Attacking the XNU Kernel in El Capitan

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About Me

- Independent vulnerability researcher from Venice, Italy
- Focusing on Apple’s products, particularly attracted by jailbreaking techniques
- Author of several XNU Kernel-related CVEs and exploits
    - “vpwn” (< 10.10.2 LPE) - CVE-2015-1140 / CVE-2015-5865
    - “tpwn” (< 10.11 LPE) - CVE-2015-5932 / CVE-2015-5847 / CVE-2015-5864
    - “npwn” (10.11 SIP bypass) - CVE-2015-6974

Why attack XNU?

- XNU has been a target primarily for iOS jailbreaking
- Yosemite enforces KEXT signatures
- El Capitan introduces “System Integrity Protection”
    - System-wide, kernel-enforced sandbox profile that prevents access to system resources
- Attacking the kernel is a viable way to bypass rootless and sandbox

the xnu heap

A quick overview

The XNU Heap: Zone Allocator (zalloc)

- zinit(…) / zalloc(zone) / zfree(zone, ptr)
- Each zone has a LIFO linked list containing free chunks
- Allocations in a zone are same-sized
- When allocating from a zone without free chunks, a new page is mapped in, page is split in chunks and each chunk is added to the free list
- Discussed in detail in countless talks by Stefan Esser

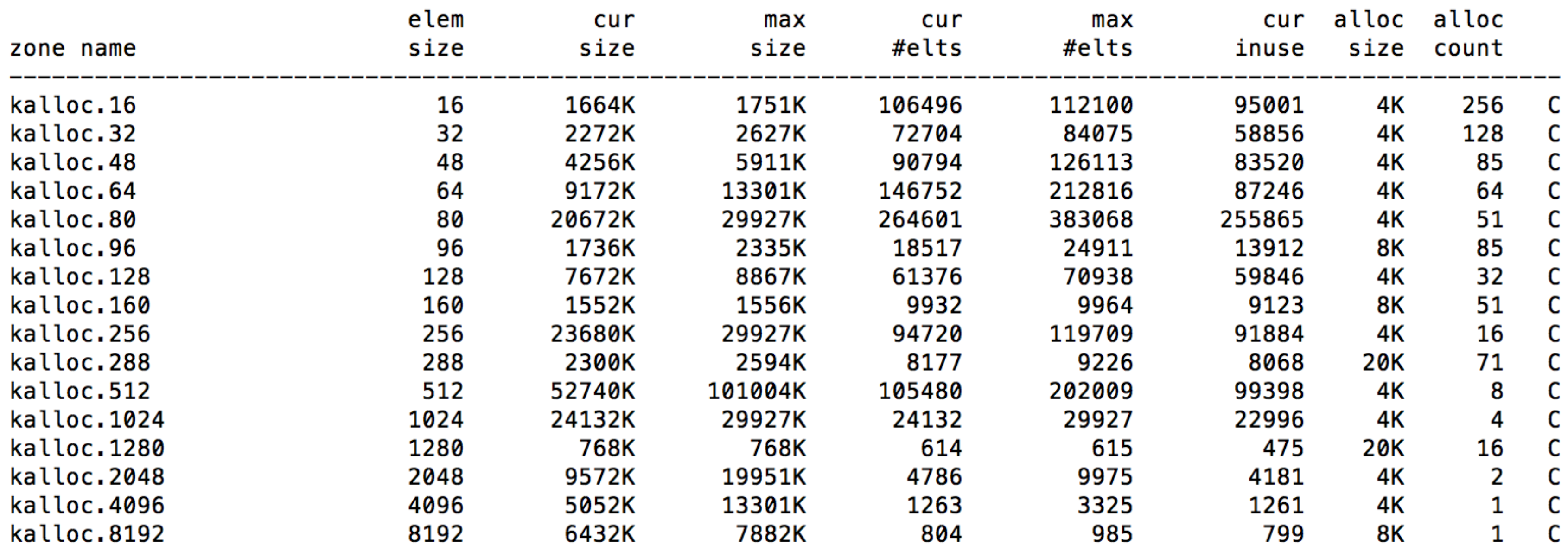
The XNU Heap: Zone Allocator (zalloc)

- No inline metadata for allocated chunks, free list metadata on free chunks
- Free list metadata is not an interesting target due to hardening
- Application metadata is the only target
- Different zones use different areas of memory, so cross-zone attacks aren’t feasible
- This does not apply to large allocations

The XNU Heap: Zone Allocator (kalloc)

- kalloc(size), kfree(ptr, size)
- Wrapper around zalloc
- Registers several generic zones with various sizes
- Essentially provides a malloc-like interface, but lack of metadata in allocated chunks requires passing “size” to kfree

The XNU Heap: Zone Allocator (kalloc)



```
                            elem         cur         max        cur         max         cur  alloc  alloc
zone name                   size        size        size      #elts       #elts       inuse   size  count
-------------------------------------------------------------------------------------------------------------
kalloc.16                     16       1664K       1751K     106496      112100       95001     4K    256   C
kalloc.32                     32       2272K       2627K      72704       84075       58856     4K    128   C
kalloc.48                     48       4256K       5911K      90794      126113       83520     4K     85   C
kalloc.64                     64       9172K      13301K     146752      212816       87246     4K     64   C
kalloc.80                     80      20672K      29927K     264601      383068      255865     4K     51   C
kalloc.96                     96       1736K       2335K      18517       24911       13912     8K     85   C
kalloc.128                   128       7672K       8867K      61376       70938       59846     4K     32   C
kalloc.160                   160       1552K       1556K       9932        9964        9123     8K     51   C
kalloc.256                   256      23680K      29927K      94720      119709       91884     4K     16   C
kalloc.288                   288       2300K       2594K       8177        9226        8068    20K     71   C
kalloc.512                   512      52740K     101004K     105480      202009       99398     4K      8   C
kalloc.1024                 1024      24132K      29927K      24132       29927       22996     4K      4   C
kalloc.1280                 1280        768K        768K        614         615         475    20K     16   C
kalloc.2048                 2048       9572K      19951K       4786        9975        4181     4K      2   C
kalloc.4096                 4096       5052K      13301K       1263        3325        1261     4K      1   C
kalloc.8192                 8192       6432K       7882K        804         985         799     8K      1   C
```

kalloc zones on 10.11

(output of “zprint kalloc” as root)

(for some reason “zprint kalloc” segfaults in 10.11, but “zprint | grep kalloc” works)

vm_map_copy corruption

A quick overview of 10.10 techniques

The XNU Heap: vm_map_copy in 10.10

- Introduced as an easy way to do data-only memory leaks by Tarjei Mandt and Mark Dowd’s HITB2012KUL “iOS 6 Security” presentation
- vm_map_copy is a structure used to hold a copy of some data
- For small amounts of data the kernel heap is used
- Targeted by an endless amount of kernel exploits

The XNU Heap: vm_map_copy in 10.10

- Allocated with kalloc(sizeof(struct vm_map_copy) + data_size)
    - **Controlled size!**
- Can be created and accessed easily via OOL mach_msg data
- Completely unaffected by sandboxing

The XNU Heap: vm_map_copy in 10.10

```
10.10 source:

struct vm_map_copy {
    int          type;
#define VM_MAP_COPY_ENTRY_LIST      1
#define VM_MAP_COPY_OBJECT      2
#define VM_MAP_COPY_KERNEL_BUFFER   3
    vm_object_offset_t  offset;
    vm_map_size_t       size;
    union {
        struct vm_map_header    hdr;    /* ENTRY_LIST */
        vm_object_t         object; /* OBJECT */
        struct {
        void                *kdata;     /* KERNEL_BUFFER */
        vm_size_t           kalloc_size;  /* size of this copy_t */
        } c_k;
    } c_u;
};
```

Usual info-leak targets

x86_64 sizeof(struct vm_map_copy) = 0x58

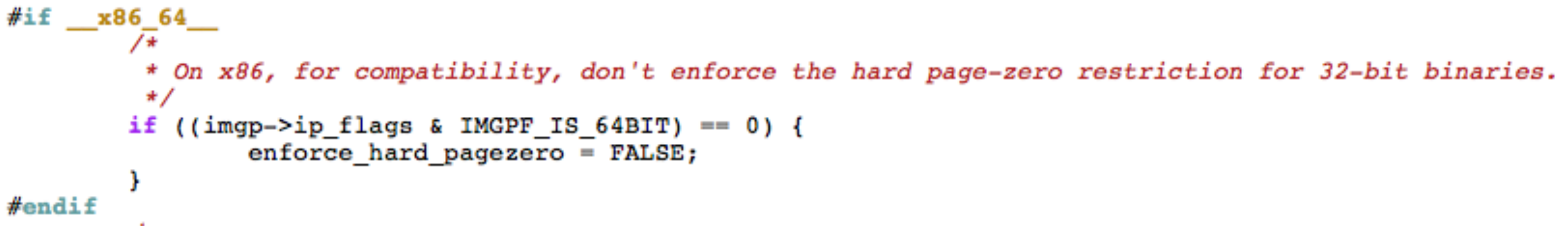
tpwn: a 10.10 kernel exploit

tpwn: a 10.10 kernel exploit

- Released in Aug 2015
- 0-day at the time
  - CVE-2015-5932 / CVE-2015-5847 / CVE-2015-5864
- Core issue is a type confusion in handling mach ports in io_service_open_extended
- Ports passed as “task” with a non-IKOT_TASK type would cause NULL to be passed as pointer to task struct to IOUserClients (CVE-2015-5932)

tpwn: __PAGEZERO strikes again

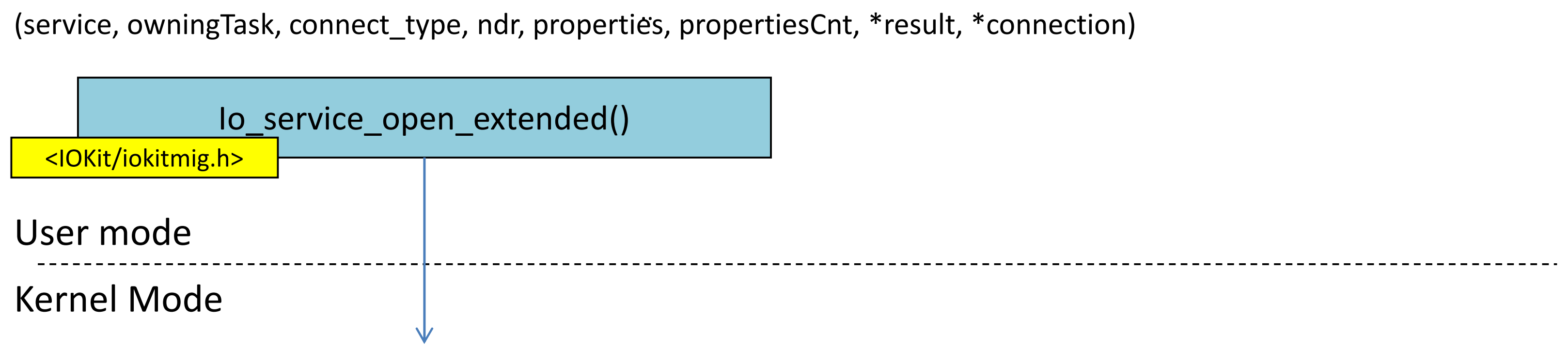
- The Mach-O format defines __PAGEZERO as a guard area
  - 32-bit: 4K, used to trap NULL pointer dereferences
- Apple enforces “hard page zero” to prevent mapping NULL
- But



```
#if __x86_64__
        /*
         * On x86, for compatibility, don't enforce the hard page-zero restriction for 32-bit binaries.
         */
        if ((imgp->ip_flags & IMGPF_IS_64BIT) == 0) {
                enforce_hard_pagezero = FALSE;
        }
#endif
```

Page zero is left wide open in 32-bit binaries!

