Heap Exploitation

讲师 Jr @ Lancet
ID起了好多个自己都忘了

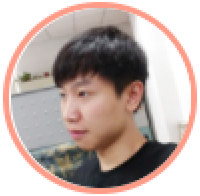
About me

XCTF

课程题目： 《CTF中的堆利用技术》

课程大纲：

1. Linux堆管理基础
2. 堆溢出的基本利用技巧（Unlink、Double Free、Use After Free）
3. 堆溢出进阶（Malloc maleficarum、XXXBin Attack、Off by one）
4. 常见的几种导致堆破坏的场景



讲师： 简容

1. Lancet战队bin选手2. 主攻写段子，虽然没有学医但是也想成为安全老司机 3. 广告位招租

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Heap Overview

- Why use Heap
- 堆的分配和释放可以由用户自由控制
- 堆的空间不一定连续
- 不同的系统有着不同的堆管理机制

```
Start              End                Perm      Name
0x0000555555554000 0x0000555555555000 r-xp      /root/pwn_course/heap
0x0000555555754000 0x0000555555755000 r--p      /root/pwn_course/heap
0x0000555555755000 0x0000555555756000 rw-p      /root/pwn_course/heap
0x0000555555756000 0x0000555555777000 rw-p      [heap]
0x00007ffff7a3b000 0x00007ffff7bd0000 r-xp      /lib/x86_64-linux-gnu/libc-2.24.so
```

Heap Overview

malloc、free、realloc

不一样的实现方法

- dlmalloc – General purpose allocator
- ptmalloc2 – glibc
- jemalloc – Firefox and Android
- tcmalloc – Google Chrome
- libumem – Solaris
- homework – Yourself

Heap Overview

- **Read The Fucking Source Code**
    - http://ftp.gnu.org/gnu/glibc/
- 对于堆管理的实现，比较直观的印象(your homework require)
    - 将一片内存切分成块
    - 使用合理的数据结构来组织（链表、树、等等）
    - 被释放的堆应该能被快速重用
    - 适当减少堆碎片的产生
    - 加上一丢丢的安全机制

Heap Overview

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- 为了减少系统调用的次数，heap allocator充当了中间层的作用
- 从前没有堆，brk之后就有了堆
- 这一片连续的空间，被称作arena
- 由于是主线程创建的arena，因此被称作main_arena

Heap Chunk

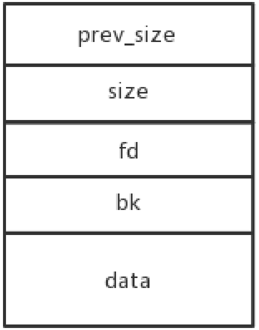
- chunk是堆的基本单位

```c
struct malloc_chunk {

INTERNAL_SIZE_T prev_size; /* Size of previous chunk (if free). */
INTERNAL_SIZE_T size; /* Size in bytes, including overhead. */

struct malloc_chunk* fd; /* double links -- used only if free. */
struct malloc_chunk* bk;

/* Only used for large blocks: pointer to next larger size. */
struct malloc_chunk* fd_nextsize; /* double links -- used only if free. */
struct malloc_chunk* bk_nextsize;
};
```



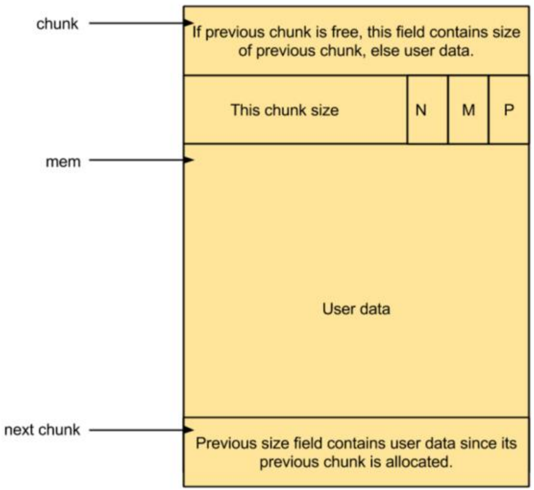
Heap Chunk

- size
  - 堆块的长度
  - 由于size的后3bit恒为0，故将这3位用于标志位（p、m、n）
- prev_size
  - 代表前一个相邻堆块的大小
  - 仅在p标志位为1时才有意义
  - <u>当前一个堆不处于空闲态时</u>，则可以为前一个堆中用户写入的数据
- fd&bk
  - 堆块在allocated状态时，无意义
  - freed状态下，用于形成链表结构

Heap Chunk

- 堆空间被切分为许多个chunk
- 两种状态：allocated、freed

allocated



P：prev inuse

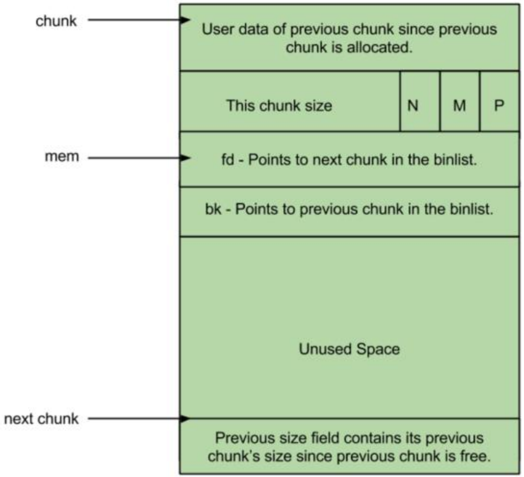
M：is_mmaped

N：non_main_arena

Heap Chunk

- 堆空间被切分为许多个chunk
- 两种状态：allocated、freed

freed



- 双向链表：fd和bk同时被使用
- 单向链表：仅仅使用fd

Heap Chunk

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- Top chunk
- 在第一次malloc时，heap将会被分成两个部分，第一部分就是被分配出去的堆；剩下的部分就叫做top chunk
- 在之后的分配中，若空间不足，则会从top chunk中切分
- 一个小实验

```
p1 = malloc(0x18);
p2 = malloc(0x88);
p3 = malloc(0x38);
memset(p1, 'a', 0x18);
free(p2);
```

