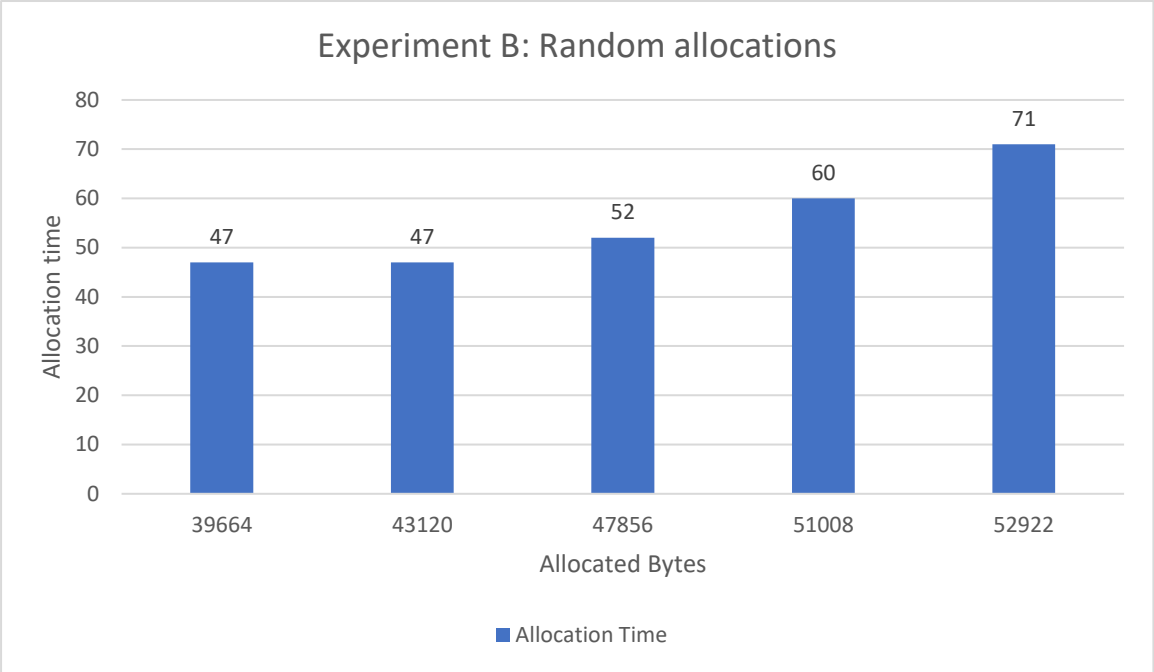
```
sum of total size desired to be allocated : 54405
13171 byte allocation request successfully done
9632 byte allocation request successfully done
9371 byte allocation request successfully done
8637 byte allocation request successfully done
13594 byte allocation request successfully done
total allocaton time of 5 random amounts between 5000 and 15000 bytes in microseconds: 56
blocks after allocation:
A, 0x00007f9d3c7c7000, 0x400 (1024)
A, 0x00007f9d3c7c7080, 0x100 (256)
A, 0x00007f9d3c7c70a0, 0x3380 (13184)
A, 0x00007f9d3c7c7710, 0x25a0 (9632)
A, 0x00007f9d3c7c7bc4, 0x24a0 (9376)
A, 0x00007f9d3c7c8058, 0x21c0 (8640)
A, 0x00007f9d3c7c8490, 0x3520 (13600)
F, 0x00007f9d3c7c8b34, 0x2660 (9824)
internal fragmentation amount: 27
p2 and p4 are freed in microseconds: 6
blocks after freeing p2 and p4:
A, 0x00007f9d3c7c7000, 0x400 (1024)
A, 0x00007f9d3c7c7080, 0x100 (256)
A, 0x00007f9d3c7c70a0, 0x3380 (13184)
F, 0x00007f9d3c7c7710, 0x25a0 (9632)
A, 0x00007f9d3c7c7bc4, 0x24a0 (9376)
F, 0x00007f9d3c7c8058, 0x21c0 (8640)
A, 0x00007f9d3c7c8490, 0x3520 (13600)
F, 0x00007f9d3c7c8b34, 0x2660 (9824)
a block that is large enough could not be found
alloc error
a block that is large enough could not be found
alloc error
total reallocaton time of 2 new random amounts between 5000 and 15000 bytes for p2 and p4 in microseconds: 22
blocks after reallocation of p2 and p4:
A, 0x00007f9d3c7c7000, 0x400 (1024)
A, 0x00007f9d3c7c7080, 0x100 (256)
A, 0x00007f9d3c7c70a0, 0x3380 (13184)
F, 0x00007f9d3c7c7710, 0x25a0 (9632)
A, 0x00007f9d3c7c7bc4, 0x24a0 (9376)
F, 0x00007f9d3c7c8058, 0x21c0 (8640)
A, 0x00007f9d3c7c8490, 0x3520 (13600)
F, 0x00007f9d3c7c8b34, 0x2660 (9824)
p2 was null
p4 was null
All allocations are freed in microseconds: 13
blocks after freeing:
A, 0x00007f9d3c7c7000, 0x400 (1024)
A, 0x00007f9d3c7c7080, 0x100 (256)
F, 0x00007f9d3c7c70a0, 0xfb00 (64256)
internal fragmentation amount after reallocation and freeing: 51
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
sum of total size desired to be allocated : 52281
14147 byte allocation request successfully done
11059 byte allocation request successfully done
8670 byte allocation request successfully done
10472 byte allocation request successfully done
7933 byte allocation request successfully done
total allocaton time of 5 random amounts between 5000 and 15000 bytes in microseconds: 58
blocks after allocation:
A, 0x00007f5f75a99000, 0x400 (1024)
A, 0x00007f5f75a99080, 0x100 (256)
A, 0x00007f5f75a990a0, 0x3750 (14160)
A, 0x00007f5f75a9978a, 0x2b40 (11072)
A, 0x00007f5f75a99cf2, 0x21e0 (8672)
A, 0x00007f5f75a9a12e, 0x28f0 (10480)
A, 0x00007f5f75a9a64c, 0x1f00 (7936)
F, 0x00007f5f75a9aa2c, 0x2ea0 (11936)
internal fragmentation amount: 39
p2 and p4 are freed in microseconds: 7
blocks after freeing p2 and p4:
A, 0x00007f5f75a99000, 0x400 (1024)
A, 0x00007f5f75a99080, 0x100 (256)
A, 0x00007f5f75a990a0, 0x3750 (14160)
F, 0x00007f5f75a9978a, 0x2b40 (11072)
A, 0x00007f5f75a99cf2, 0x21e0 (8672)