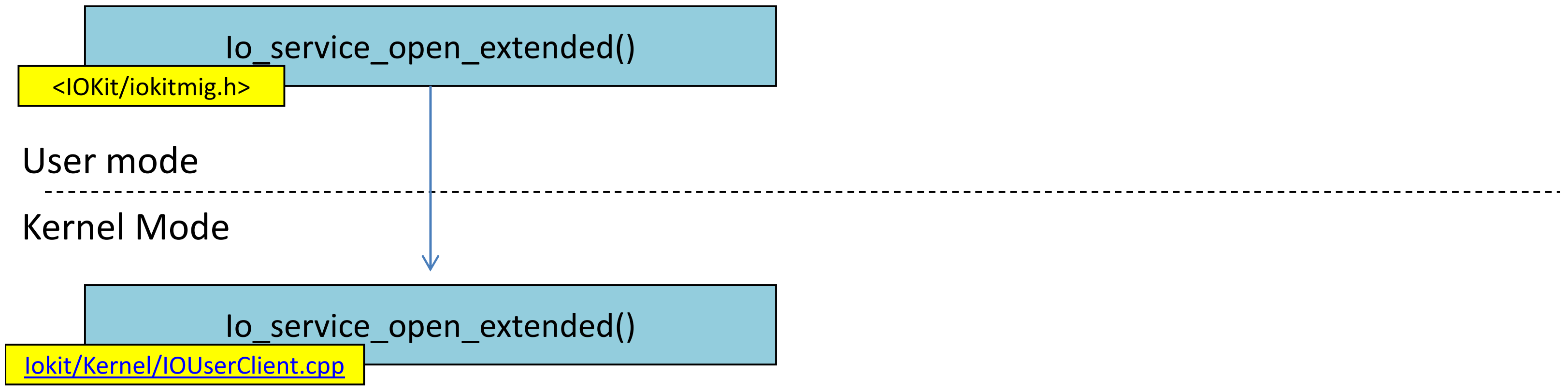
tpwn: a 10.10 kernel exploit


(service, owningTask, connect_type, ndr, properties, propertiesCnt, *result, *connection)
Io_service_open_extended()
<IOKit/iokitmig.h>
User mode
Kernel Mode

`io_service_open_extended` is one of several undocumented MIG functions to communicate with IOKit drivers from user mode

tpwn: a 10.10 kernel exploit

(service, owningTask, connect_type, ndr, properties, propertiesCnt, *result, *connection)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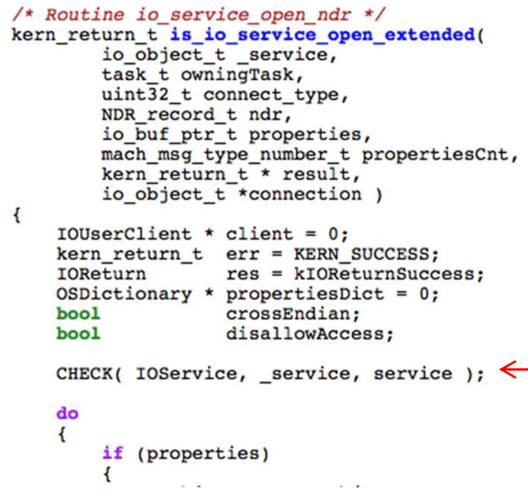
<IOKit/iokitmig.h>
User mode
Kernel Mode
Io_service_open_extended()
Iokit/Kernel/IOUserClient.cpp

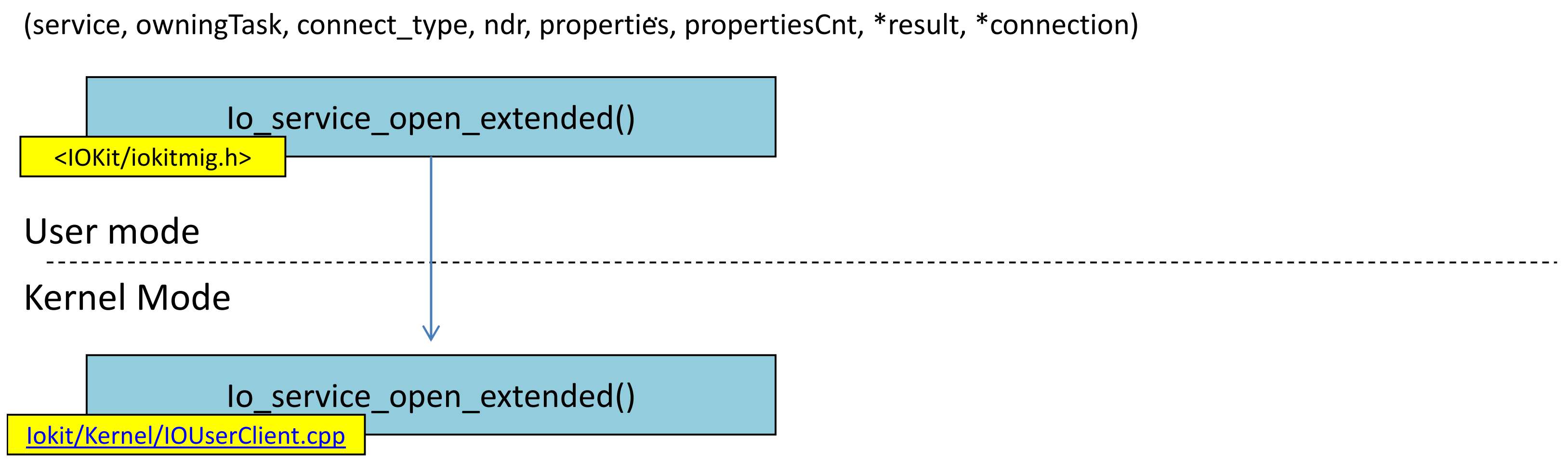


```
/* Routine io_service_open_ndr */
kern_return_t is_io_service_open_extended(
        io_object_t _service,
        task_t owningTask,
        uint32_t connect_type,
        NDR_record_t ndr,
        io_buf_ptr_t properties,
        mach_msg_type_number_t propertiesCnt,
        kern_return_t * result,
        io_object_t *connection )
{
    IOUserClient * client = 0;
    kern_return_t  err = KERN_SUCCESS;
    IOReturn       res = kIOReturnSuccess;
    OSDictionary * propertiesDict = 0;
    bool           crossEndian;
    bool           disallowAccess;

    CHECK( IOService, _service, service );

    do
    {
        if (properties)
        {
```

...

Note NO CHECK ON owningTask!

tpwn: a 10.10 kernel exploit


(service, owningTask, connect_type, ndr, properties, propertiesCnt, *result, *connection)
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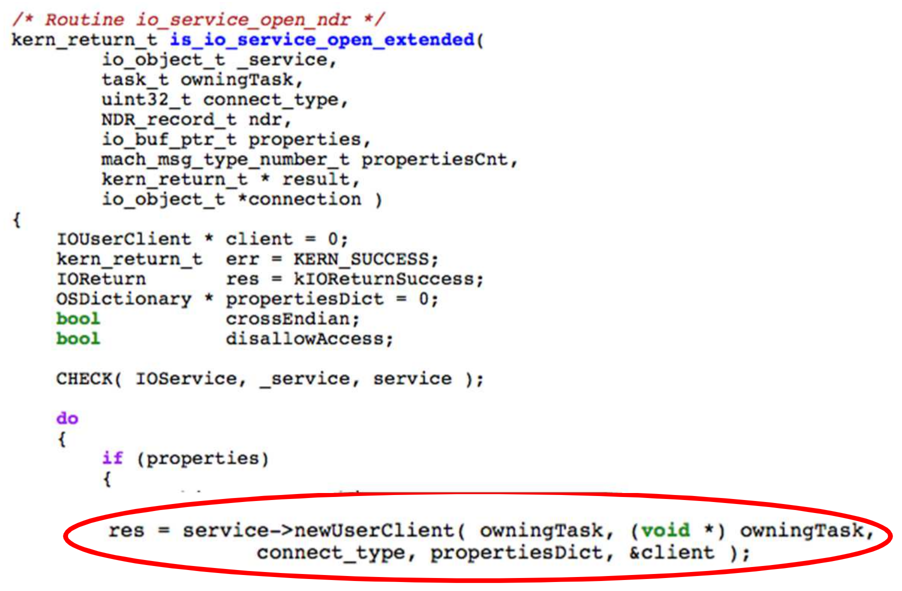
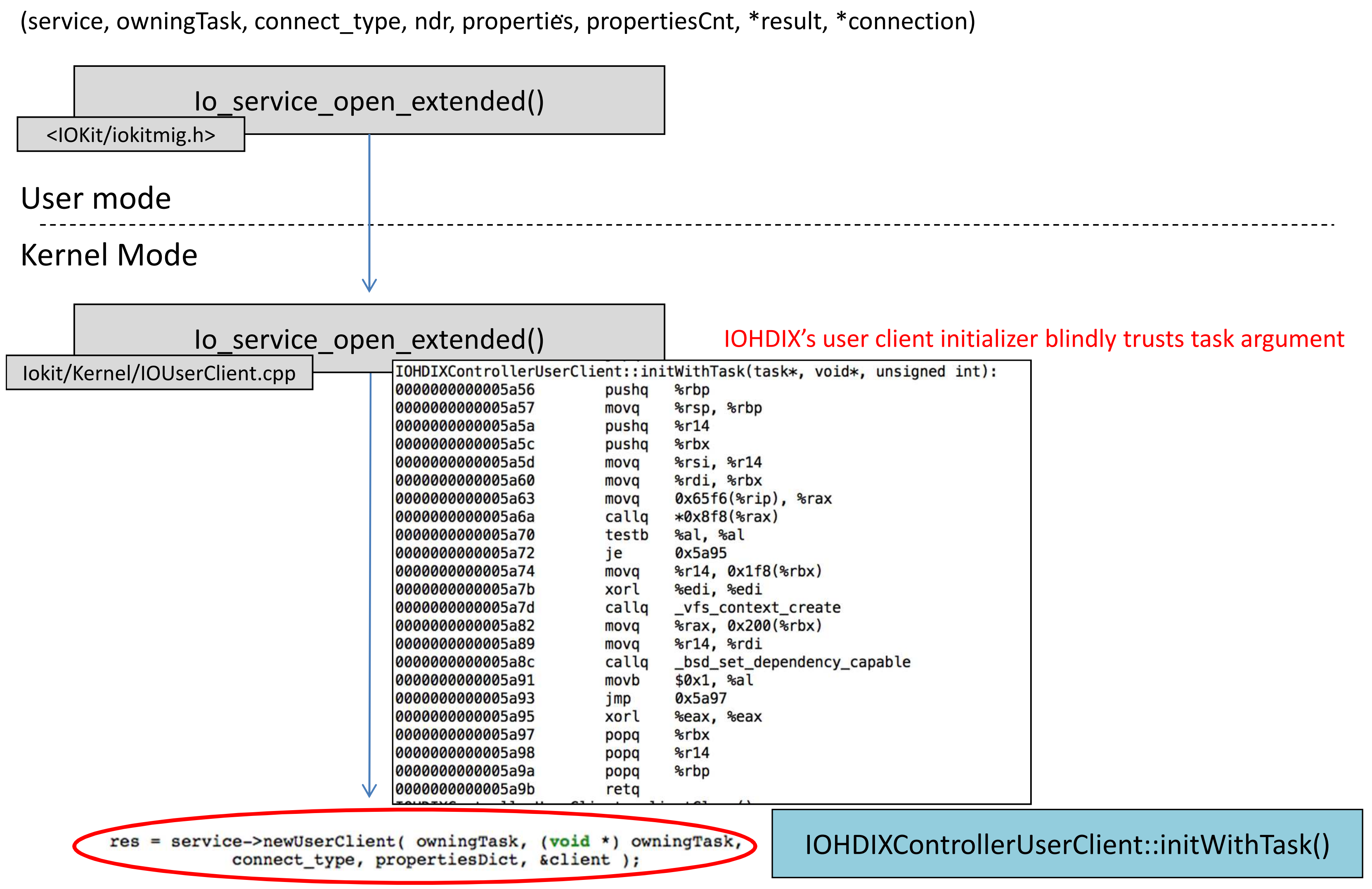
Iokit/Kernel/IOUserClient.cpp



```
/* Routine io_service_open_ndr */
kern_return_t is_io_service_open_extended(
        io_object_t _service,
        task_t owningTask,
        uint32_t connect_type,
        NDR_record_t ndr,
        io_buf_ptr_t properties,
        mach_msg_type_number_t propertiesCnt,
        kern_return_t * result,
        io_object_t *connection )
{
    IOUserClient * client = 0;
    kern_return_t  err = KERN_SUCCESS;
    IOReturn       res = kIOReturnSuccess;
    OSDictionary * propertiesDict = 0;
    bool           crossEndian;
    bool           disallowAccess;

    CHECK( IOService, _service, service );

    do
    {
        if (properties)
        {

        res = service->newUserClient( owningTask, (void *) owningTask,
                    connect_type, propertiesDict, &client );
```

