掘金CTF

——CTF中的内存漏洞利用技巧

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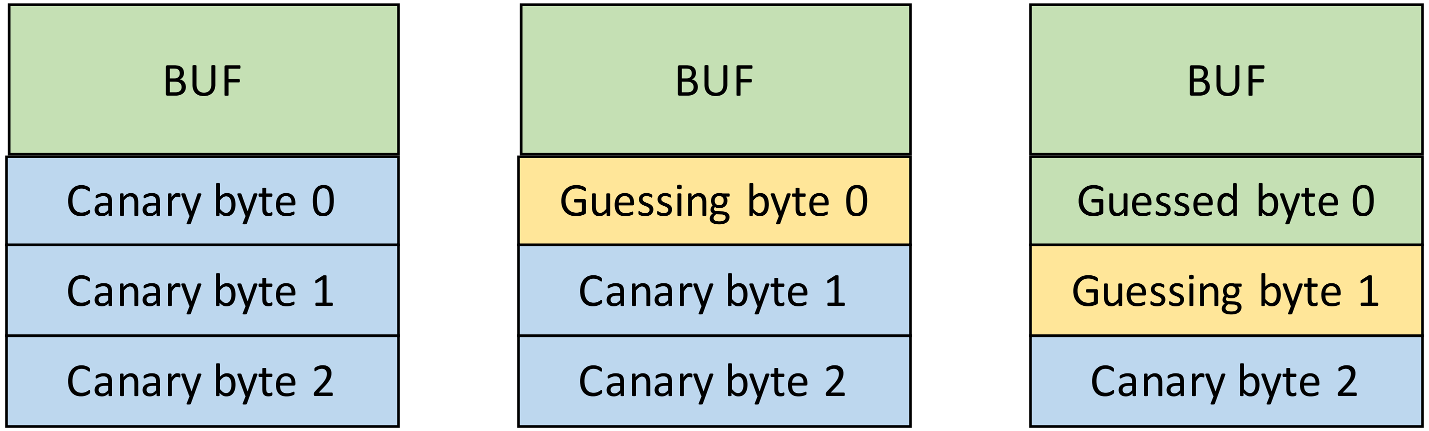
BLUE-LOTUS

Outline

- Stack Overflow
    - Stack Canary Leakage/Overwrite
    - PC Partial Overwrite
    - FP Overwrite
- Heap Overflow
    - Fastbin
    - Unlink
    - Off-by-one
- Libc Symbol Resolution
    - Libc Database
    - Leaklib
    - Return to dl_resolve
- Useful Gadgets
    - Magic System Address
    - Universal Gadgets

Stack Canary

- Brute force canary byte-by-byte
  - 30C3 bigdata

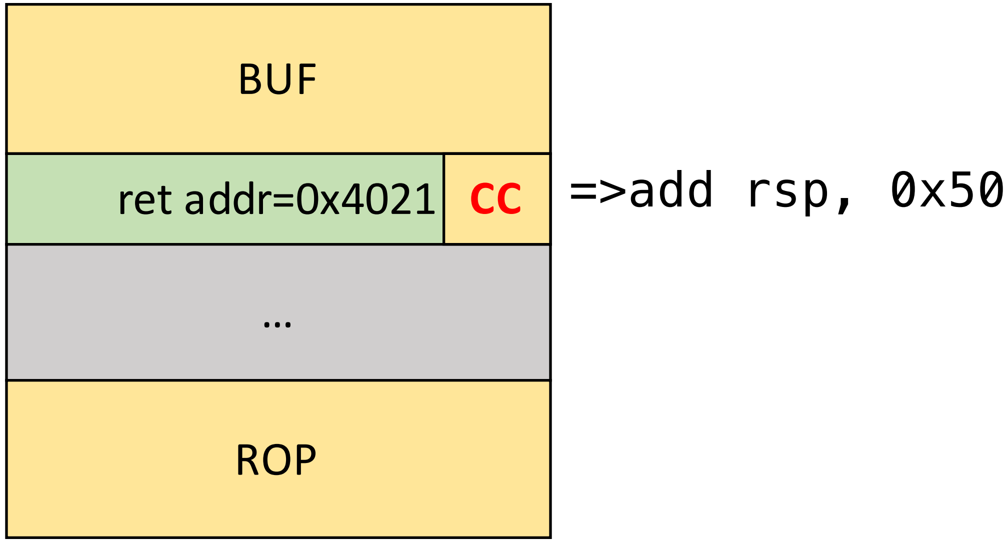


BUF	BUF	BUF
Canary byte 0	Guessing byte 0	Guessed byte 0
Canary byte 1	Canary byte 1	Guessing byte 1
Canary byte 2	Canary byte 2	Canary byte 2

- Overwrite canary in TLS
  - Canary is stored in TLS
  - Initialized by ld.so
  - Example: ISG CTF Finals 2014, pepper, unintended solution
    - Array Index overflow, write 0 to arbitrary address

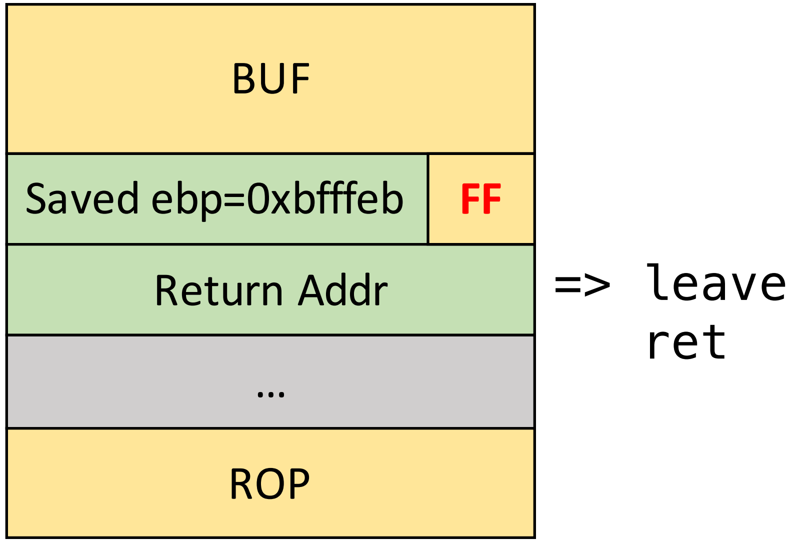
PC Partial Overwrite

- Challenges
  - Stack payload is null terminated, and the code address starts with null byte
  - Overflow is not enough to do ROP
- Solution
  - Overwrite several bytes of return address
  - Stack Pivot
- Example
  - DEFCON Finals 2014, eliza