F, 0x00007f5f75a9a12e, 0x28f0 (10480)
A, 0x00007f5f75a9a64c, 0x1f00 (7936)
F, 0x00007f5f75a9aa2c, 0x2ea0 (11936)
5523 byte allocation request successfully done
6438 byte allocation request successfully done
total reallocaton time of 2 new random amounts between 5000 and 15000 bytes for p2 and p4 in microseconds: 13
blocks after reallocation of p2 and p4:
A, 0x00007f5f75a99000, 0x400 (1024)
A, 0x00007f5f75a99080, 0x100 (256)
A, 0x00007f5f75a990a0, 0x3750 (14160)
A, 0x00007f5f75a9978a, 0x15a0 (5536)
F, 0x00007f5f75a99a3e, 0x15a0 (5536)
A, 0x00007f5f75a99cf2, 0x21e0 (8672)
A, 0x00007f5f75a9a12e, 0x1930 (6448)
F, 0x00007f5f75a9a454, 0xfc0 (4032)
A, 0x00007f5f75a9a64c, 0x1f00 (7936)
F, 0x00007f5f75a9aa2c, 0x2ea0 (11936)
All allocations are freed in microseconds: 13
blocks after freeing:
A, 0x00007f5f75a99000, 0x400 (1024)
A, 0x00007f5f75a99080, 0x100 (256)
F, 0x00007f5f75a990a0, 0xfb00 (64256)
internal fragmentation amount after reallocation and freeing: 62
```

```
projectfizz@Monster:~/Desktop/finalProject3/project3 (1)/project 3$ ./app
sum of total size desired to be allocated : 52281
14147 byte allocation request successfully done
11059 byte allocation request successfully done
8670 byte allocation request successfully done
10472 byte allocation request successfully done
7933 byte allocation request successfully done
total allocaton time of 5 random amounts between 5000 and 15000 bytes in microseconds: 58
blocks after allocation:
A, 0x00007f5f75a99000, 0x400 (1024)
A, 0x00007f5f75a99080, 0x100 (256)
A, 0x00007f5f75a990a0, 0x3750 (14160)
A, 0x00007f5f75a9978a, 0x2b40 (11072)
A, 0x00007f5f75a99cf2, 0x21e0 (8672)
A, 0x00007f5f75a9a12e, 0x28f0 (10480)
A, 0x00007f5f75a9a64c, 0x1f00 (7936)
F, 0x00007f5f75a9aa2c, 0x2ea0 (11936)
internal fragmentation amount: 39
p2 and p4 are freed in microseconds: 7
blocks after freeing p2 and p4:
A, 0x00007f5f75a99000, 0x400 (1024)
A, 0x00007f5f75a99080, 0x100 (256)
A, 0x00007f5f75a990a0, 0x3750 (14160)
F, 0x00007f5f75a9978a, 0x2b40 (11072)
A, 0x00007f5f75a99cf2, 0x21e0 (8672)
F, 0x00007f5f75a9a12e, 0x28f0 (10480)
A, 0x00007f5f75a9a64c, 0x1f00 (7936)
F, 0x00007f5f75a9aa2c, 0x2ea0 (11936)
5523 byte allocation request successfully done
6438 byte allocation request successfully done
total reallocaton time of 2 new random amounts between 5000 and 15000 bytes for p2 and p4 in microseconds: 13
blocks after reallocation of p2 and p4:
A, 0x00007f5f75a99000, 0x400 (1024)
A, 0x00007f5f75a99080, 0x100 (256)
A, 0x00007f5f75a990a0, 0x3750 (14160)
A, 0x00007f5f75a9978a, 0x15a0 (5536)
F, 0x00007f5f75a99a3e, 0x15a0 (5536)
A, 0x00007f5f75a99cf2, 0x21e0 (8672)
A, 0x00007f5f75a9a12e, 0x1930 (6448)
F, 0x00007f5f75a9a454, 0xfc0 (4032)
A, 0x00007f5f75a9a64c, 0x1f00 (7936)
F, 0x00007f5f75a9aa2c, 0x2ea0 (11936)
All allocations are freed in microseconds: 13
blocks after freeing:
A, 0x00007f5f75a99000, 0x400 (1024)
A, 0x00007f5f75a99080, 0x100 (256)
F, 0x00007f5f75a990a0, 0xfb00 (64256)
internal fragmentation amount after reallocation and freeing: 62
```