owningTask then gets passed to User Clients

tpwn: a 10.10 kernel exploit

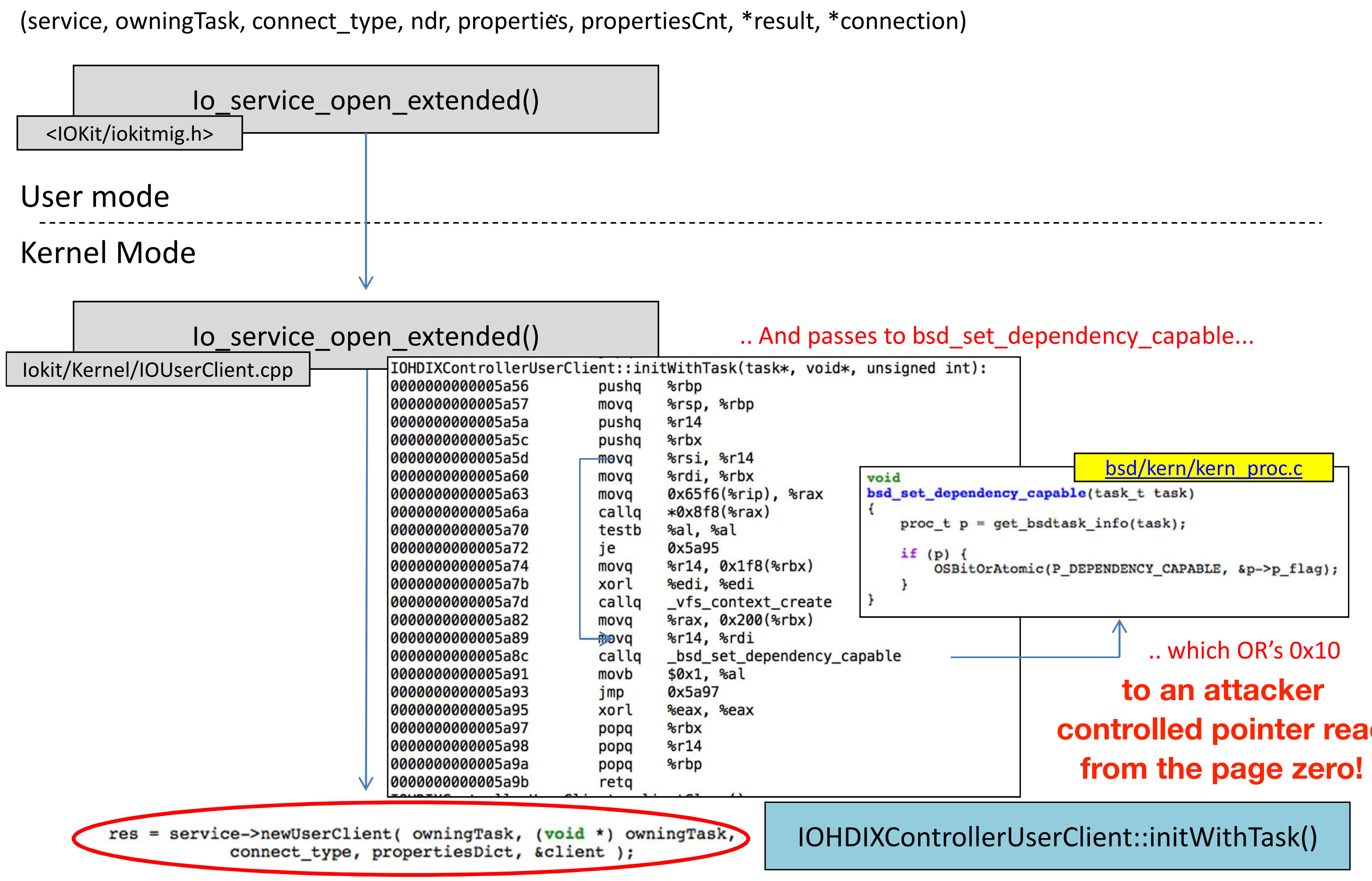


(service, owningTask, connect_type, ndr, properties, propertiesCnt, *result, *connection)
Io_service_open_extended()
<IOKit/iokitmig.h>
User mode
Kernel Mode
Io_service_open_extended()
Iokit/Kernel/IOUserClient.cpp
IOHDIX's user client initializer blindly trusts task argument
IOHDIXControllerUserClient::initWithTask()

```
IOHDIXControllerUserClient::initWithTask(task*, void*, unsigned int):
0000000000005a56        pushq   %rbp
0000000000005a57        movq    %rsp, %rbp
0000000000005a5a        pushq   %r14
0000000000005a5c        pushq   %rbx
0000000000005a5d        movq    %rsi, %r14
0000000000005a60        movq    %rdi, %rbx
0000000000005a63        movq    0x65f6(%rip), %rax
0000000000005a6a        callq   *0x8f8(%rax)
0000000000005a70        testb   %al, %al
0000000000005a72        je      0x5a95
0000000000005a74        movq    %r14, 0x1f8(%rbx)
0000000000005a7b        xorl    %edi, %edi
0000000000005a7d        callq   _vfs_context_create
0000000000005a82        movq    %rax, 0x200(%rbx)
0000000000005a89        movq    %r14, %rdi
0000000000005a8c        callq   _bsd_set_dependency_capable
0000000000005a91        movb    $0x1, %al
0000000000005a93        jmp     0x5a97
0000000000005a95        xorl    %eax, %eax
0000000000005a97        popq    %rbx
0000000000005a98        popq    %r14
0000000000005a9a        popq    %rbp
0000000000005a9b        retq
```

```
res = service->newUserClient( owningTask, (void *) owningTask,
              connect_type, propertiesDict, &client );
```

tpwn: a 10.10 kernel exploit


(service, owningTask, connect_type, ndr, properties, propertiesCnt, *result, *connection)
Io_service_open_extended()
<IOKit/iokitmig.h>
User mode
Kernel Mode
Io_service_open_extended()
Iokit/Kernel/IOUserClient.cpp
.. And passes to bsd_set_dependency_capable...
bsd/kern/kern_proc.c
.. which OR's 0x10

to an attacker controlled pointer read from the page zero!

```
IOHDIXControllerUserClient::initWithTask(task*, void*, unsigned int):
0000000000005a56        pushq   %rbp
0000000000005a57        movq    %rsp, %rbp
0000000000005a5a        pushq   %r14
0000000000005a5c        pushq   %rbx
0000000000005a5d        movq    %rsi, %r14
0000000000005a60        movq    %rdi, %rbx
0000000000005a63        movq    0x65f6(%rip), %rax
0000000000005a6a        callq   *0x8f8(%rax)
0000000000005a70        testb   %al, %al
0000000000005a72        je      0x5a95
0000000000005a74        movq    %r14, 0x1f8(%rbx)
0000000000005a7b        xorl    %edi, %edi
0000000000005a7d        callq   _vfs_context_create
0000000000005a82        movq    %rax, 0x200(%rbx)
0000000000005a89        movq    %r14, %rdi
0000000000005a8c        callq   _bsd_set_dependency_capable
0000000000005a91        movb    $0x1, %al
0000000000005a93        jmp     0x5a97
0000000000005a95        xorl    %eax, %eax
0000000000005a97        popq    %rbx
0000000000005a98        popq    %r14
0000000000005a9a        popq    %rbp
0000000000005a9b        retq
```

```
void
bsd_set_dependency_capable(task_t task)
{
    proc_t p = get_bsdtask_info(task);

    if (p) {
        OSBitOrAtomic(P_DEPENDENCY_CAPABLE, &p->p_flag);
    }
}
```

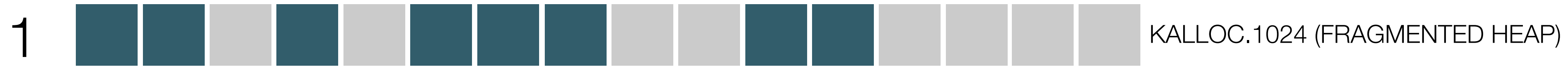
```
res = service->newUserClient( owningTask, (void *) owningTask,
        connect_type, propertiesDict, &client );
```

IOHDIXControllerUserClient::initWithTask()

tpwn: a 10.10 kernel exploit

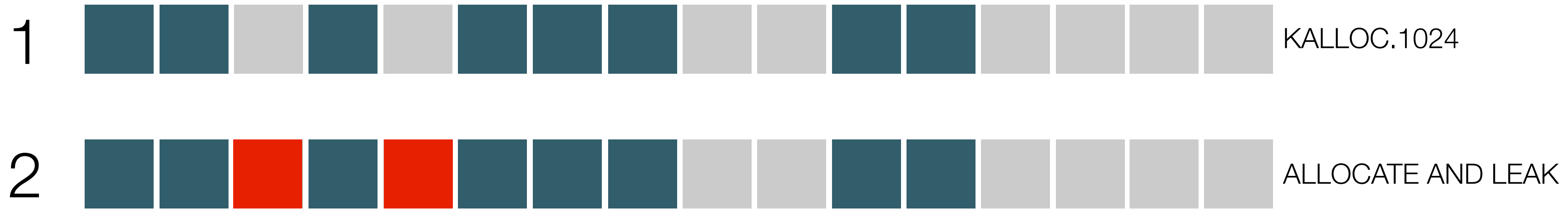
- Using an heap info leak (CVE-2015-5864) we can locate a C++ object in kalloc.1024
- We need to locate a vm_map_copy and make sure it's adjacent to a C++ object
- Corrupt the size of the vm_map_copy to read the C++ object's memory
- Derive kASLR slide from there
- Gain instruction pointer control, pivot the stack