Stack Frame Pointer Overwrite

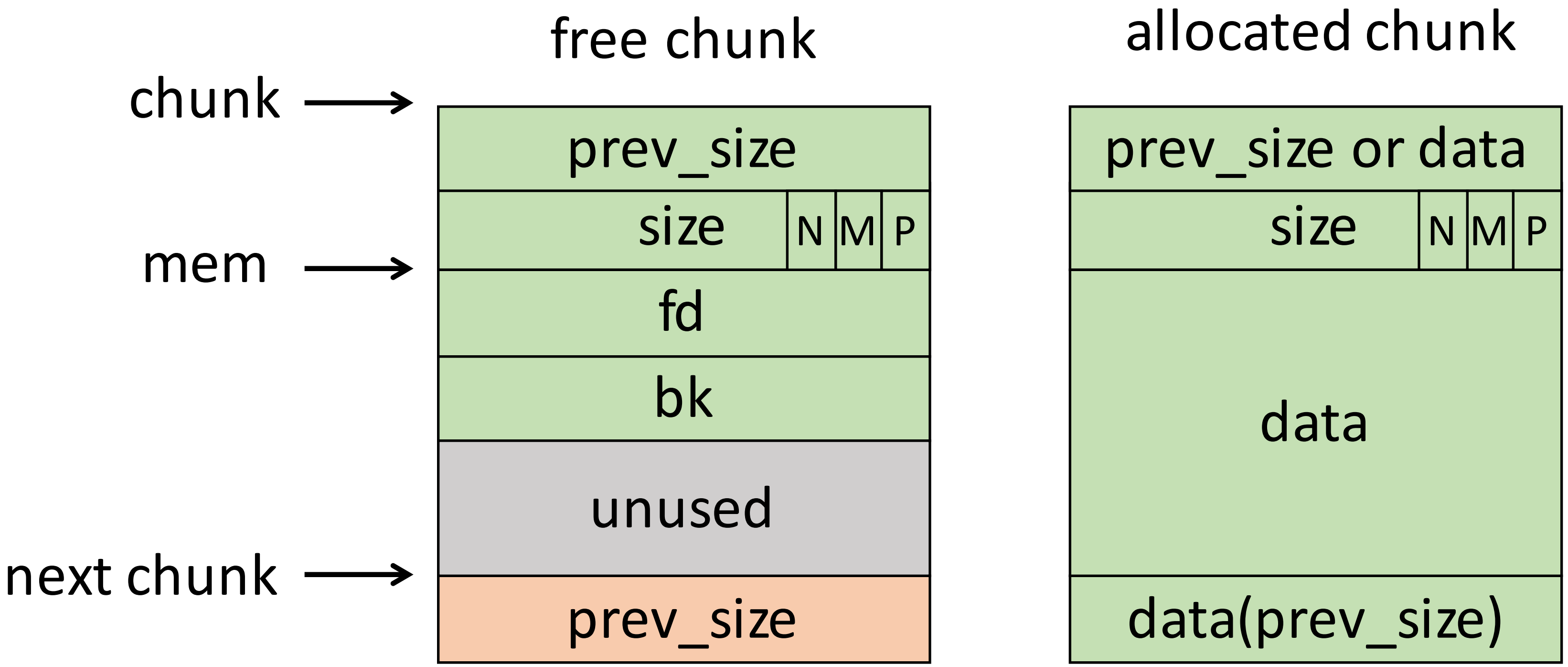
- Challenge
  - Overflow but cannot overrun the return address, e.g. off-by-one stack overflow
- Solution
  - Overwrite stack frame pointer register(ebp for x86)
  - ebp is restored, stack is moved with another “leave ret”
  - Do ROP in a controlled stack position
- Example
  - Codegate CTF Finals 2015, chess



Heap

- dlmalloc – General purpose allocator
- ptmalloc2 – glibc
- jemalloc - FreeBSD and firefox
- tcmalloc – Google
- libumem - Solaris

Chunks



free chunk

chunk

prev_size

size | N | M | P

mem

fd

bk

unused

next chunk

prev_size

allocated chunk

prev_size or data

size | N | M | P

data

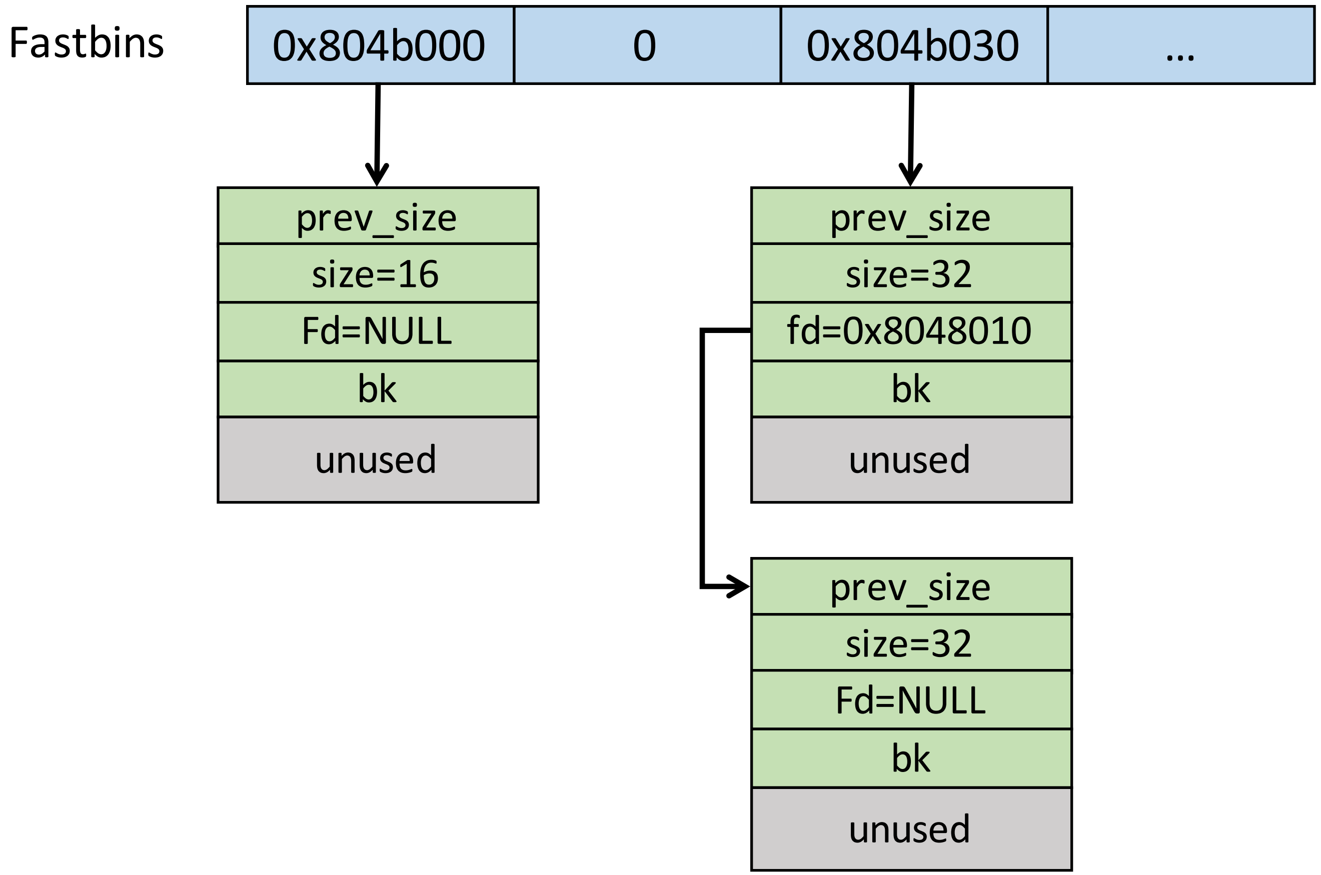
data(prev_size)