Experiment A: Time of allocations
45
40
35
30
25
20
15
10
5
0
Allocation times
2000
5000
10000
20000
50000
Allocation sizes
16
17
18
19
20


Experiment A: Time of freeings
25
20
15
10
5
0
Freeing times
2000
5000
10000
20000
50000
Allocation sizes
16
17
18
19
20



Results

In results of experiment A, we can see that allocation time increases when allocated size increases. It is obvious since allocation is performed by O(n) time complexity and bits are traversed to find a place to allocate according to first fit. Also, we can see that for the same allocation sizes, when we increase the segment size, allocation time increases. This happens because library looks for a free place from the beginning and when we increase segment size, we indirectly increase bitmap size too. Therefore, traverse of a larger bitmap increases the allocated time. Similar results can be seen in graphs for freeing time too. There are fluctuations but they are not frequent to disrupt the result.

In results of experiment B, allocation time increases but not in a specific proportion. Reason of it is the different sizes of different allocations. Because of this difference, program spends various amounts of time for each allocation. In general, allocation size determines the time but time values could be different with same total size but different allocation sizes for each allocation.

The experiment with sequences of allocations and freeing some of these allocations is conducted to test the functionalities of the library. We also conducted similar tests with app.c program and you can see a simple test case in our submitted file.

We added screenshots of our terminal outputs for detailed results.