tpwn: controlling the heap layout



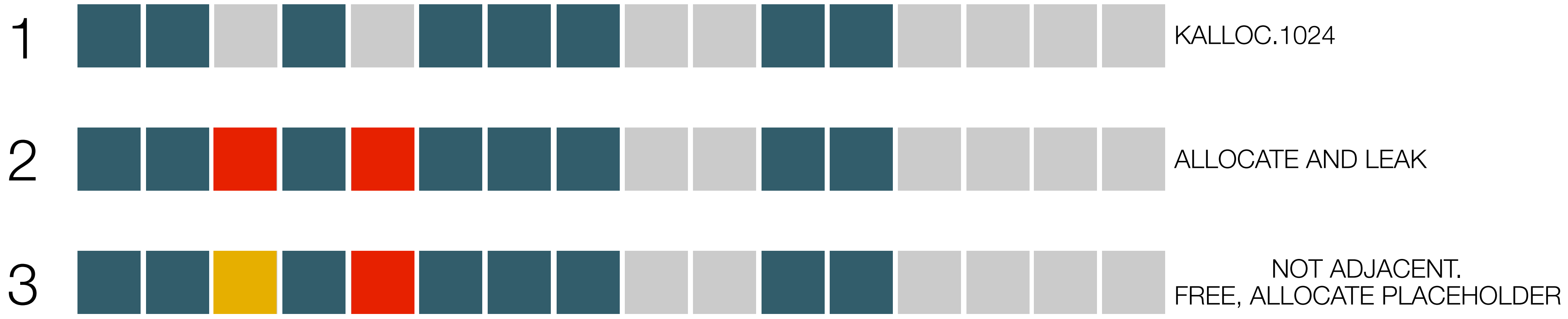
🟦 ALLOCATED ⬜ FREE HOLE 🟥 IOAudioEngineUserClient 🟨 vm_map_copy

tpwn: controlling the heap layout



🟦	ALLOCATED	⬜	FREE HOLE	🟥	IOAudioEngineUserClient	🟨	vm_map_copy

tpwn: controlling the heap layout



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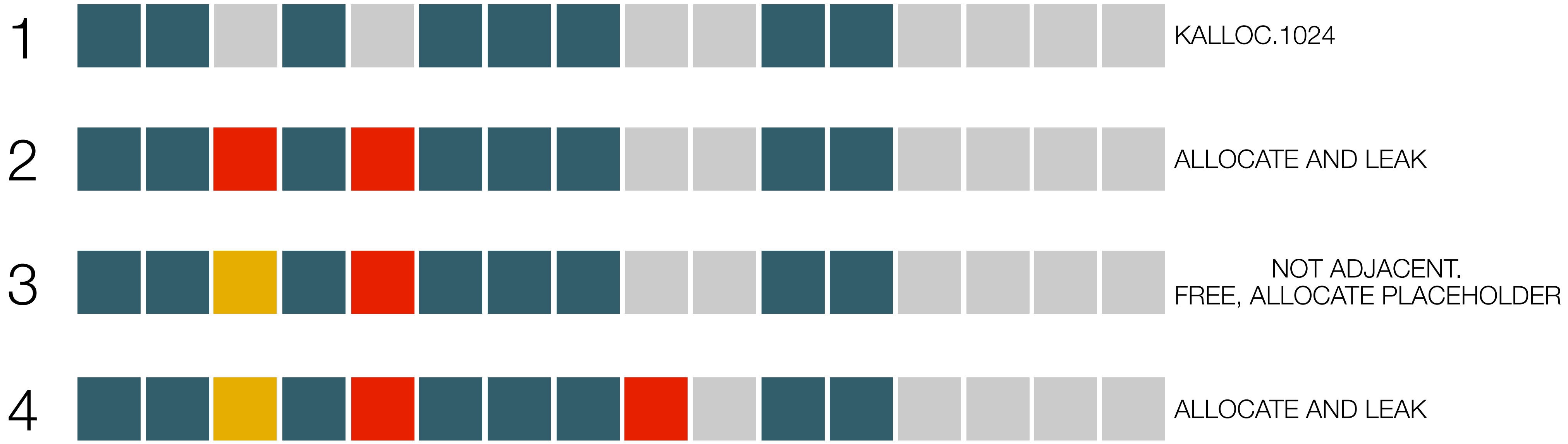
tpwn: controlling the heap layout



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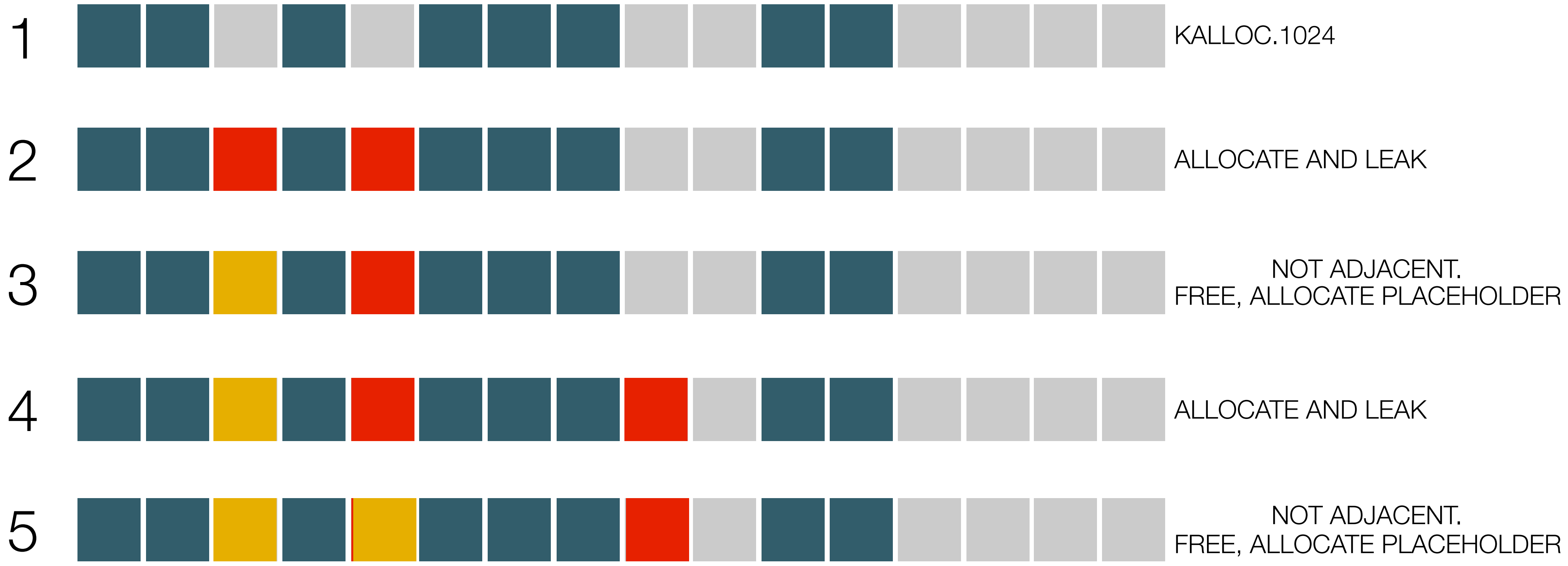
tpwn: controlling the heap layout



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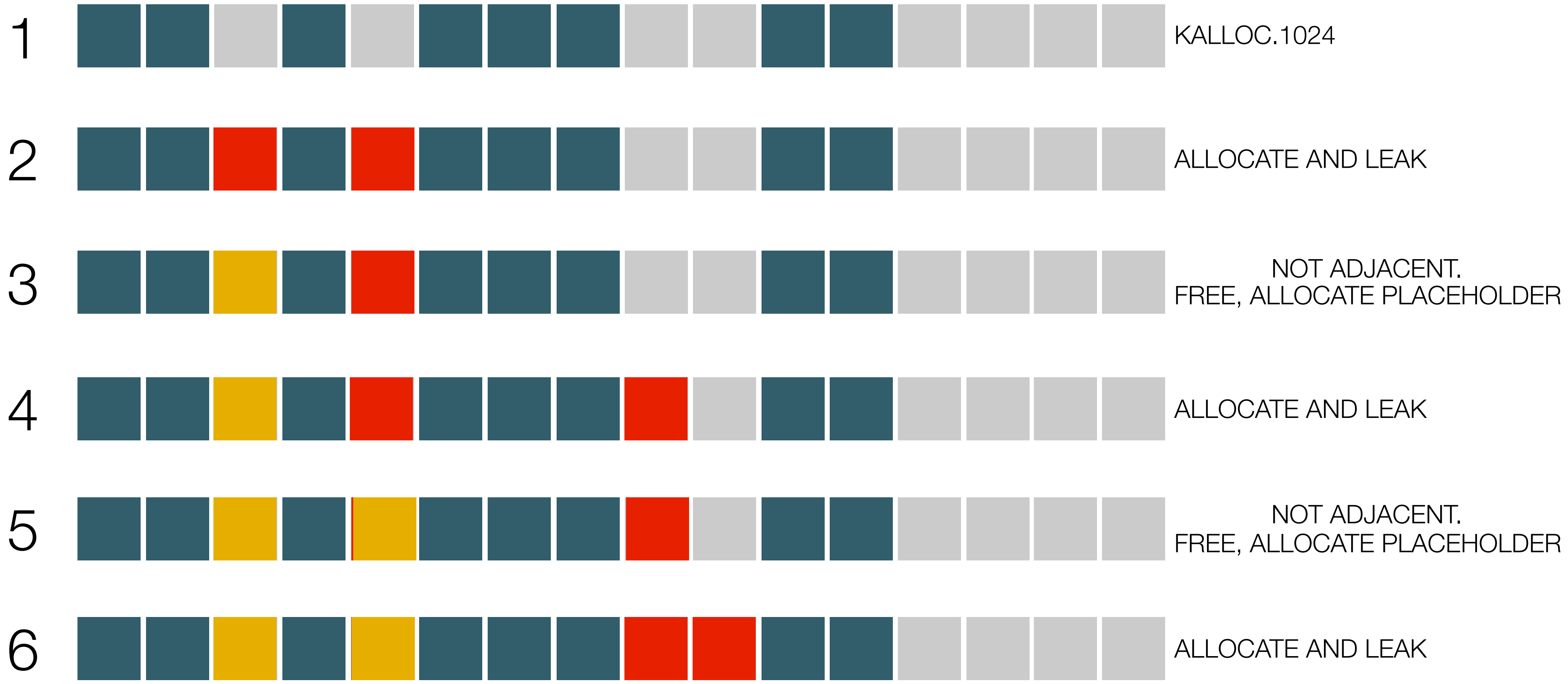
tpwn: controlling the heap layout