PREV_INUSE(P)
IS_MAPPED(M)
NON_MAIN_ARENA(N)

Bins

- Fast bins
  - 16 ~ 64 bytes for x86_32; 32 ~ 128 bytes for x86_64
  - LIFO: Single Linked List
  - No coalescing
- Bins
  - Circular double linked list
  - Bin 1 - Unsorted bin
    - freed small and large chunks are temporarily added to unsorted bin
  - Bin 2 to Bin 63 - Small bin
    - 16, 24, 32, …, 508 bytes for x86_32, in each bin contains chunks with the same size
  - Bin 64 to Bin 126 - Large bin
    - >=512 bytes(x86_32)

Fast bin



Fastbins

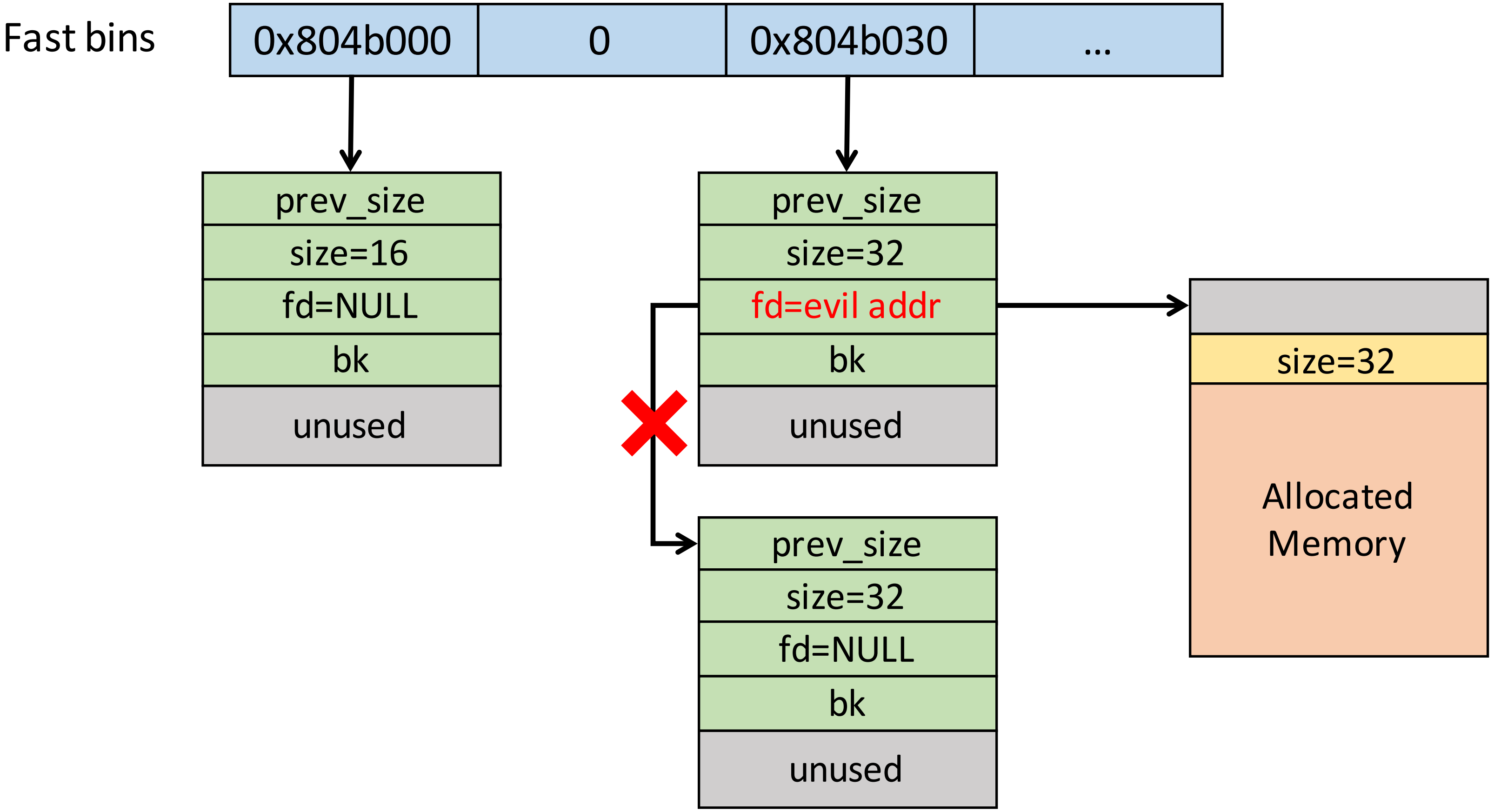
0x804b000 | 0 | 0x804b030 | ...