- malloc(0x18) -> 用户得到什么？size字段实际有多大？
- free掉p2后，prev_size和size的标志位有何变化？

Heap Chunk

- p2被free之前

```
addr                prev              size       status
0x555555756000      0x0               0x20       Used
0x555555756020      0x61616161616161610x90       Used
0x5555557560b0      0x0               0x40       Used
```

chunk->	0x555555756000:	0x0000000000000000	0x0000000000000021
user ptr->	0x555555756010:	0x6161616161616161	0x6161616161616161
	0x555555756020:	0x6161616161616161	0x0000000000000091
	0x555555756030:	0x0000000000000000	0x0000000000000000
	0x555555756040:	0x0000000000000000	0x0000000000000000
	0x555555756050:	0x0000000000000000	0x0000000000000000
	0x555555756060:	0x0000000000000000	0x0000000000000000
	0x555555756070:	0x0000000000000000	0x0000000000000000
	0x555555756080:	0x0000000000000000	0x0000000000000000
	0x555555756090:	0x0000000000000000	0x0000000000000000
	0x5555557560a0:	0x0000000000000000	0x0000000000000000
	0x5555557560b0:	0x0000000000000000	0x0000000000000041
	0x5555557560c0:	0x0000000000000000	0x0000000000000000

Heap Chunk

- p2被free之后

addr	prev	size	status	fd	bk
0x555555756000	0x0	0x20	Used	None	None
0x555555756020	0x61616161616161610x90		Freed	0x7ffff7dd3b58	0x7ffff7dd3b58
0x5555557560b0	0x90	0x40	Used	None	None

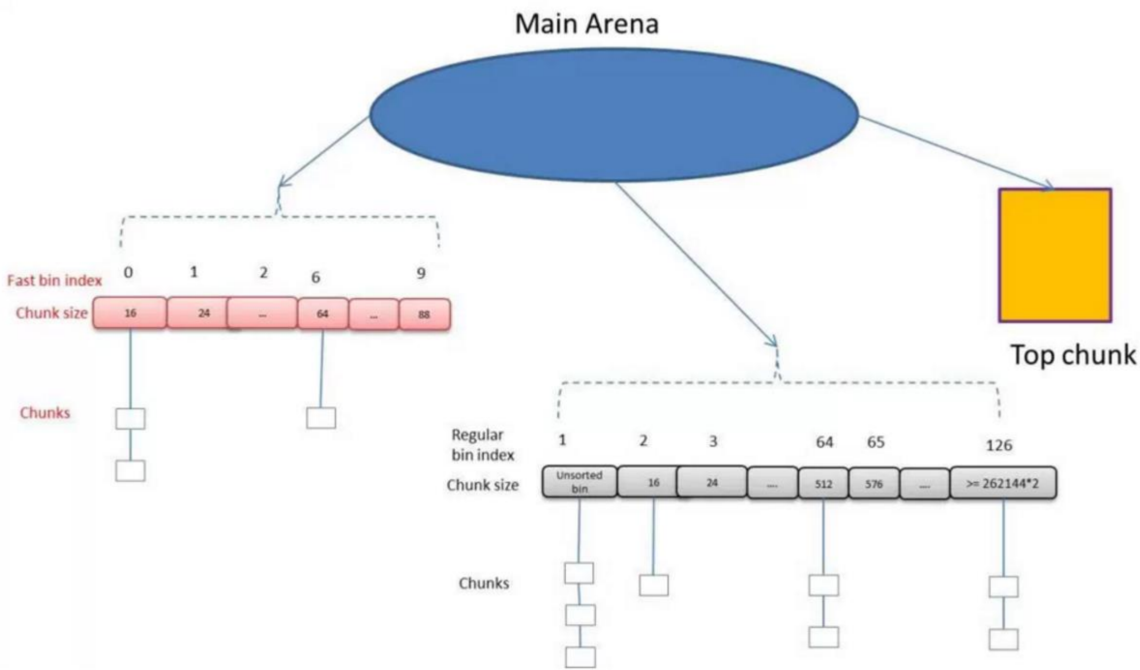
0x555555756000:	0x0000000000000000	0x0000000000000021
0x555555756010:	0x6161616161616161	0x6161616161616161
0x555555756020:	0x6161616161616161	0x0000000000000091
0x555555756030:	0x00007ffff7dd3b58	0x00007ffff7dd3b58
0x555555756040:	0x0000000000000000	0x0000000000000000
0x555555756050:	0x0000000000000000	0x0000000000000000
0x555555756060:	0x0000000000000000	0x0000000000000000
0x555555756070:	0x0000000000000000	0x0000000000000000
0x555555756080:	0x0000000000000000	0x0000000000000000
0x555555756090:	0x0000000000000000	0x0000000000000000
0x5555557560a0:	0x0000000000000000	0x0000000000000000
0x5555557560b0:	0x0000000000000090	0x0000000000000040
0x5555557560c0:	0x0000000000000000	0x0000000000000000

Main Arena

- chunk需要被有效的组织和利用
- main_arena是堆管理中的一个重要结构
- main_arena之大，源码一页贴不下
- 其对应的数据结构为malloc_state

mutex	用于多线程支持
flagd	用于标识该Arena的性质，例如是否连续，是否有fastbin可用等
fastbinsY[NFASTBINS]	fastbin指针数组
top	指向top chunk的指针
bins[NBINS * 2 - 2]	bins数组指针
*next	指向下一个Arena，构成一个循环单向链表
*next_free	指向idle Arena，便于线程快速匹配

Main Arena



Main Arena
Fast bin index
0
1
2
6
9
Chunk size
16
24
...
64
...
88
Chunks
Top chunk
Regular
bin index
1
2
3
64
65
126
Chunk size
Unsorted
bin
16
24
...
512
576
...
>= 262144*2
Chunks

Multi-thread arena

- 产品经理说了，多线程的我们也要handle
- 一个小实验

```
void* threadFunc(void* arg) {
      printf("Before malloc in thread 1\n");
      getchar();
      char* addr = (char*) malloc(1000);
      printf("After malloc and before free in thread 
1\n");
      getchar();
      free(addr);
      printf("After free in thread 1\n");
      getchar();
}
```

Multi-thread arena

- Before thread malloc

```
0x0000555555554000 0x0000555555555000 r-xp     /root/pwn_course/heap
0x0000555555754000 0x0000555555755000 r--p     /root/pwn_course/heap
0x0000555555755000 0x0000555555756000 rw-p     /root/pwn_course/heap
0x0000555555756000 0x0000555555777000 rw-p     [heap]
0x00007ffff781e000 0x00007ffff79b3000 r-xp     /lib/x86_64-linux-gnu/libc-2.24.so
```