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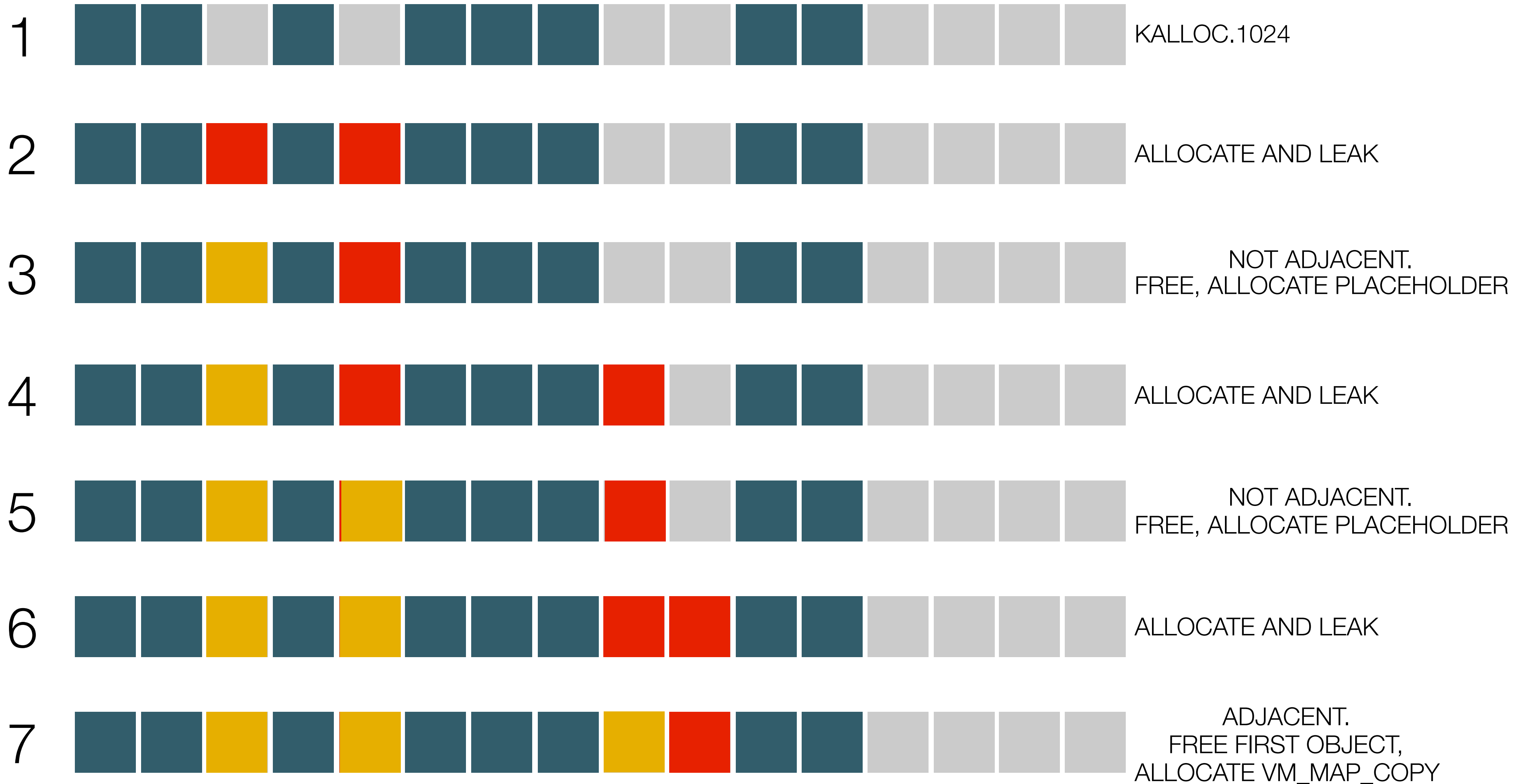
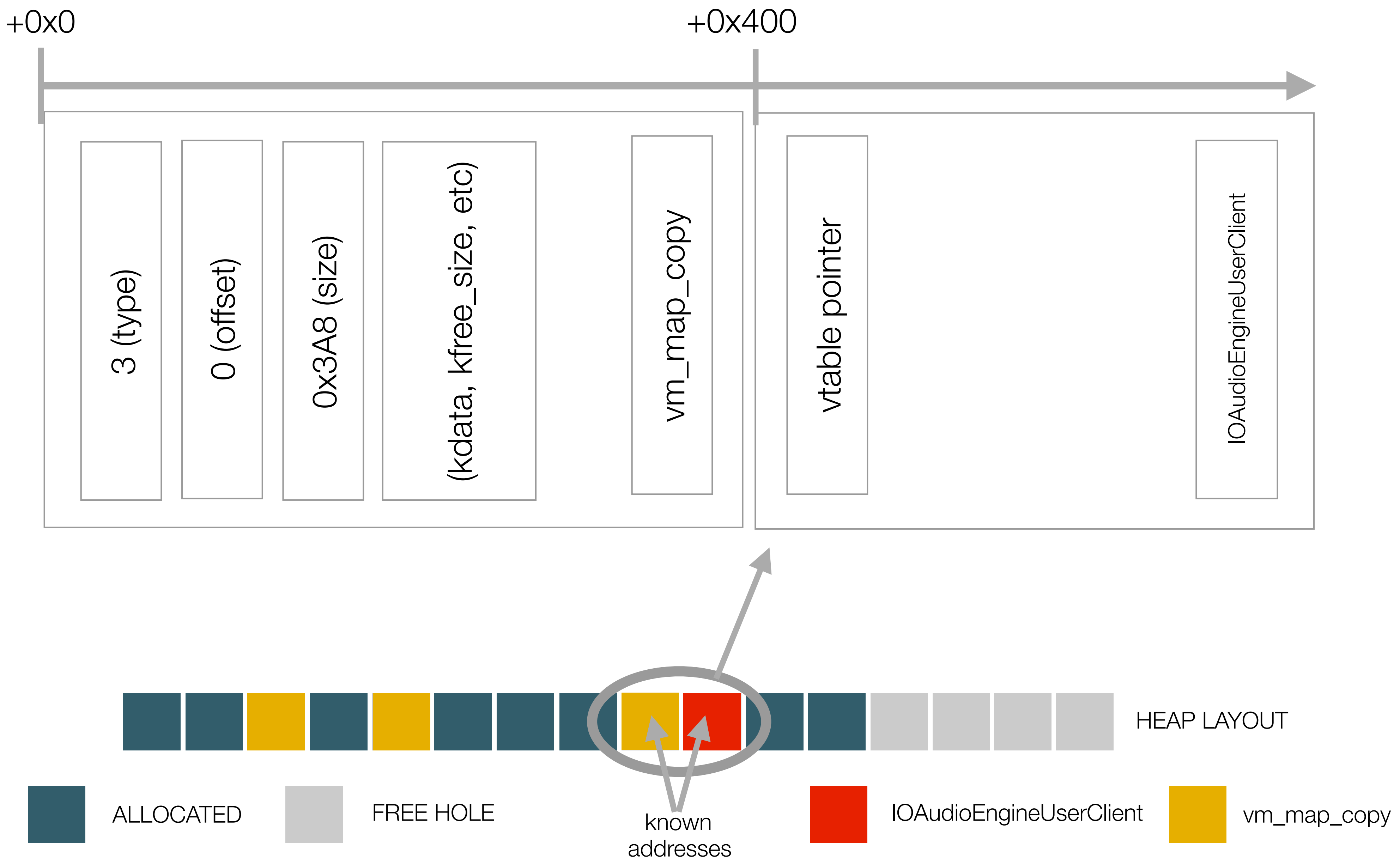
tpwn: controlling the heap layout

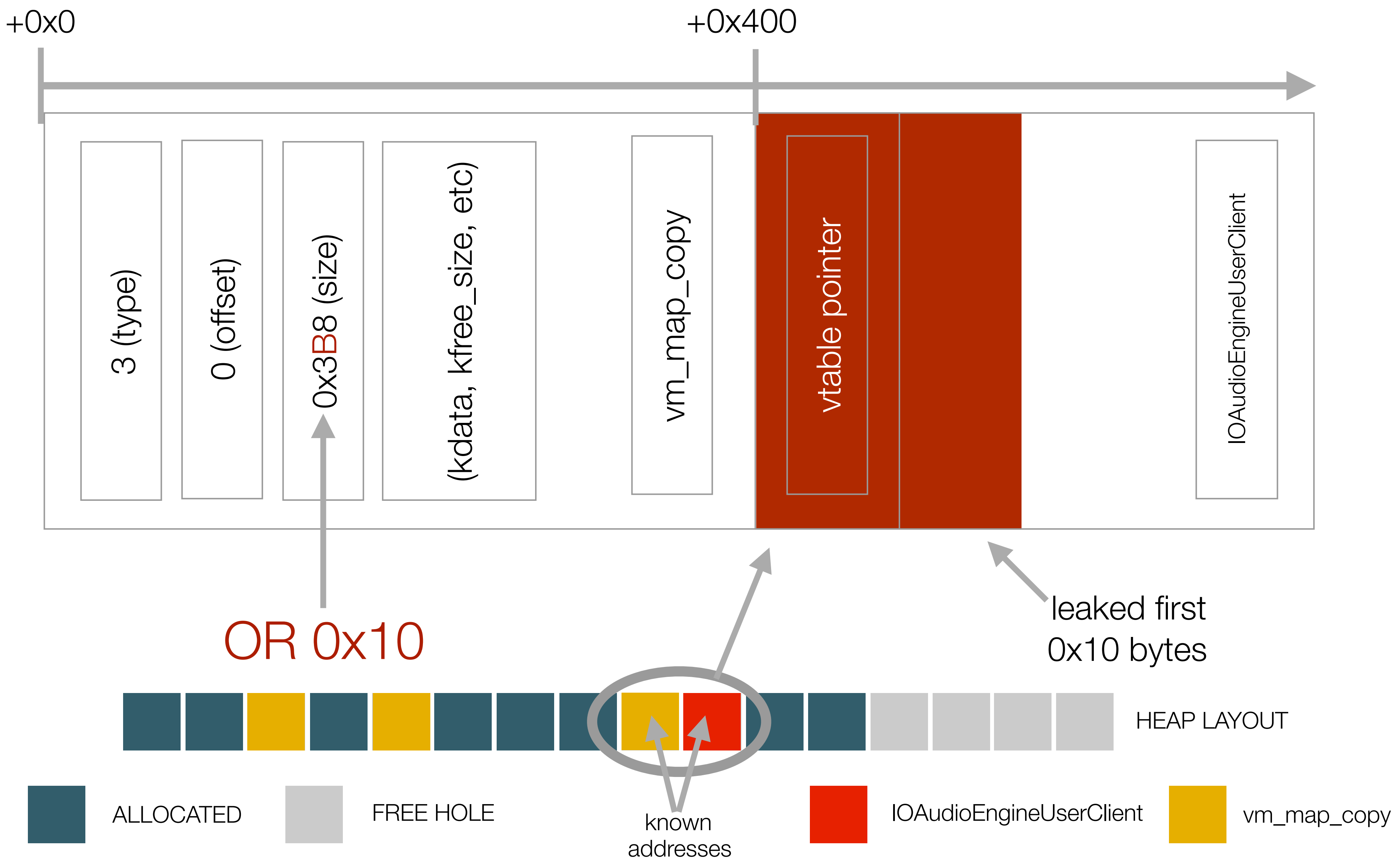


🟦 ALLOCATED ⬜ FREE HOLE 🟥 IOAudioEngineUserClient 🟨 vm_map_copy

tpwn: 10.10 kASLR leaking strategy



tpwn: 10.10 kASLR leaking strategy



tpwn: a 10.10 kernel exploit

- Result:

https://github.com/kpwn/tpwn

(fairly straightforward code)

vm_map_copy corruption

10.11 Info Leaking Strategies

The XNU Heap: vm_map_copy in 10.11

- Structure has been changed in 10.11
- On x86_64 sizeof(vm_map_copy) is 0x18 now

```
10.11 debug kernel:
struct vm_map_copy
{
  int type;
  vm_object_offset_t offset;
  vm_map_size_t size;
  vm_map_copy::$30C14F0EB10F809AE5F27A96BE564370 c_u;
};

union vm_map_copy::$30C14F0EB10F809AE5F27A96BE564370
{
  vm_map_header hdr;
  vm_object_t object;
  uint8_t_0 kdata[];
};
```

```
10.10 source:

struct vm_map_copy {
    int         type;
#define VM_MAP_COPY_ENTRY_LIST      1
#define VM_MAP_COPY_OBJECT      2
#define VM_MAP_COPY_KERNEL_BUFFER   3
    vm_object_offset_t  offset;
    vm_map_size_t       size;
    union {
        struct vm_map_header    hdr;    /* ENTRY_LIST */
        vm_object_t         object; /* OBJECT */
        struct {
        void            *kdata;       /* KERNEL_BUFFER */
        vm_size_t       kalloc_size;  /* size of this copy_t */
        } c_k;
    } c_u;
};
```