prev_size
size=16
Fd=NULL
bk
unused

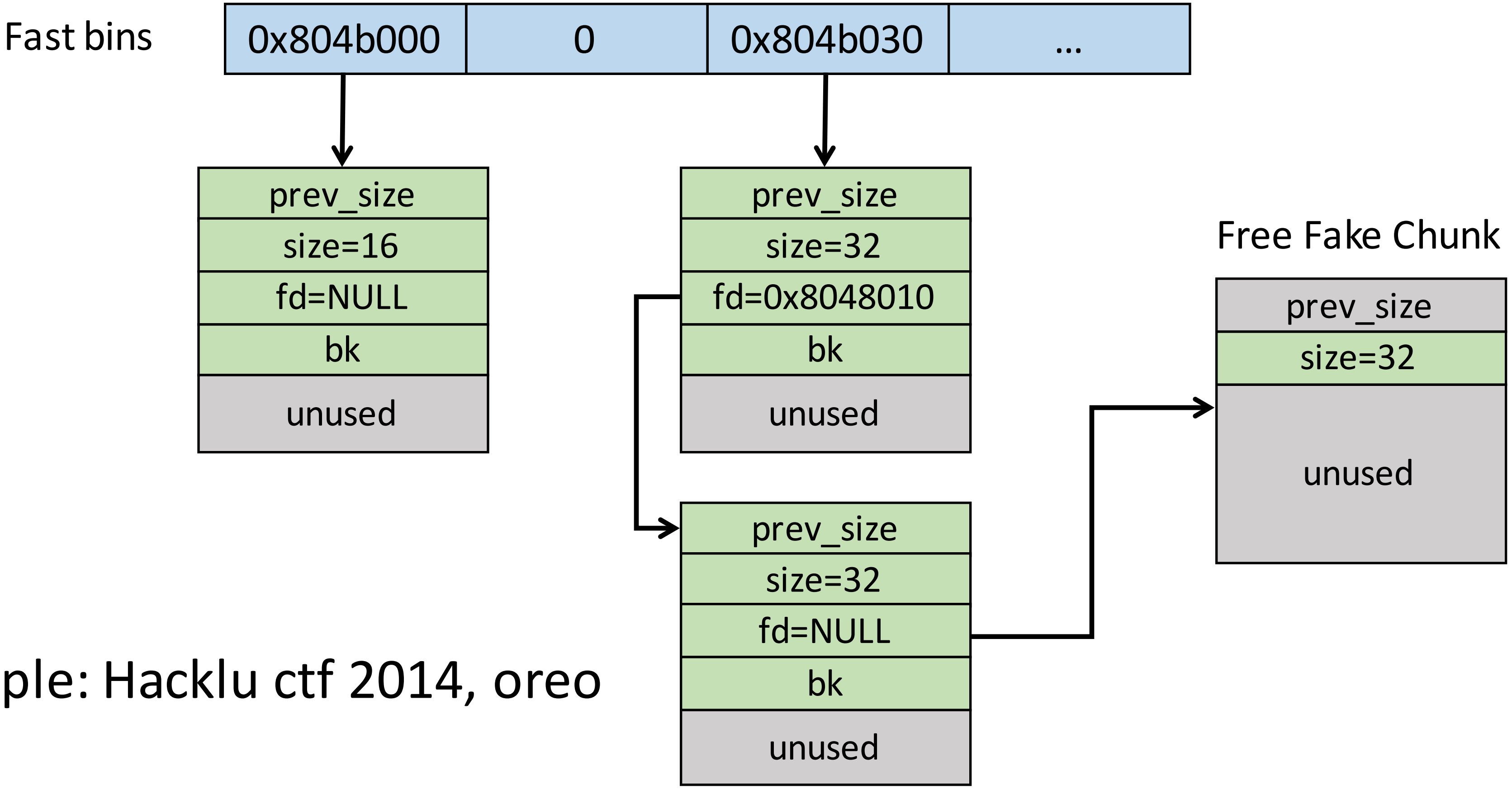
prev_size
size=32
fd=0x8048010
bk
unused