- After thread malloc

```
0x0000555555554000 0x0000555555555000 r-xp     /root/pwn_course/heap
0x0000555555754000 0x0000555555755000 r--p     /root/pwn_course/heap
0x0000555555755000 0x0000555555756000 rw-p     /root/pwn_course/heap
0x0000555555756000 0x0000555555777000 rw-p     [heap]
0x00007ffff0000000 0x00007ffff0021000 rw-p     mapped
0x00007ffff0021000 0x00007ffff4000000 ---p     mapped
0x00007ffff701d000 0x00007ffff701e000 ---p     mapped
0x00007ffff701e000 0x00007ffff781e000 rw-p     mapped
```

- 在线程中创建的arena，被称作thread arena
- 虽然我们只请求了1000bytes，但是mmap了0x781e000的大小
- 在新mmap的空间中，只有两个区域被标记位rw

Multi-thread arena

- thread_arena不是想要就能要
- arena最大数量由CPU核心数决定
  - 32bit system ： Number of arena = 2 * Number of cores
  - 64bit system ： Number of arena = 8 * Number of cores
- 当num threads > num arenas
  - 遍历找到可用的arena
  - 使用mutex机制为arena加锁

Mechanism

<u>以32位系统为例</u>

Bins是空闲堆块链表中的基本数据结构，它们被用于保存空闲堆块

- Fast bins
- Unsorted bins
- Small bins
- Large bins

后面三种均在bins[NBINS*2 – 2]中

- Bin 1 – Unsorted bin
- Bin 2 to Bin 63 – Small bin
- Bin 64 to Bin 126 – Large bin
- 注意其双向链表结构

Fast bin

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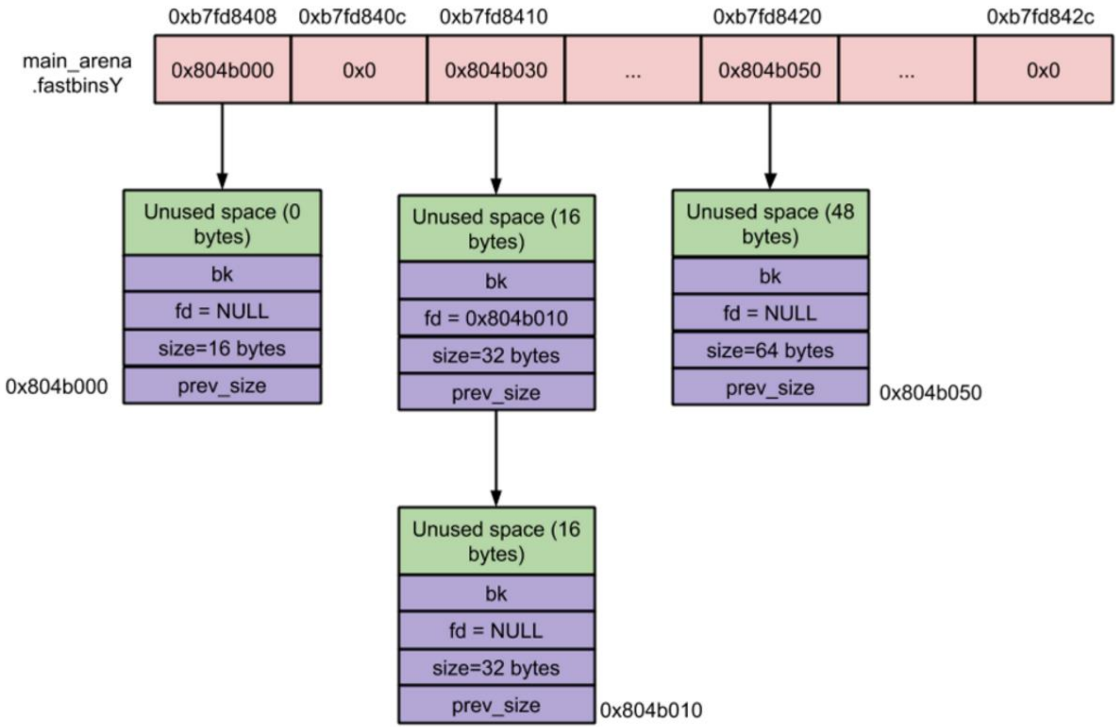
fast bin range ： 0x10(16) <= size <= 0x40(64)

- 单向链表 —— FILO
- 每个链表中的size相同，以8bytes为单位递增
- 被free的堆块仍被标记位inuse（防止堆块合并）

Fast bin



0xb7fd8408
0xb7fd840c
0xb7fd8410
0xb7fd8420
0xb7fd842c
main_arena
.fastbinsY
0x804b000
0x0
0x804b030
...
0x804b050
...
0x0
Unused space (0 bytes)
bk
fd = NULL
size=16 bytes
prev_size
0x804b000
Unused space (16 bytes)
bk
fd = 0x804b010
size=32 bytes
prev_size
Unused space (48 bytes)
bk
fd = NULL
size=64 bytes
prev_size
0x804b050
Unused space (16 bytes)
bk
fd = NULL
size=32 bytes
prev_size
0x804b010

Unsorted bin

当一个Small chunk或者Large chunk被free的时候，它们不会被放入对应的bin链表中，而是被加入到Unsorted bin中

- 只有一个，双向循环链表 —— FIFO
- 任何大小的chunk都可以存在于Unsorted bin
- 为了glibc快速重用被释放的堆

Bin 1 – Unsorted bin

Bin 2 to Bin 63 – Small bin

Bin 64 to Bin 126 – Large bin

Small bin

small bin range ： 0x10(16) <= size <= 0x1F8(504)