The XNU Heap: vm_map_copy in 10.11

- Size to kfree and data size have been unified
  - Cannot read adjacent memory without corrupting it, since increasing data size past heap allocation boundaries will free into the wrong zone
- Pointer to data has been removed
  - Can’t read data pointer off adjacent vm_map_copy
  - Can’t swap data pointer to leak arbitrary memory
- New techniques are needed

vm_map_copy: Leaking adjacent data in 10.11

- Leaking adjacent bytes can now be done only by first reading and corrupting, then writing back the read data
    - Not as reliable as corrupting data size since it involves a re-allocation

Leaking heap pointers in 10.11

- You can’t read the data pointer off a vm_map_copy to leak heap pointers since it has been removed from the structure
- Heap address leaks are useful since they allow you to locate controlled data in the kernel heap
- Just use another structure containing heap pointers
- The free list is an easy target

Leaking heap pointers in 10.11

- Allocate two adjacent vm_map_copy structures
- Free the second
- Corrupt the first to increase size
- Read the first (leaking adjacent memory)
- Allocate a new vm_map_copy with the leaked data
- Allocate two vm_map_copy structures in the same zone, second you allocate will be located at the pointer you've leaked off the free list

Leaking arbitrary memory in 10.11

- You can’t swap the data pointer off a vm_map_copy to get arbitrary memory leaks since it has been removed from the structure
- OSData is a kernel C++ object used to represent generic data. On x86_64 it lives in kalloc.48
- Use io_service_open_extended’s OSUnserializeXML to create OSData objects
  - Although dated, the “iOS Kernel Heap Armageddon” talk by Esser explains more about OSUnserializeXML and libkern objects

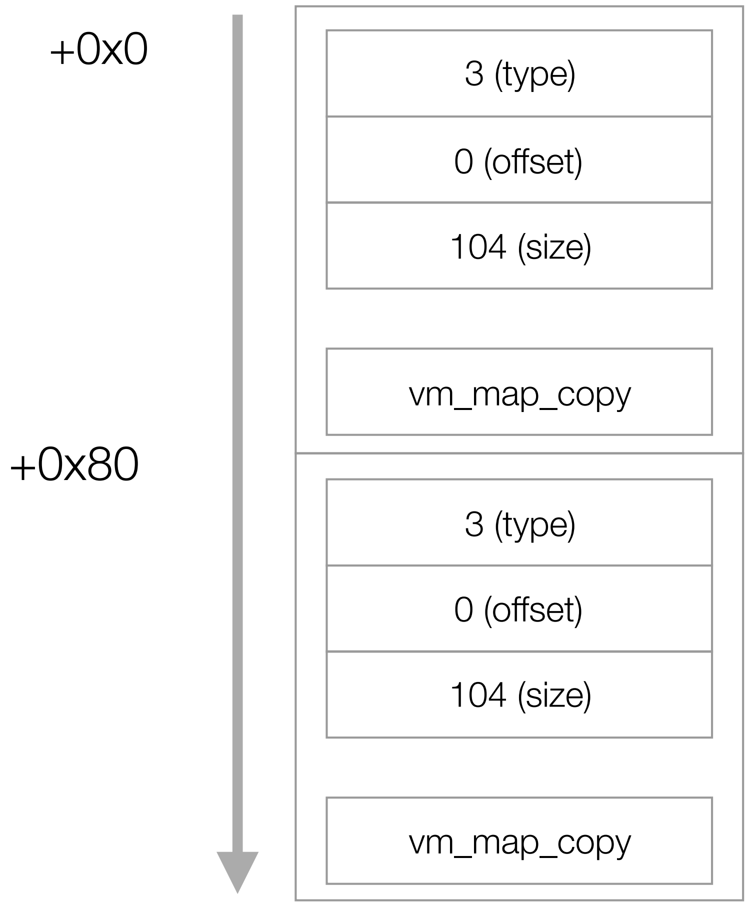
Leaking arbitrary memory in 10.11

- Allocate two adjacent vm_map_copy structures
- Corrupt the first one's size
- Read out the data, change the second structure's size to 24, write it back
- Read the second vm_map_copy out, causing a wrong free to the kalloc.48 zone
- Allocate OSData

Leaking arbitrary memory in 10.11

- OSData object now overlaps vm_map_copy’s data
- Can read/write to it in userland
- vtable pointer leaks kASLR slide
- Data pointer leaks a pointer to arbitrary user-controlled data
- Changing the data pointer and setting capacity to 0xFFFFFFFF allows arbitrary memory leaks on 10.11 -> Just use IORegistryEntryCreateCFProperties to retrieve data

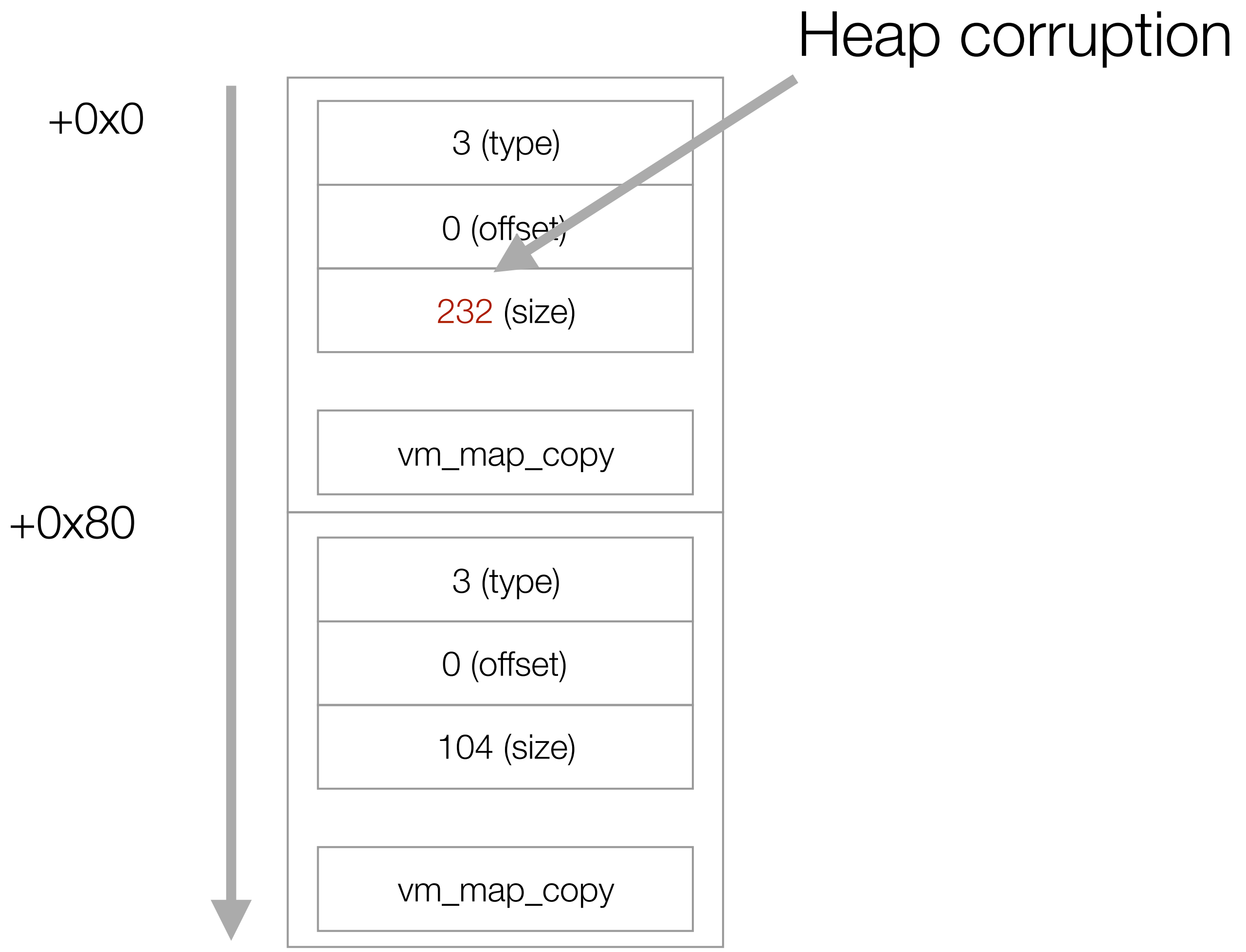
Leaking arbitrary memory in 10.11



🟥 overlapping heap chunk ⬜ heap chunk

(assuming kalloc.128)

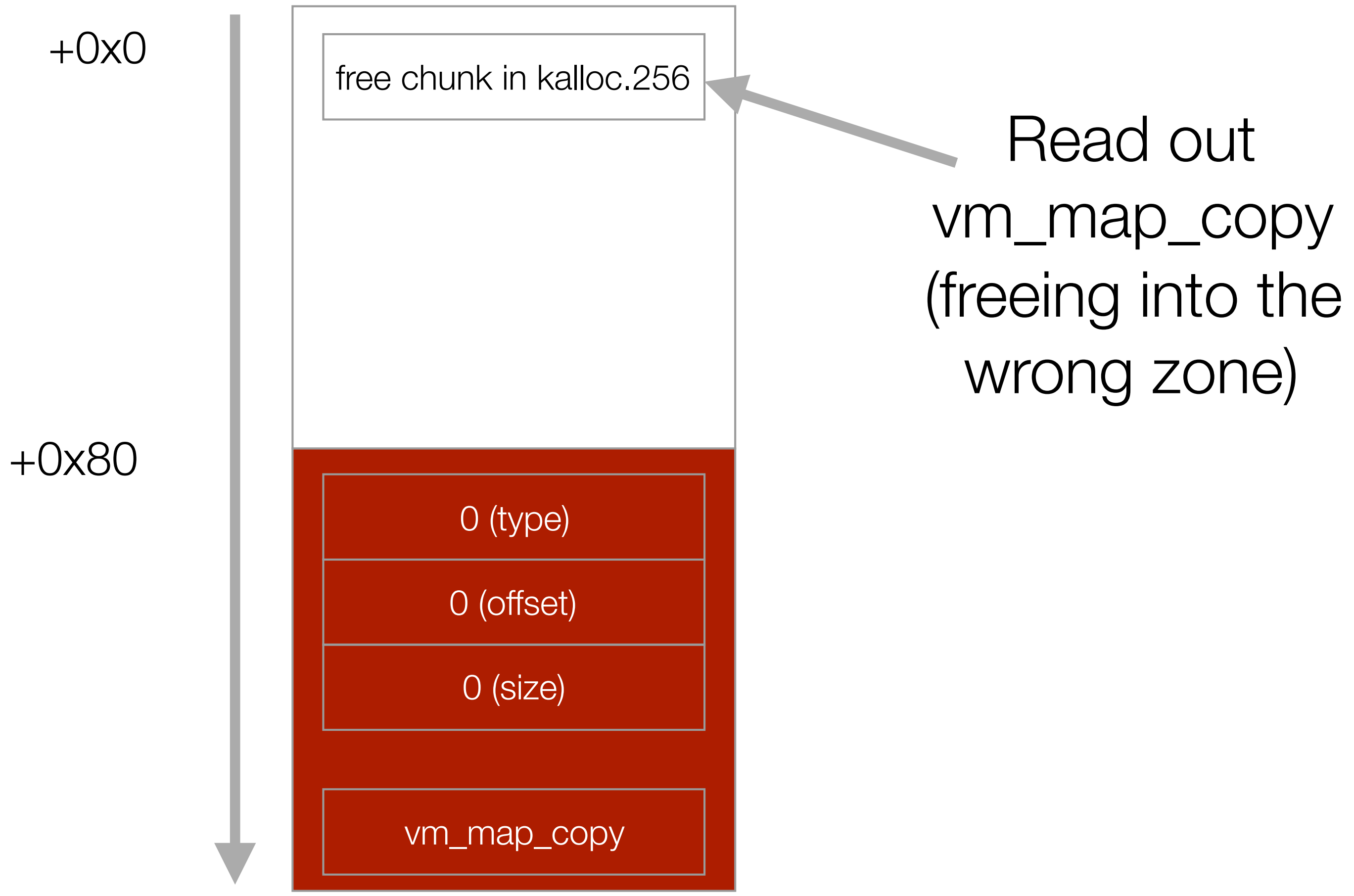
Leaking arbitrary memory in 10.11



🟥 overlapping heap chunk ⬜ heap chunk

(assuming kalloc.128)