prev_size
size=32
Fd=NULL
bk
unused

Fast bin Attack

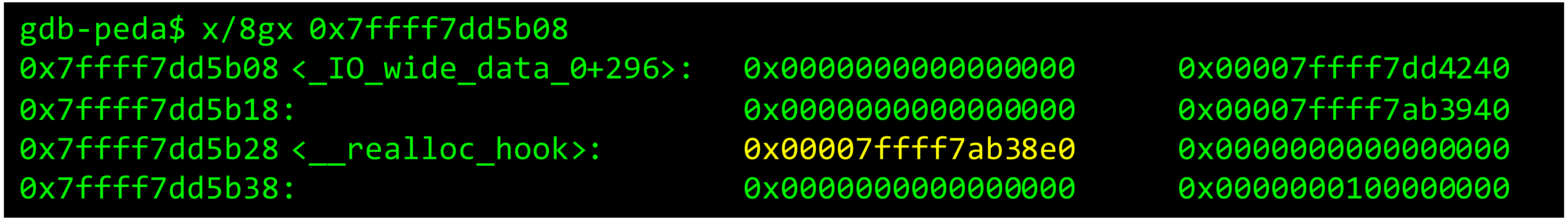


Fast bin Attack

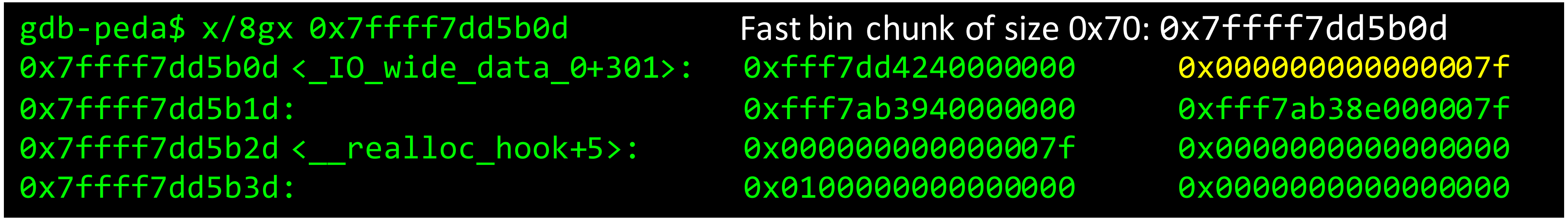


Example: Hacklu ctf 2014, oreo

Overwrite realloc_hook in glibc



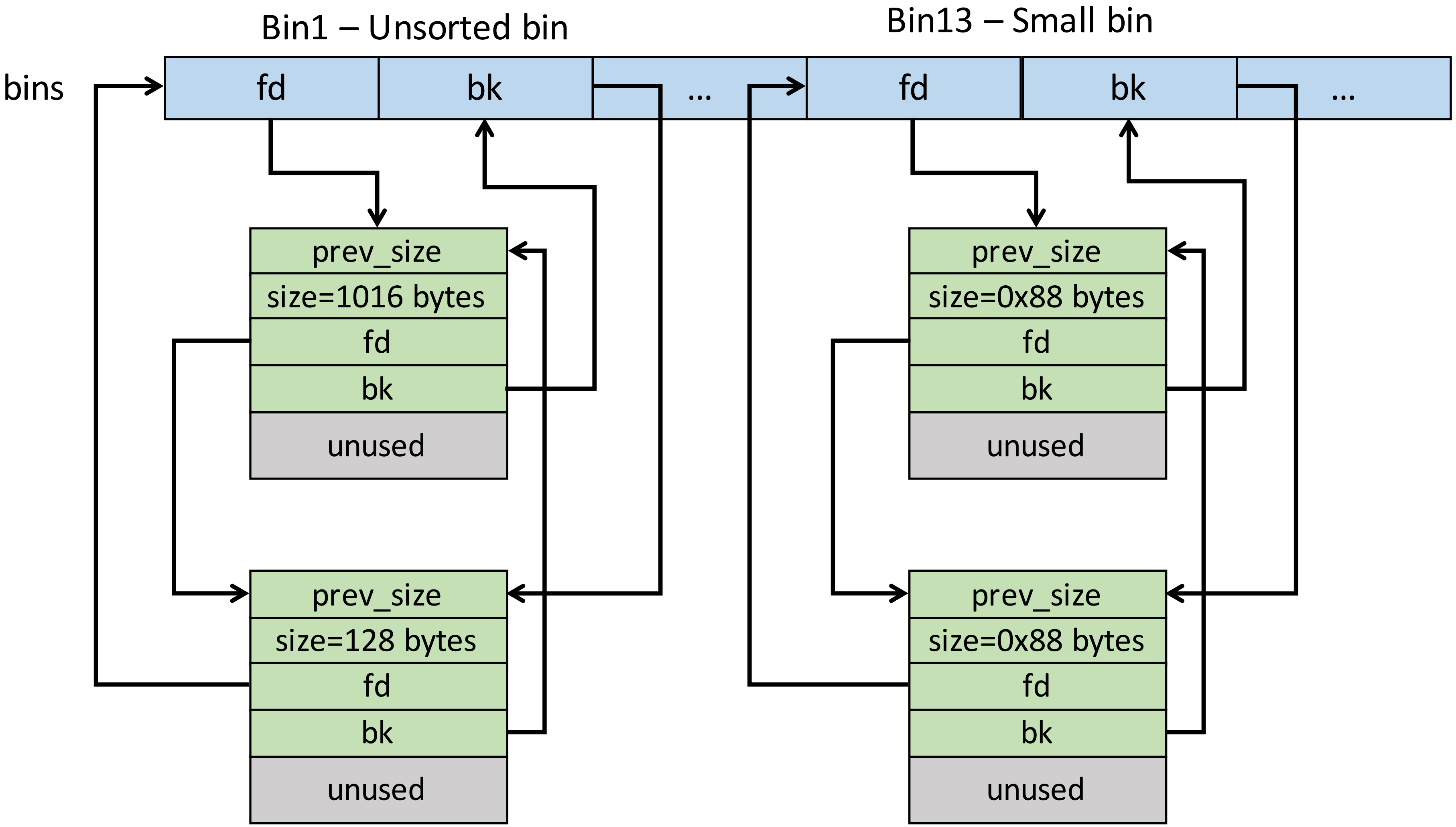
```
gdb-peda$ x/8gx 0x7ffff7dd5b08
0x7ffff7dd5b08 <_IO_wide_data_0+296>:   0x0000000000000000      0x00007ffff7dd4240
0x7ffff7dd5b18:                         0x0000000000000000      0x00007ffff7ab3940
0x7ffff7dd5b28 <__realloc_hook>:        0x00007ffff7ab38e0      0x0000000000000000
0x7ffff7dd5b38:                         0x0000000000000000      0x0000000100000000
```



```
gdb-peda$ x/8gx 0x7ffff7dd5b0d          Fast bin chunk of size 0x70: 0x7ffff7dd5b0d
0x7ffff7dd5b0d <_IO_wide_data_0+301>:   0xfff7dd4240000000      0x000000000000007f
0x7ffff7dd5b1d:                         0xfff7ab3940000000      0xfff7ab38e000007f
0x7ffff7dd5b2d <__realloc_hook+5>:      0x000000000000007f      0x0000000000000000
0x7ffff7dd5b3d:                         0x0100000000000000      0x0000000000000000
```

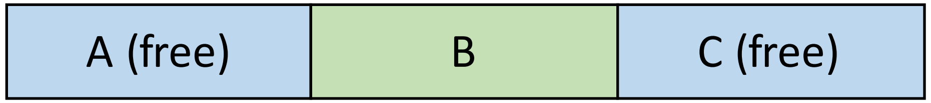
- Example
  - PlaidCTF 2014, datastore
  - HITCON CTF 2015, fooddb

Unsorted bin and Small bin



Unlink

- Condition
  - Chunk A or chunk C is free
  - Free(chunk B)
- Consolidate chunk 0 or chunk 2 with chunk 1
- Unlink chunk 0 or chunk 2



A (free)

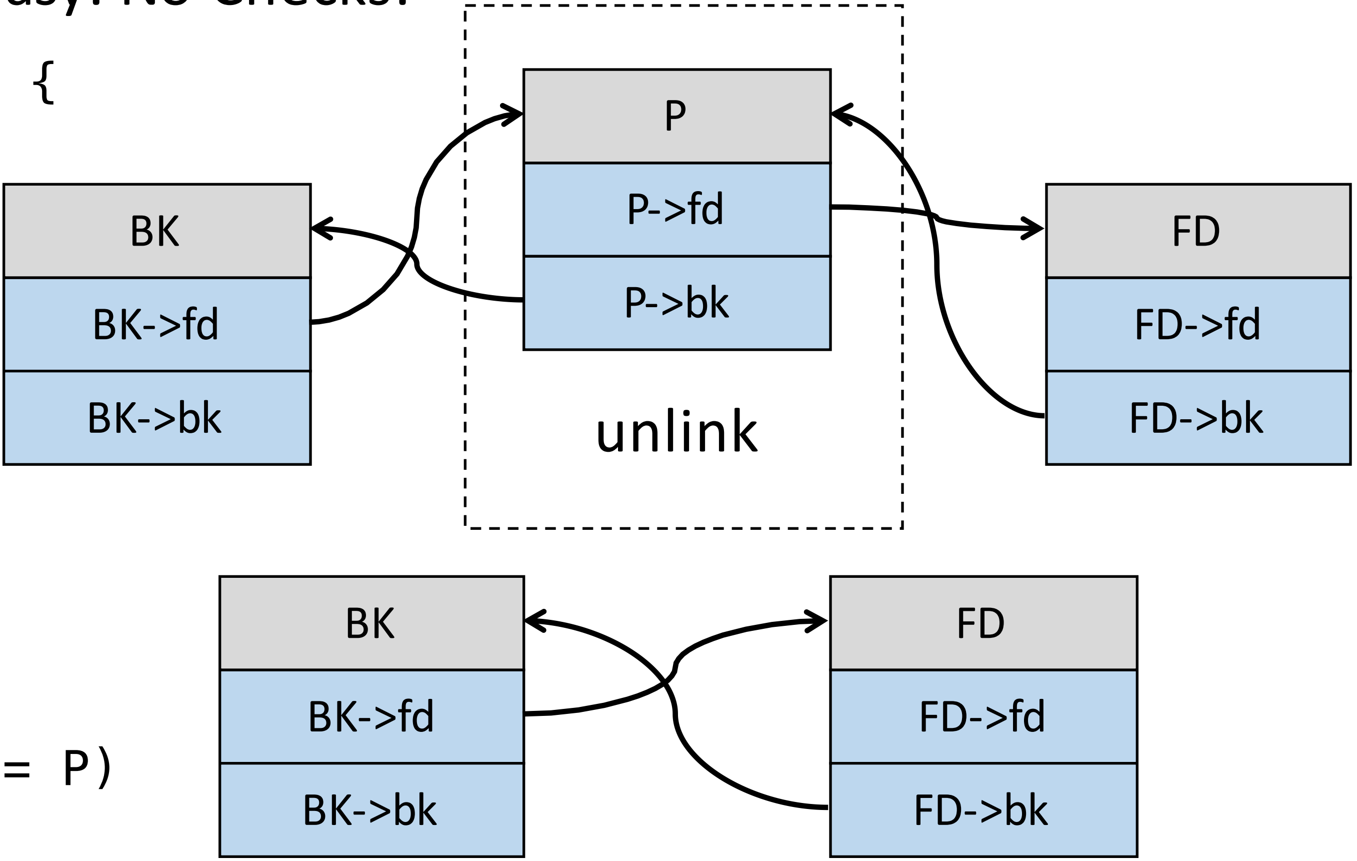
B

C (free)

Unlink

Old school unlink technique is easy: No Checks!