- 双向循环链表 —— FIFO
- 每个链表中的size相同，以8bytes为单位递增

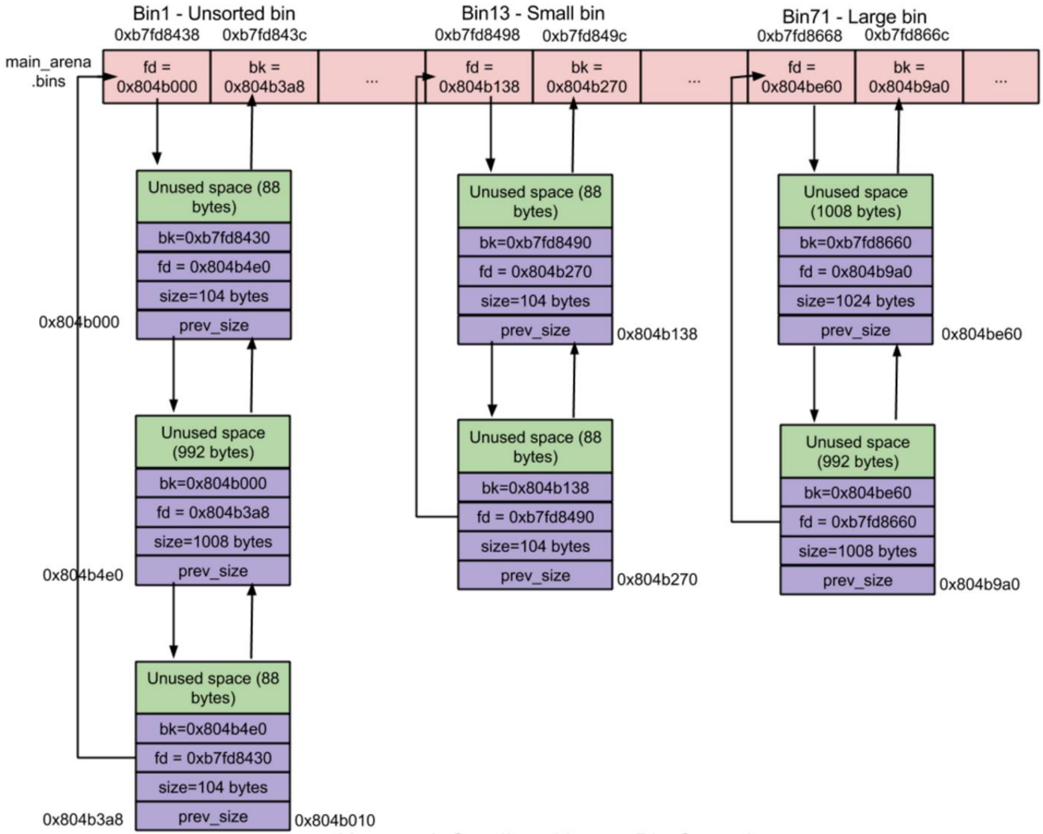
small bin size范围好像和fast bin有重合？

Large bin

Large bin range ： size >= 0x200(512)

- 双向循环链表 —— 可以在任意位置被拆卸
- 每个链表中的size不相同
    - 32个包含以64bytes为单位递增的链表。如第一个Large bin(bin 64)包含了512<=size<576的块
    - 16个包含以512bytes为单位递增的链表
    - 8个包含以4096bytes为单位递增的链表
    - 4包含以32768bytes为单位递增的链表
    - 2包含以262144bytes为单位递增的链表
    - 1包含剩下大小块的链表
- 每个链表中，chunk降序排列

Bins Overview



Unsorted, Small and Large Bin Snapshot

Free Mechanism

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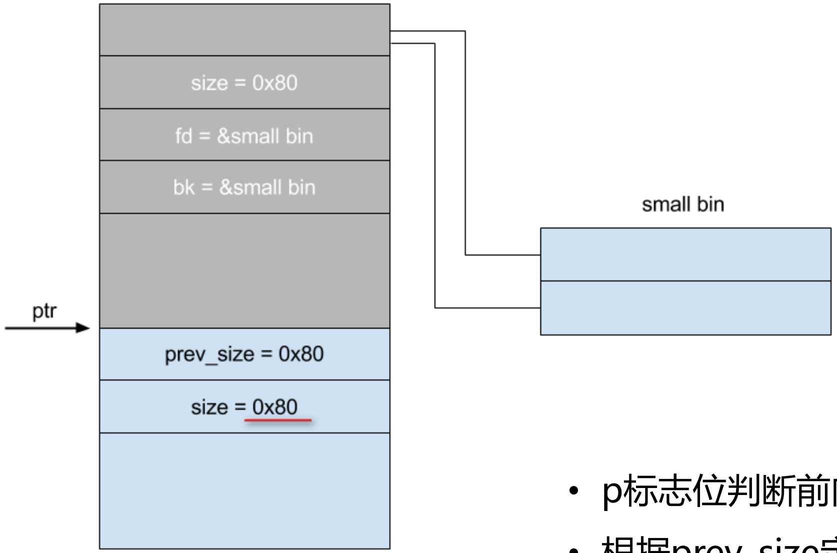
当一个chunk被free时

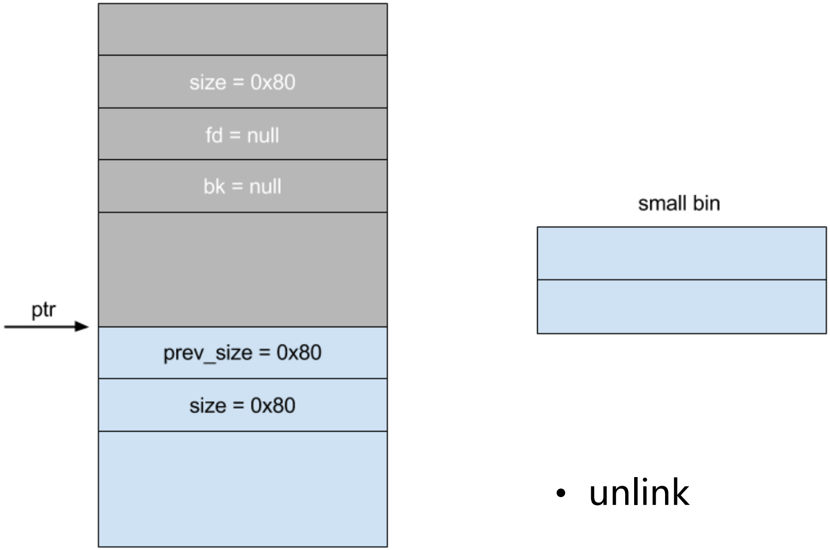
- size是否属于fast bin？
  - 是，插入fast bin 链表，结束
- 是不是mmap分配出去的内存？
  - 是，munmap，结束
- 与当前被free chunk的前一个相邻堆块是不是freed状态？
  - 是，则两个chunk合并
- 与当前被free chunk的后一个相邻堆块是不是top chunk？
  - 是，则与top chunk合并，结束
- 与当前被free chunk的后一个相邻堆块是不是freed状态？
  - 是，则两个chunk合并
- 将该chunk链入Unsorted bin