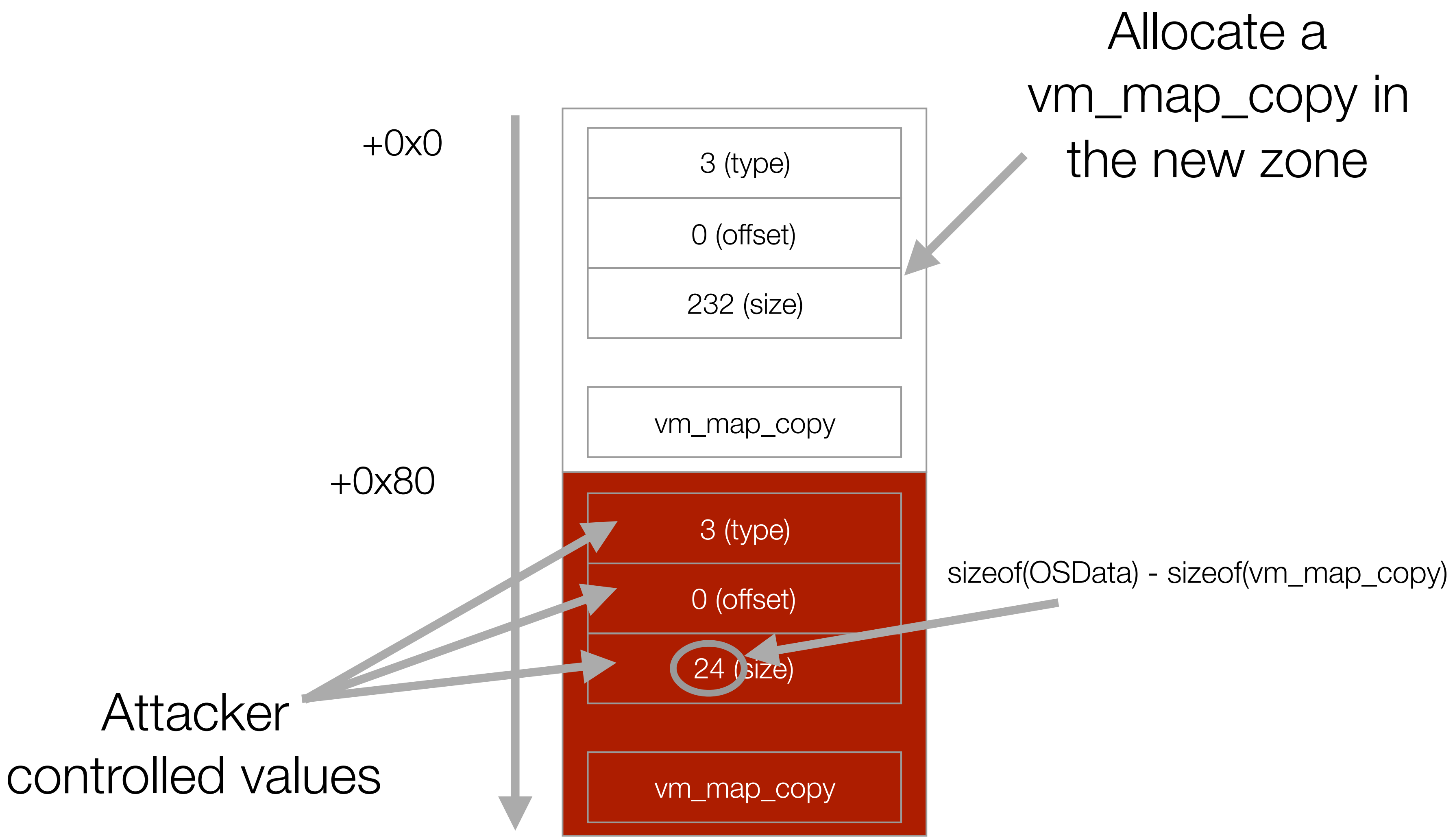
Leaking arbitrary memory in 10.11



🟥 overlapping heap chunk ⬜ heap chunk

(assuming kalloc.128)

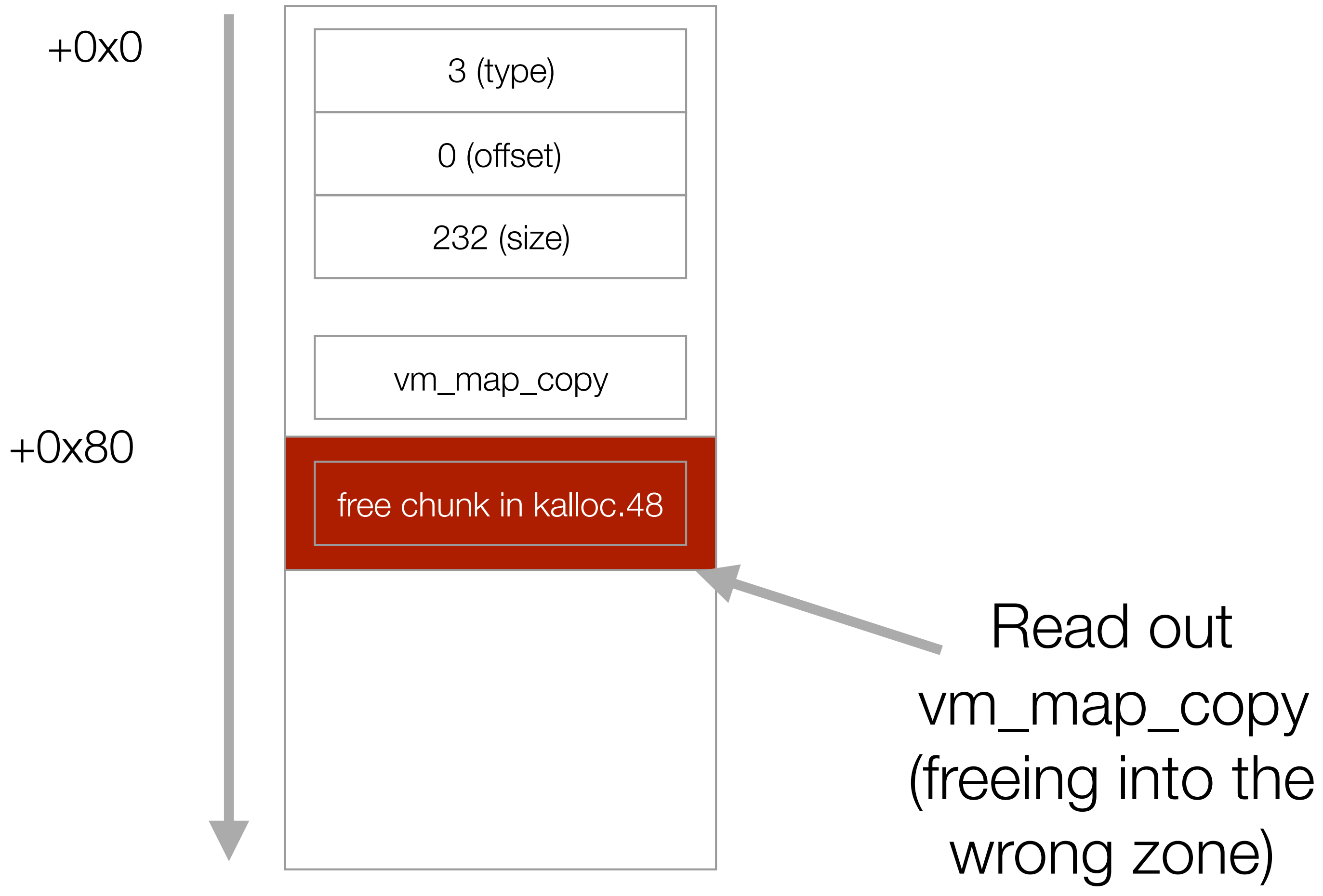
Leaking arbitrary memory in 10.11


Allocate a vm_map_copy in the new zone
+0x0
3 (type)
0 (offset)
232 (size)
vm_map_copy
+0x80
3 (type)
0 (offset)
24 (size)
vm_map_copy
sizeof(OSData) - sizeof(vm_map_copy)
Attacker controlled values

🟥 overlapping heap chunk ⬜ heap chunk

(assuming kalloc.128)

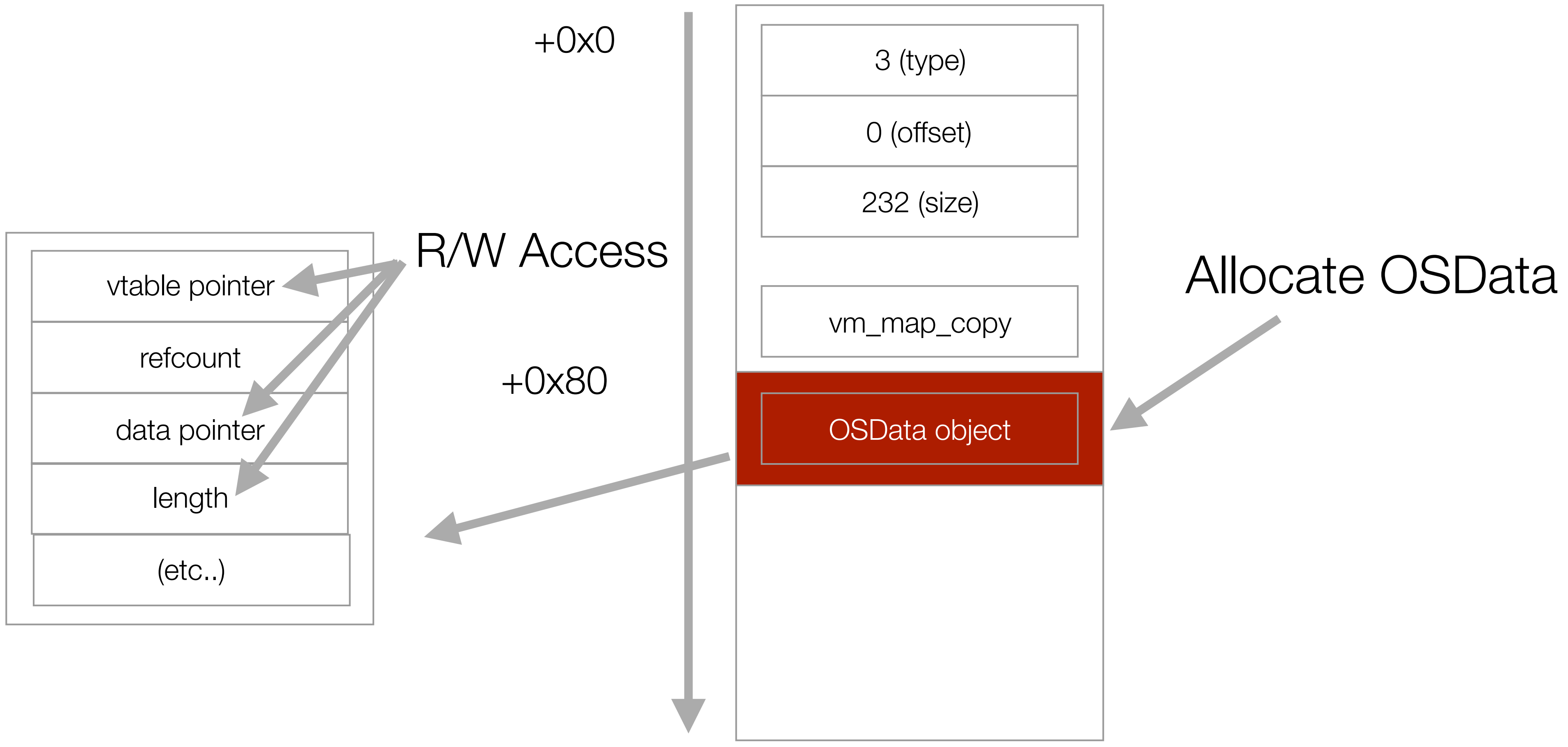
Leaking arbitrary memory in 10.11



🟥 overlapping heap chunk ⬜ heap chunk

(assuming kalloc.128)