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



Unlink checks in modern glibc:

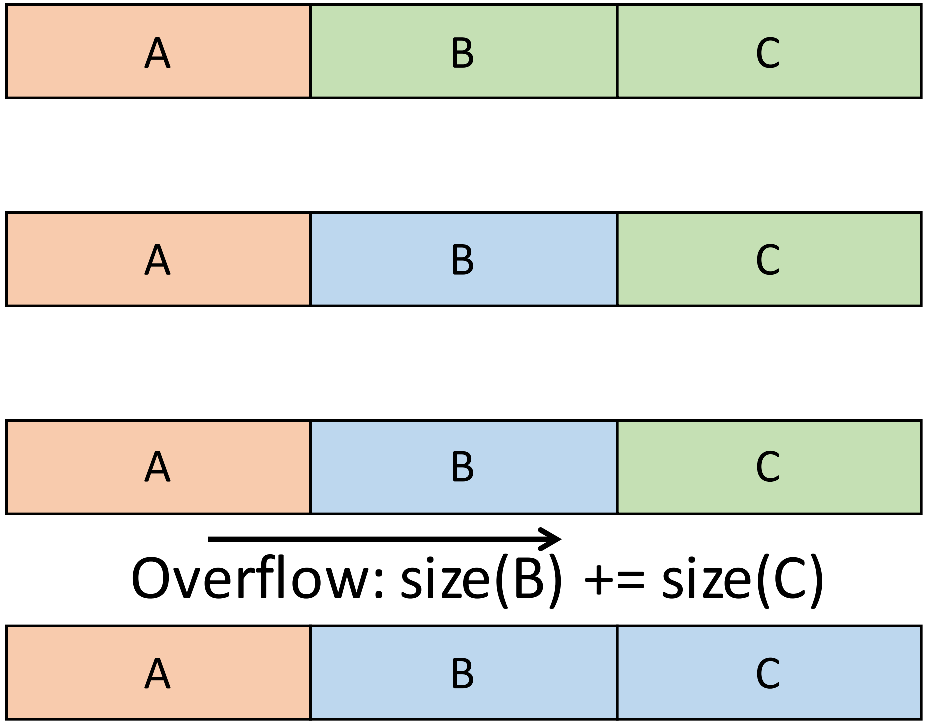
```
assert(P->fd->bk == P)
assert(P->bk->fd == P)
```

Bypass:

- Find a pointer X to P(*X = P)
- Set P->fd and P->bk to X
- Trigger Unlink(P)
- We have *P = X

Off-by-one

- Extending Free Chunks



Initial State

B is freed

Overflow into B

Overflow: size(B) += size(C)