Free Mechanism



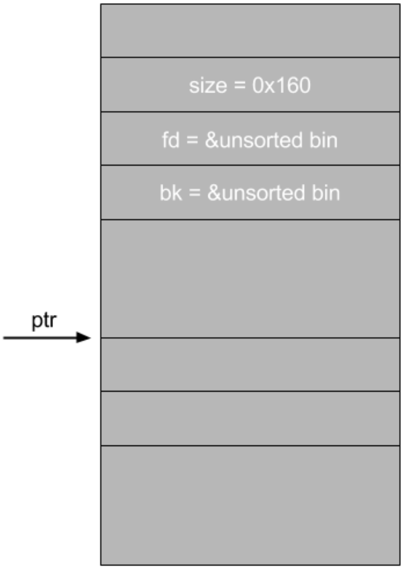
- p标志位判断前向堆块的状态
- 根据prev_size定位

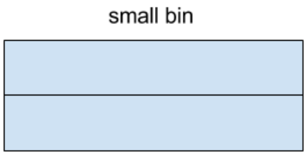
Free Mechanism



- unlink

Free Mechanism





- merge
- 链入Unsorted bin

Malloc Mechanism

当使用malloc分配内存时

- size是否属于fast bin？
    - 是，寻找对应链表
        - 若找到，则拆下对应chunk，结束
- size是否属于small bin？
    - 是，寻找对应链表
        - 若找到，则拆下对应chunk，结束
- 尝试使用Unsorted bin分配
    - 遍历、分割、拆卸

Malloc Mechanism

Unsorted bin 分配机制

- 从链表尾部开始遍历
  - 切分操作（剩下的仍存在于Unsorted bin）

```
in_smallbin_range (nb) &&
bck == unsorted_chunks (av) &&
victim == av->last_remainder &&
(unsigned long) (size) > (unsigned long) (nb + MINSIZE))
```

  - 若不满足切分条件，则进行拆链操作

```
/* remove from unsorted list */
unsorted_chunks (av)->bk = bck;
bck->fd = unsorted_chunks (av);
```

  - 若当前chunk不满足条件，则根据大小放入对应list(Small or Large) —— small bin 和 fast bin size range有重合的原因
- victim即使不满足分配需要，拆链和放入list的操作都会进行
- 遍历下一个chunk

Malloc Mechanism

当Unsorted bin 分配失败时

- size是否属于large bin？
    - 是，寻找对应链表
        - 若找到，则拆下(切分)对应chunk
        - 剩下的加入Unsorted bin，结束
- large bin 仍然不满足要求
    - 再次从small bin 和 large bin中寻找
    - 是否存在size(victim) > size(nb)的chunk
    - 若有，则切分，剩下的加入Unsorted bin
- 还是不行？则使用top chunk
- 还是不行？？江郎才尽，扩展堆空间吧

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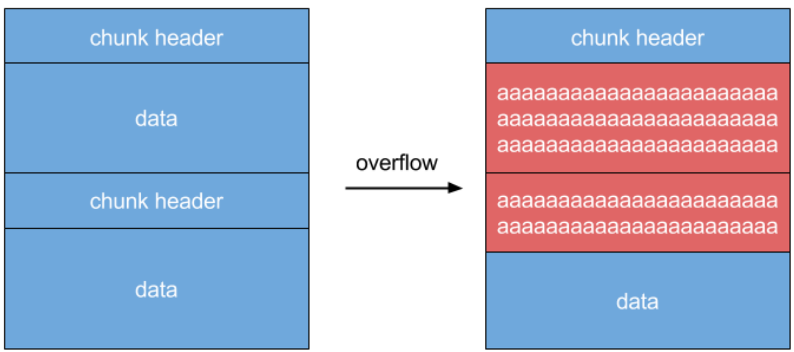
Vulnerability of Heap

Base on memory corruption

- Heap overflow
- Overwrite important heap metadata
- Overwrite important user data (eg. func_ptr)



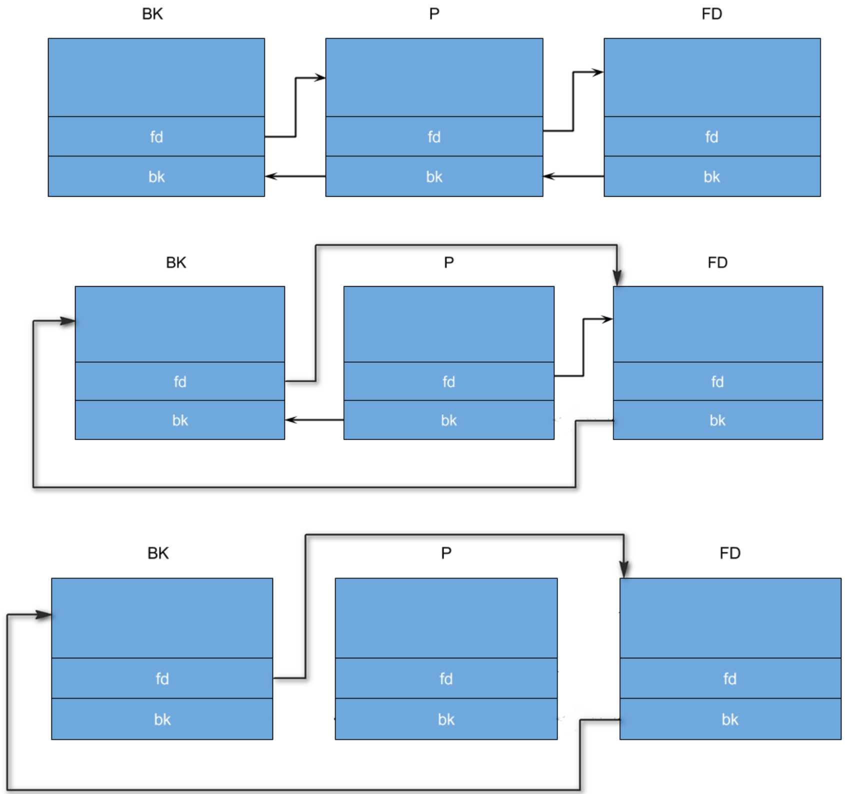
Unlink

链表结构？

- overwrite fd or bk
- trigger unlink
- unlink in ancient times

```
unlink(P, BK, FD) {
        FD = P -> fd;
        BK = P -> bk;
        FD -> bk = BK;
        BK -> fd = FD;
}
```

Unlink




```
unlink(P, BK, FD) {
        FD = P -> fd;
        BK = P -> bk;
        FD -> bk = BK;
        BK -> fd = FD;
}
```

Unlink

what if fd & bk are under control ?