Free chunk is extended

A Vulnerable chunk

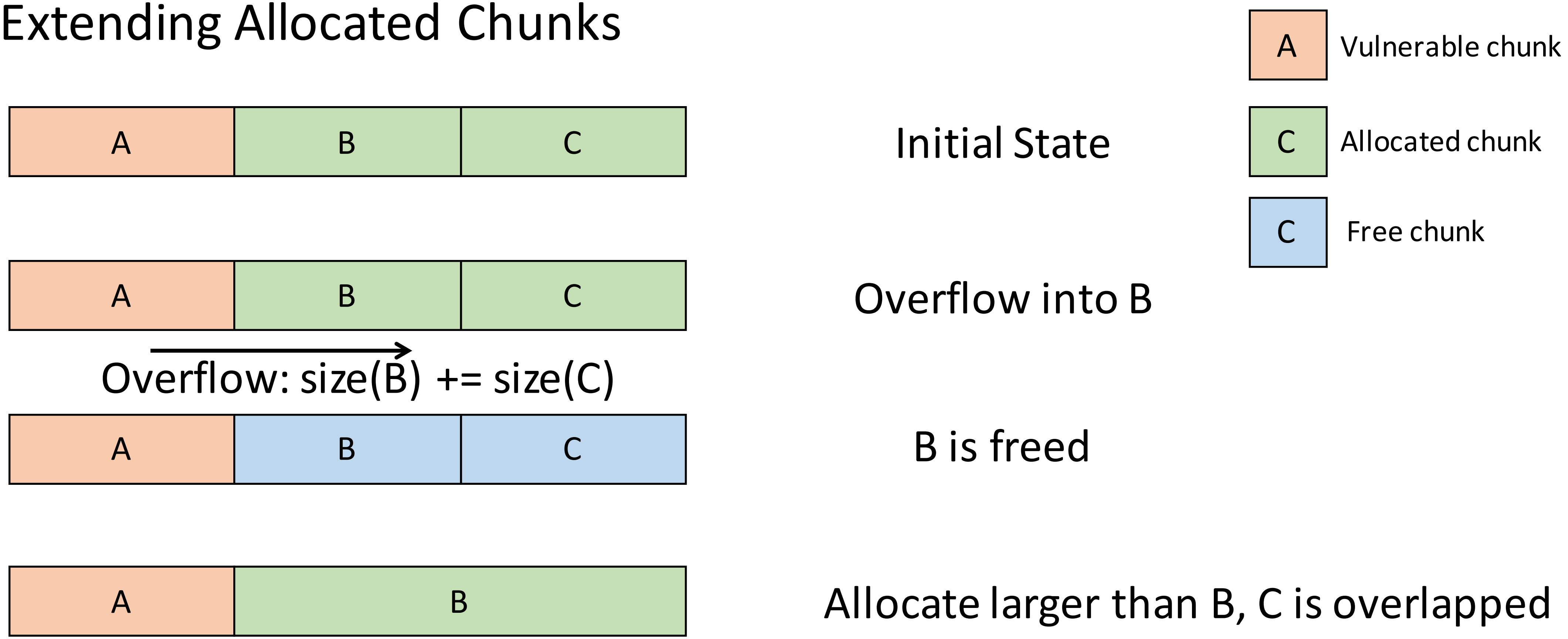
C Allocated chunk

C Free chunk

Example:
gethostbyname() heap overflow

Off-by-one

- Extending Allocated Chunks



Initial State

Overflow into B

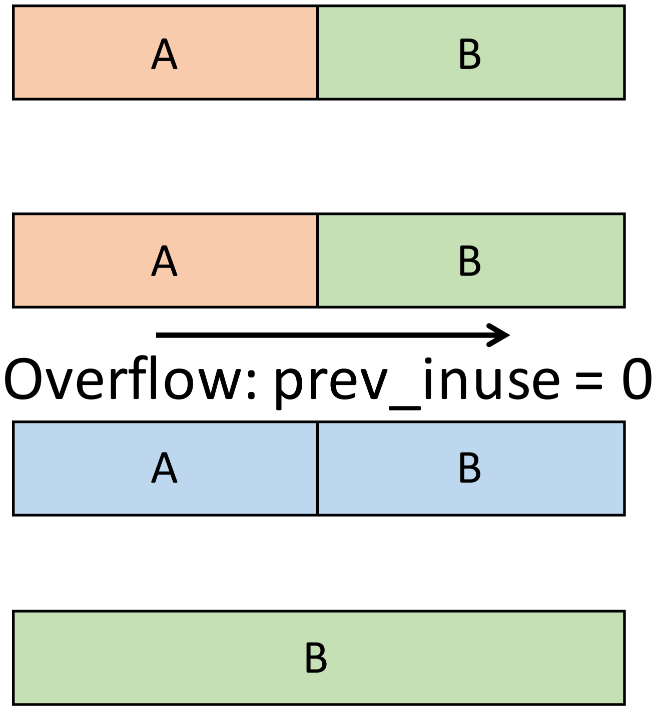
Overflow: size(B) += size(C)

B is freed

Allocate larger than B, C is overlapped

Null Byte Off-by-one

- Extending Allocated Chunks



Initial State

prev_inuse

B is freed, A is consolidated

Allocate larger than B, A is overlapped

A Vulnerable chunk

C Allocated chunk

C Free chunk

Example: PlaidCTF 2015, datastore

Libc Problem

- Challenges
  - Binary doesn’t import crucial libc function, e.g. system(), mprotect()
  - We can leak libc base address, but
- Solutions
  - Libc database
  - Leaklib: Arbitrary memory read = arbitrary lib symbol resolution
  - Return-to-dl_resolve

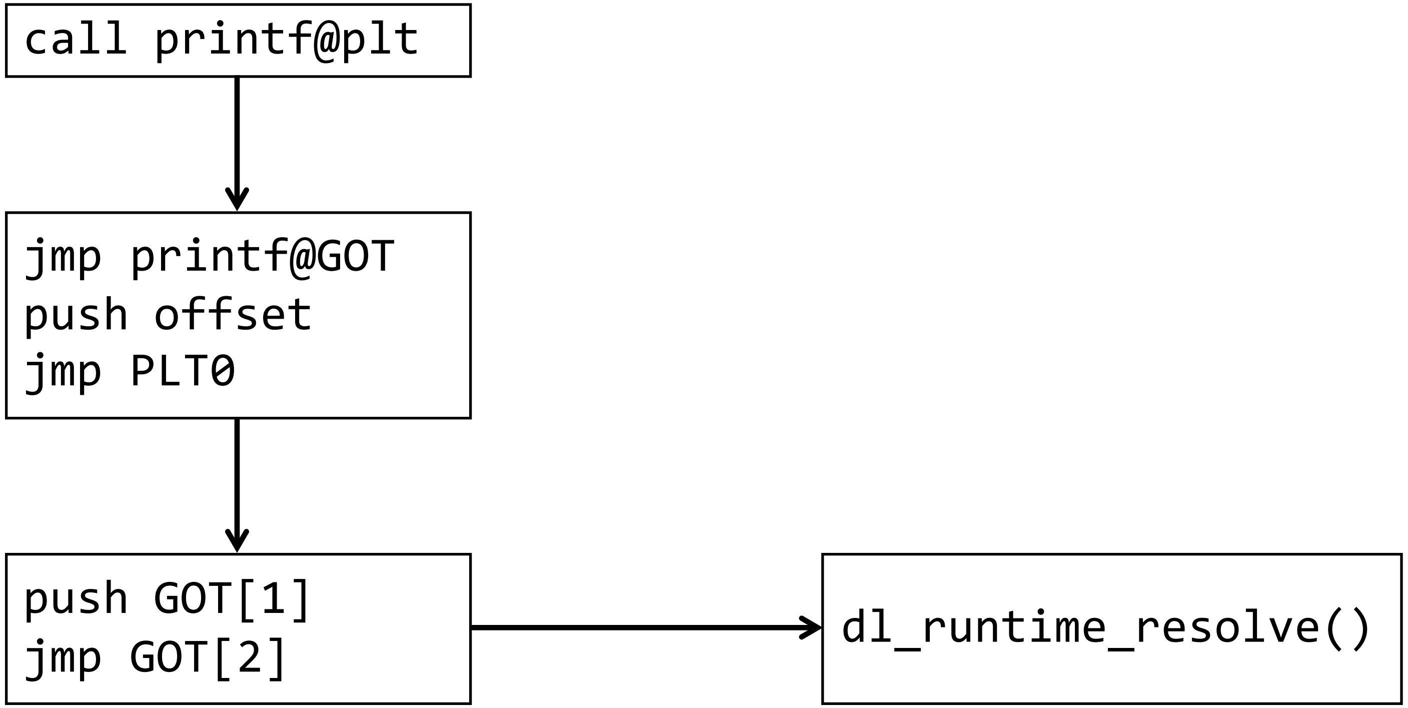
Libc database

- Steps
  - Leak some symbol address
  - Do match in collected libc files
- Existing Resource
  - https://github.com/niklasb/libc-database

leaklib

- Precondition: Arbitrary memory leak
  - Leak link_map addr (in DT_DEBUG)
  - Leak lib base addr
  - Lookup the hash of desired symbol in hashtbr
  - Lookup in Strtab
  - Lookup in Symtab
- Tools
  - Pwntools: pwnlib.dynelf
    - Pass a memory leak handler

Libc symbol resolve



```
call printf@plt
```

```
jmp printf@GOT
push offset
jmp PLT0
```

```
push GOT[1]
jmp GOT[2]
```

```
dl_runtime_resolve()
```

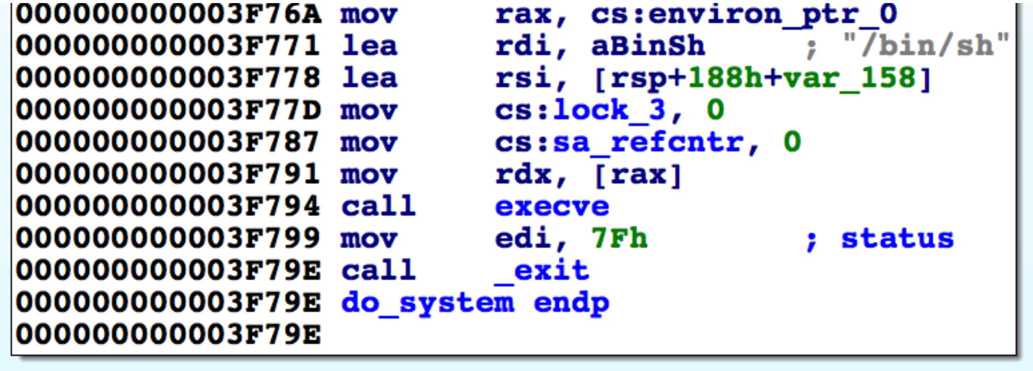
Return to dl_resolve

- Libc symbol resolving
  - Push link_map
  - Push rel_offset
  - Call _dl_runtime_resolve(link_map, rel_offset)
    - rel_entry = JMPREL + rel_offset;
    - Elf32_Sym *sym_entry = SYMTAB[ELF32_R_SYM(rel_entry->r_info)];
    - char *sym_name = STRTAB + sym_entry->st_name;
- How about we control rel_offset?
  - Construct rel_entry
  - Construct symtab
  - Construct strtab
  - Call arbitrary symbol! Win!

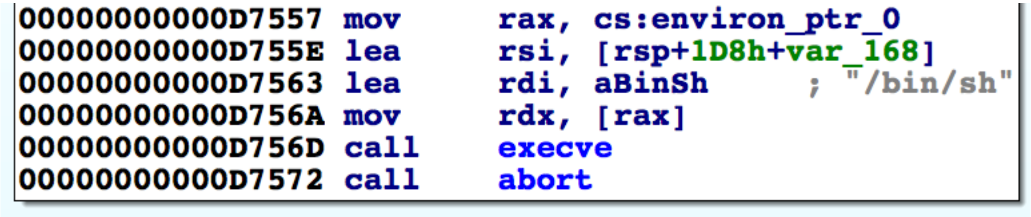
Example:
HITCON CTF Quals 2015, readable
Codegate CTF Finals 2015, yocto

Magic System Address

- RCE on Linux
  - System(cmd)
  - mprotect + shellcode
- One Gadget RCE
  - If stdin is redirected, controlled PC directly leads to RCE
  - Invented by Ricky from PPP?

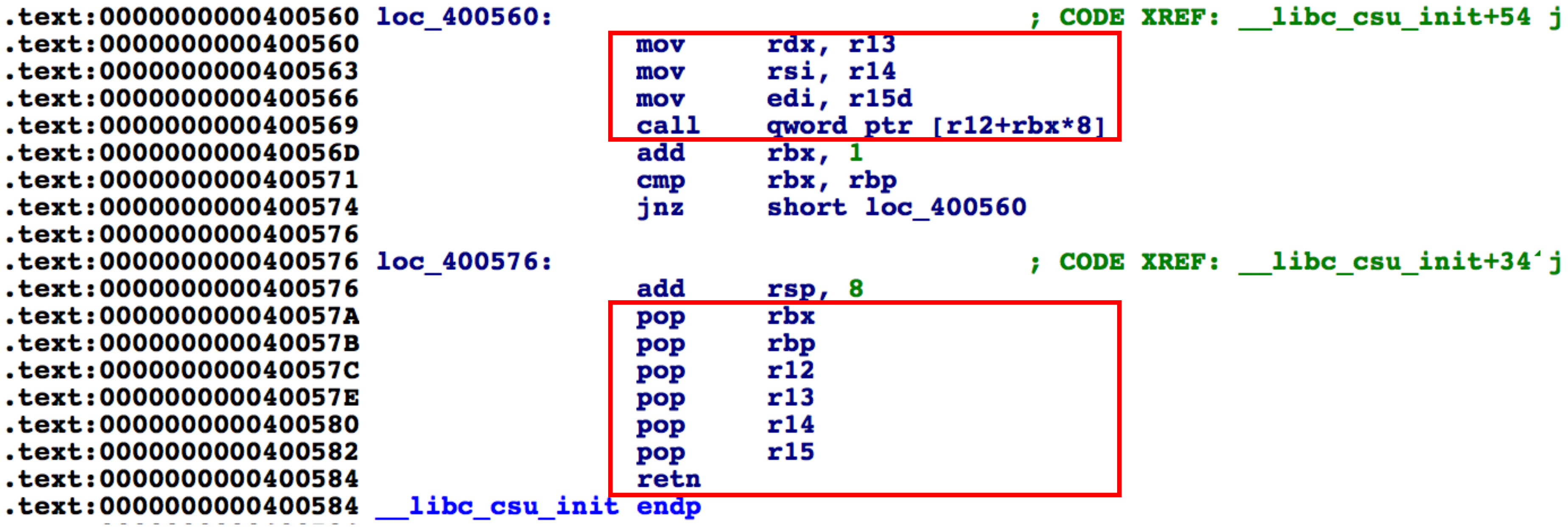


```
000000000003F76A mov     rax, cs:environ_ptr_0
000000000003F771 lea     rdi, aBinSh      ; "/bin/sh"
000000000003F778 lea     rsi, [rsp+188h+var_158]
000000000003F77D mov     cs:lock_3, 0
000000000003F787 mov     cs:sa_refcntr, 0
000000000003F791 mov     rdx, [rax]
000000000003F794 call    execve
000000000003F799 mov     edi, 7Fh         ; status
000000000003F79E call    _exit
000000000003F79E do_system endp
000000000003F79E
```



```
00000000000D7557 mov     rax, cs:environ_ptr_0
00000000000D755E lea     rsi, [rsp+1D8h+var_168]
00000000000D7563 lea     rdi, aBinSh      ; "/bin/sh"
00000000000D756A mov     rdx, [rax]
00000000000D756D call    execve
00000000000D7572 call    abort
```

__libc_csu_init Gadgets for x64



```
.text:0000000000400560 loc_400560:                             ; CODE XREF: __libc_csu_init+54 j
.text:0000000000400560                 mov     rdx, r13
.text:0000000000400563                 mov     rsi, r14
.text:0000000000400566                 mov     edi, r15d
.text:0000000000400569                 call    qword ptr [r12+rbx*8]
.text:000000000040056D                 add     rbx, 1
.text:0000000000400571                 cmp     rbx, rbp
.text:0000000000400574                 jnz     short loc_400560
.text:0000000000400576
.text:0000000000400576 loc_400576:                             ; CODE XREF: __libc_csu_init+34‘j
.text:0000000000400576                 add     rsp, 8
.text:000000000040057A                 pop     rbx
.text:000000000040057B                 pop     rbp
.text:000000000040057C                 pop     r12
.text:000000000040057E                 pop     r13
.text:0000000000400580                 pop     r14
.text:0000000000400582                 pop     r15
.text:0000000000400584                 retn
.text:0000000000400584 __libc_csu_init endp
```

References

- http://phrack.org/issues/58/4.html
- http://acez.re/ctf-writeup-hitcon-ctf-2014-stkof-or-modern-heap-overflow/
- Glibc Adventures: The Forgotten Chunks, http://www.contextis.com/documents/120/Glibc_Adventures-The_Forgotten_Chunks.pdf
- https://sploitfun.wordpress.com/2015/02/10/understanding-glibc-malloc/