- FD -> bk = BK
  - shellcode + 12 = got_entry – 8
- BK -> fd = FD
  - got_entry = shellcode

P

prev_size = 0
size = 0x81
fd = &shellcode
bk = got_entry - 8

Unlink

一个栗子

P

prev_size = 0
size = 0x81
fd = &shellcode
bk = got_entry - 8

Unlink

unlink in real world

```
if (__builtin_expect (FD->bk != P || BK->fd != P, 0))                \
      malloc_printerr (check_action, "corrupted double-linked list", P);
}
```

- 对指针的有效性做了检查
- 虽然能够bypass，但是可以写入的内容收到了很大限制
- 最终的结果
    - p = &p – 8（x86）
    - p = &p – 16（x64）

Unlink

unlink的利用

- 在_int_free函数中
- free chunk时的堆块前向、后向合并，将使用unlink

```
/* consolidate backward */
if (!prev_inuse(p)) {
  prevsize = p->prev_size;
  size += prevsize;
  p = chunk_at_offset(p, -((long) prevsize));
  unlink(p, bck, fwd);
}
```

```
    /* consolidate forward */
    if (!nextinuse) {
unlink(nextchunk, bck, fwd);
size += nextsize;
    } else
clear_inuse_bit_at_offset(nextchunk, 0);
```

Unlink

example

Double Free

直接double free？


```
*** Error in `./heap_2': double free or corruption (fasttop): 0x0804b008 ***
======= Backtrace: =========
/lib/i386-linux-gnu/libc.so.6(+0x6737a)[0xf7e6137a]
/lib/i386-linux-gnu/libc.so.6(+0x6dfb7)[0xf7e67fb7]
/lib/i386-linux-gnu/libc.so.6(+0x6e776)[0xf7e68776]
./heap_2[0x80488f3]
./heap_2[0x8048a75]
/lib/i386-linux-gnu/libc.so.6(__libc_start_main+0xf6)[0xf7e12276]
./heap_2[0x8048551]
```

glibc中有许多检查是否double free的机制

Double Free

glibc中有许多检查是否double free的机制

```
    if (__builtin_expect (p == av->top, 0))
      {
  errstr = "double free or corruption (top)";
  goto errout;
      }
    /* Or whether the next chunk is beyond the boundaries of
    if (__builtin_expect (contiguous (av)
          && (char *) nextchunk
          >= ((char *) av->top + chunksize(av->top)), 0))
      {
  errstr = "double free or corruption (out)";
  goto errout;
      }
    /* Or whether the block is actually not marked used.  */
    if (__builtin_expect (!prev_inuse(nextchunk), 0))
      {
  errstr = "double free or corruption (!prev)";
```

Double Free

Double Free

```
+-------------------------+-------------------------+-------------------------+
|        Chunk 1          |        Chunk 2          |        Chunk 3          |
+-------------------------+-------------------------+-------------------------+
0x60000                   0x60080                   0x60100


+-------------------------+---------------------------------------------------+
|         Chunk 1         |        Chunk 4                                    |
+-------------------------+---------------------------------------------------+
0x60000                   0x60080                   0x60100


+-------------------------+---------------------------------------------------+
|         Chunk 1         |        Chunk 4                                    |
|   Fake chunk, FD and BK |                         prev_size points to the   |
|   point into the table  |                         fake chunk in Chunk 1     |
+-------------------------+---------------------------------------------------+
0x60000                   0x60080                   0x60100
```

Use after Free

有些堆死了，它还活着

- free完毕之后，并没有做好收尾工作
    - 指针未清0
    - 数据结构未更改
- 通过重用该chunk，可导致不同程度的影响
    - 一个直观栗子

Use after Free

```c
typedef struct _cmdlist {
    void (*sayhello)();
    void (*saygoodbyte)();
}cmdlist;

typedef struct _data {
    int age;
    int score;
}data;

int main() {
    cmdlist *p = (cmdlist *)malloc(sizeof(cmdlist));
    free(p);
    /* do something */
    data *q = (data *)malloc(sizeof(data));
    q -> age = 0x61616161;
    (*(p -> sayhello))();
    return 0;
}
```

Use after Free

- 由于cmdlist和data结构体size相同
  - malloc将重用被free掉的cmdlist
  - `data *q = (data *)malloc(sizeof(data));`
  - p和q此时指向同一chunk
- 通过设置data.age，得以劫持控制流
  - `(*(p -> sayhello))();`

```
gdb-peda$ x/i $pc
=> 0x56555619 <main+89>:        call    eax
gdb-peda$ i r eax
eax            0x61616161       0x61616161
```

Malloc-maleficarum

XCTF

Some stories before house of cards

- 2004年，glibc针对当时常用的一些攻击手法进行了版本更新
    - 包括unlink在内的版本强势英雄被削
- 2005年，Phantasmal Phantasmagoria发表了文章Malloc Maleficarum（ ***Malleus Maleficarum 女巫之锤***）
- 提出了一系列攻击heap机制的新方法
- ~~2013年纸牌屋第一季正式开播~~

Malloc-maleficarum

- ~~House of Prime~~
- ~~House of Mind~~
- House of Force
- ~~House of Lore~~
- House of Spirit

House of Force

在使用Top chunk进行分配的时候：

```
use_top:
   victim = av->top;
   size = chunksize (victim);   //top块的大小
   if ((unsigned long) (size) >= (unsigned long) (nb + MINSIZE))  //nb为需要分配的块大小
    {
     remainder_size = size - nb;
     remainder = chunk_at_offset (victim, nb);
     av->top = remainder;
     set_head (victim, nb | PREV_INUSE |
          (av != &main_arena ? NON_MAIN_ARENA : 0));
     set_head (remainder, remainder_size | PREV_INUSE);

     check_malloced_chunk (av, victim, nb);
     void *p = chunk2mem (victim);
     alloc_perturb (p, bytes);
     return p;
    }
```

House of Force

利用条件：

- 能够覆写top chunk的size字段
- 存在一次malloc，攻击者能控制malloc的size
- 存在另一次malloc，攻击者能向此chunk写入数据

House of Force

example

- 我们想让top chunk指向0x804A058（heap_list - 8）
- 于是下一次分配，我们得以更改heap_list中的指针

- top chunk = 0x804b020
- 0x804A058 - 0x804b020 = -0xFC8 = 0xfffff038
- so we request 0xfffff038 – 4 = 0xfffff034 = -0xfcc

House of Spirit

当chunk被free时，glibc在想什么

- glibc如何确定被free的是一个真正的chunk？
- 如果我们free(0xdeadbeef)呢？

```
if (__builtin_expect ((uintptr_t) p > (uintptr_t) -size, 0)
    || __builtin_expect (misaligned_chunk (p), 0))
  {
    errstr = "free(): invalid pointer";
```

```
if (__builtin_expect (size < MINSIZE || !aligned_OK (size), 0))
  {
    errstr = "free(): invalid size";
```

如果我们想要一个fake chunk成功进入free list，需要哪些条件？

- 以进入fastbin为例

House of Spirit

如果我们想要一个fake chunk成功进入free list，需要哪些条件？

- 以进入fastbin为例

```
  if (__builtin_expect (chunk_at_offset (p, size)->size <= 2 * SIZE_SZ, 0)
|| __builtin_expect (chunksize (chunk_at_offset (p, size))
         >= av->system_mem, 0))
```

```
/* Check that the top of the bin is not the record we are going to add
   (i.e., double free).  */
if (__builtin_expect (old == p, 0))
  {
    errstr = "double free or corruption (fasttop)";
```

House of Spirit

攻击的本质：free anywhere

- 能够控制free的参数
- 能够满足free中对chunk的各项检查
- 触发free，使得fake chunk进入list
- 再次malloc得到该chunk，相当于弱化版的任意地址写

House of Mind

在free函数中

```
ar_ptr = arena_for_chunk (p);
_int_free (ar_ptr, p, 0);

#define arena_for_chunk(ptr) \
(chunk_non_main_arena (ptr) ? heap_for_ptr (ptr)->ar_ptr : &main_arena)

#define heap_for_ptr(ptr) \
((heap_info *) ((unsigned long) (ptr) & ~(HEAP_MAX_SIZE - 1)))
```

- arena_for_chunk 返回当前chunk对应的arena结构
- 若当前chunk不属于main_arena，则计算指针的值
  - p = 0x804a000
  - (0x804a000 & ~(HEAP_MAX_SIZE - 1)) -> ar_ptr = (0x8000000)

    -> ar_ptr

House of Mind

如果我们能控制指针p以及对应的chunk size，那么就相当于将arena指向了我们控制的区域

- 查找一下free中使用到arena的地方

```
    bck = unsorted_chunks(av);
    fwd = bck->fd;

    p->fd = fwd;
    p->bk = bck;
    if (!in_smallbin_range(size))
{
  p->fd_nextsize = NULL;
  p->bk_nextsize = NULL;
}
    bck->fd = p;
    fwd->bk = p;
```

House of Mind

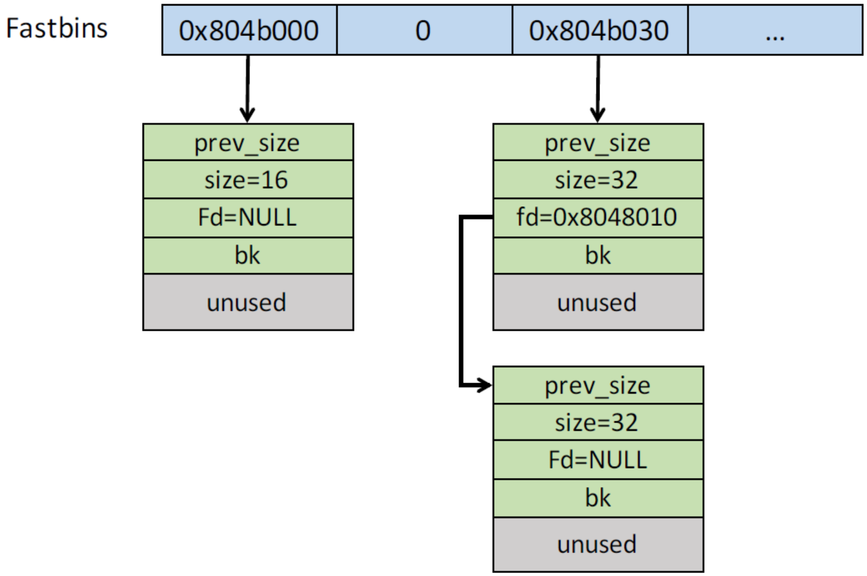
实际上，这个方法已经不能使用了

```c
    bck = unsorted_chunks(av);
    fwd = bck->fd;
    if (__builtin_expect (fwd->bk != bck, 0))
{
  errstr = "free(): corrupted unsorted chunks";
  goto errout;
}
    p->fd = fwd;
    p->bk = bck;
    if (!in_smallbin_range(size))
{
  p->fd_nextsize = NULL;
  p->bk_nextsize = NULL;
}
    bck->fd = p;
    fwd->bk = p;
```

目录 content

Fastbin Attack

fastbin 的单链表结构



Fastbin Attack

XCTF

fastbin检查（in free）

- address < -size && address alignment
- size > MINSIZE(0x20) && multiple of 0x10
- nextchunk size
    - > MINSIZE
    - < system_mem(0x21000 as usually)
- <u>链表中的第一个chunk是否和当前被free的chunk相同</u>

Fastbin Attack

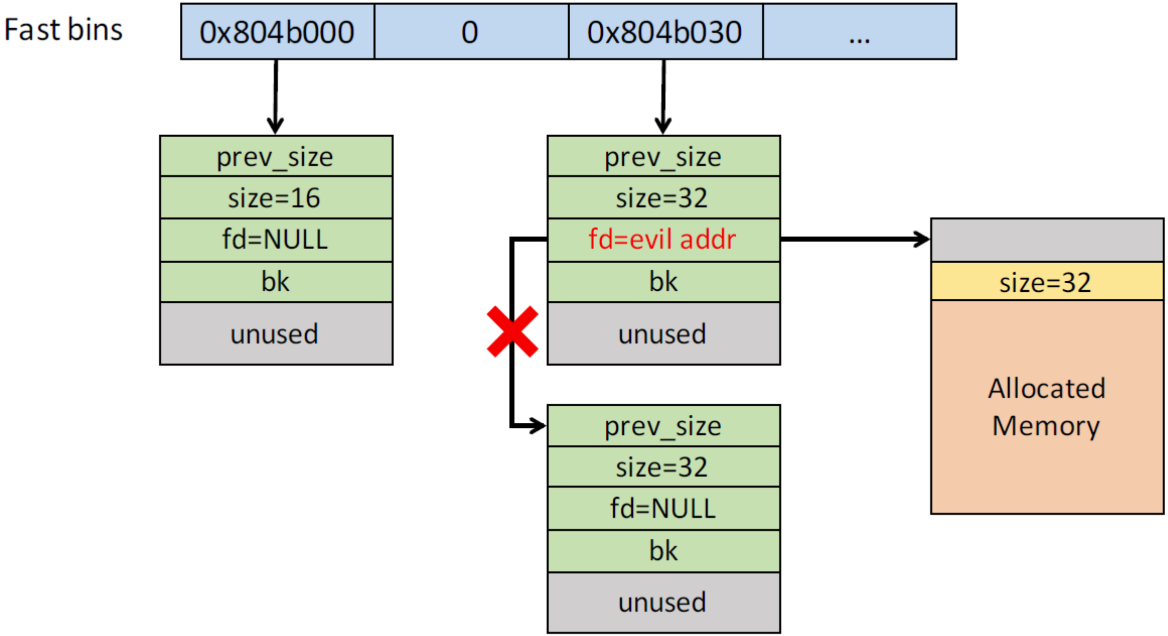
fastbin检查（in malloc）

- chunk size 是否和当前链表匹配

```
if (__builtin_expect (fastbin_index (chunksize (victim)) != idx, 0))
  {
    errstr = "malloc(): memory corruption (fast)";
```

```
#define fastbin_index(sz) \
  ((((unsigned int) (sz)) >> (SIZE_SZ == 8 ? 4 : 3)) - 2)
```

Fastbin Attack



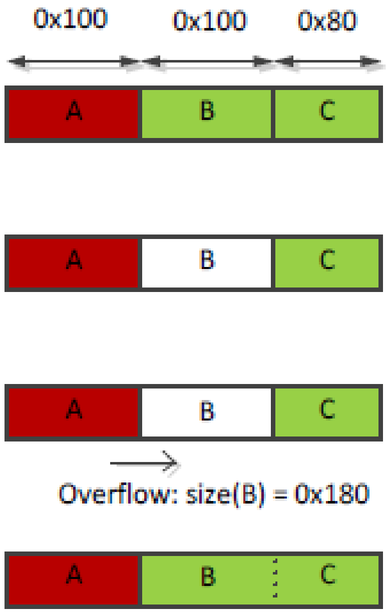
Off by One

XCTF

如果我们仅仅只能够溢出一个字节？

- 这一个字节将影响到下一个chunk的size字段
- Off by One to extend allocated chunk
- Off by Null to shrink free chunk

Extending Allocated Chunk



Initial state

B is freed

Overflow into B

Allocation larger than B’s initial size
C is overlapped

Shrinking Free Chunk

Shrinking Free Chunk

```
if (in_smallbin_range (nb) &&
    bck == unsorted_chunks (av) &&
    victim == av->last_remainder &&
    (unsigned long) (size) > (unsigned long) (nb + MINSIZE))
  {
    /* split and reattach remainder */
    //由于size字段被溢出为一个更小的值，因此导致remainder_size也偏小
    remainder_size = size - nb;
    remainder = chunk_at_offset (victim, nb);
    ...
    set_head (victim, nb | PREV_INUSE |
              (av != &main_arena ? NON_MAIN_ARENA : 0));
    set_head (remainder, remainder_size | PREV_INUSE);
    //由于此处remainder_size小于正常值，因此将不能写入chunk C的prev_size字段
    set_foot (remainder, remainder_size);
    ...
  }
```

Shrinking Free Chunk

demo

shrink.c

Other Things

- 堆溢出的利用可能会同时用到多个技巧
- 将某些漏洞转化成堆溢出
- 例如整数溢出、竞态条件

```
len = read_num();
this -> msg_len = len;
// unsigned overflow
len += 16;
p = new char[len];
this -> msg = p;
```

Other Things

- 竞态条件（Race Condition）
  - 临界区没有正确同步

```
                                       // destination is a global variable
void append(const number_list* source, number_list* destination) {
  size_t new_count = destination->count + source->count;

  if (source->count == 0 || new_count < destination->count)
    return;

  uint64_t* old_numbers = destination->numbers;
  destination->numbers = malloc(new_count * sizeof(uint64_t));

  if (destination->numbers == NULL)
    return;

  if (destination->count) {
    memcpy(destination->numbers, old_numbers,
           destination->count * sizeof(uint64_t));
    free(old_numbers);
  }

  memcpy(destination->numbers + destination->count, source->numbers,
         source->count * sizeof(uint64_t));

  destination->count = new_count;
}
```

Other Things

- 竞态条件（Race Condition）
  - 临界区没有正确同步

What happend	`dest->count`	`dest->numbers`
A malloc(a)	0	buf_a
A finished	a	buf_a
B malloc(a+b)	a	buf_ab
C malloc(a+c)	a	buf_ac
B finished	a+b	buf_ac
C at line 143: `memcpy(buf_ac, buf_ab, a+b)`	a+c	buf_ac

Other Things

XCTF

- Heap Spray
- 0x0c0c0c0c这个地址的优越性
- 当我们能够控制某个虚表指针：
    - mov ebx，[ecx]
    - mov eax，[ebx + 8]
    - call eax
- if eax == 0x41414141?
    - segment fault
- if eax == 0x0c0c0c0c?
    - the same

Other Things

- 堆喷：Unlimited Malloc Works
- eg. 浏览器
- 使得内存空间内充满 nop + shellcode 的堆空间

<table>
<tr><th>Address</th><th colspan="6">Contents</th></tr>
<tr><td></td><td colspan="6"></td></tr>
<tr><td>0c080018</td><td>0x1000 bytes
Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>...</td><td>0x1000 bytes
Nops | shellcode</td></tr>
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Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>...</td><td>0x1000 bytes
Nops | shellcode</td></tr>
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Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>...</td><td>0x1000 bytes
Nops | shellcode</td></tr>
<tr><td>0c0b0018</td><td>0x1000 bytes
Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>...</td><td>0x1000 bytes
Nops | shellcode</td></tr>
<tr><td>0c0c0018</td><td>0x1000 bytes
Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>0x1000 bytes
Nops | shellcode</td><td>...</td><td>0x1000 bytes
Nops | shellcode</td></tr>
</table>

Other Things

- 堆喷：if 0x0c0c0c0c contains 0x0c0c0c0c
  - mov ebx，[ecx]
  - mov eax，[ebx + 8]   # 0x0c0c0c0c
  - call eax   # 0x0c0c0c0c

- \x0c\x0c -> OR AL， 0C （NOP-like instruction）
- why not 0x0d0d0d0d?
  - \x0d \x0d\x0d\x0d\x0d -> OR EAX， 0x0D0D0D0D
  - 5个字节将可能造成对齐方面的问题

To the End

一道题

werewolf

X-Man

thanks