Leaking arbitrary memory in 10.11



🟥 overlapping heap chunk ☐ heap chunk

(assuming kalloc.128)

zalloc() timing attack

A new technique to increase heap feng shui reliability

zalloc() Timing Attack

- Most heap attacks require adjacent allocations of some sort
- You can get adjacent allocations fairly easily by emptying the free list since the layout of allocations in newly mapped pages is deterministic
- However you don’t get to know exactly when a particular free list runs out unless uid=0 and PE_i_can_has_debugger() returns 1
- You can try to guess by picking an “high enough” number of allocations, but this yields to probabilistic exploits (which are good enough for e.g. jailbreaking)

zalloc() Timing Attack

- You can get adjacent allocations fairly easily by emptying the free list since **the layout of allocations in newly mapped pages is deterministic**
- Mapping pages is expensive
- Expensive enough to detect it in userland?

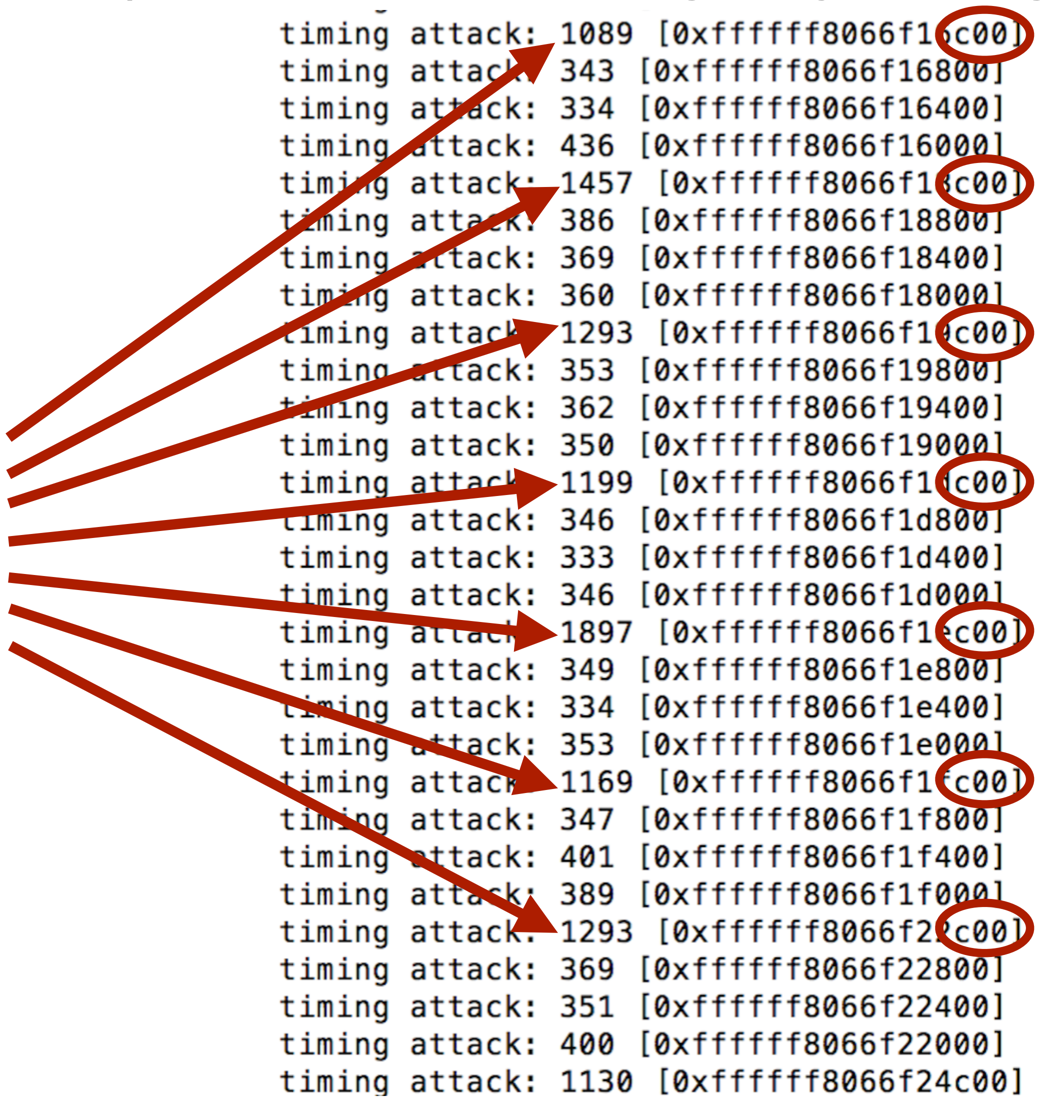
zalloc() Timing Attack

- In kalloc.1024, using a heap info leak to verify adjacency

time of execution of a mach_msg call with OOL data

vm_map_copyin

(newly mapped page)



```
timing attack: 1089 [0xffffff8066f16c00]
timing attack: 343 [0xffffff8066f16800]
timing attack: 334 [0xffffff8066f16400]
timing attack: 436 [0xffffff8066f16000]
timing attack: 1457 [0xffffff8066f18c00]
timing attack: 386 [0xffffff8066f18800]
timing attack: 369 [0xffffff8066f18400]
timing attack: 360 [0xffffff8066f18000]
timing attack: 1293 [0xffffff8066f19c00]
timing attack: 353 [0xffffff8066f19800]
timing attack: 362 [0xffffff8066f19400]
timing attack: 350 [0xffffff8066f19000]
timing attack: 1199 [0xffffff8066f1dc00]
timing attack: 346 [0xffffff8066f1d800]
timing attack: 333 [0xffffff8066f1d400]
timing attack: 346 [0xffffff8066f1d000]
timing attack: 1897 [0xffffff8066f1ec00]
timing attack: 349 [0xffffff8066f1e800]
timing attack: 334 [0xffffff8066f1e400]
timing attack: 353 [0xffffff8066f1e000]
timing attack: 1169 [0xffffff8066f1fc00]
timing attack: 347 [0xffffff8066f1f800]
timing attack: 401 [0xffffff8066f1f400]
timing attack: 389 [0xffffff8066f1f000]
timing attack: 1293 [0xffffff8066f22c00]
timing attack: 369 [0xffffff8066f22800]
timing attack: 351 [0xffffff8066f22400]
timing attack: 400 [0xffffff8066f22000]
timing attack: 1130 [0xffffff8066f24c00]
```

zalloc() Timing Attack

- You can get adjacent allocations fairly easily by emptying the free list since the layout of allocations in **newly mapped pages** is deterministic
- Mapping pages is expensive
- Expensive enough to detect it in userland? Yes!

zalloc() Timing Attack

- A good target to time is vm_map_copyin
- Create a bunch of vm_map_copy structs via mach_msg
- Read them out
- Recreate them, timing and keeping an average
- You are guaranteed that the average doesn't represent newly mapped memory
- Keeping those allocated, allocate more, timing mach_msg

zalloc() Timing Attack

- Once you get a mach_msg taking more time than the average * 1.5, a new page has just been mapped in
- Number of free list entries added = PAGE_SIZE/zone size
- Do more mach_msg timing
- A time spike is expected to happen after “number of free list entries added” allocations
- If it does, for additional reliability, do it again for another page

zalloc() Timing Attack

- Once you have pages filled with adjacent vm_map_copy structures, you can easily craft the heap layout by poking holes and reallocating the objects that most suit your needs

- Limit the number of allocations to some reasonable number to avoid running out of kernel memory

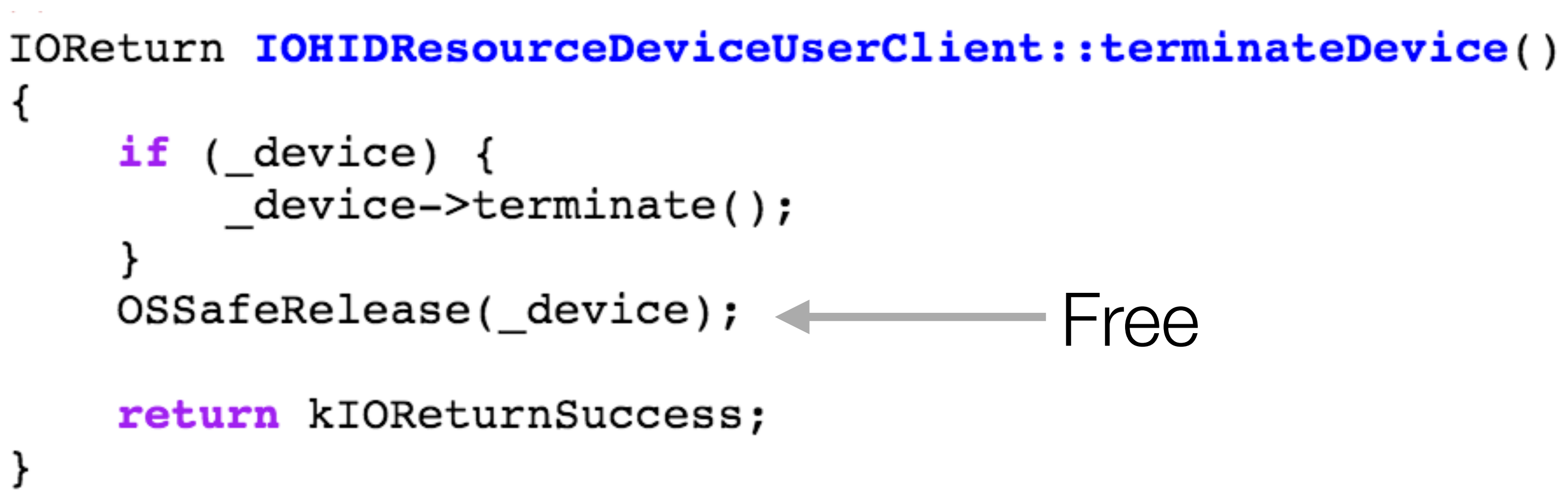
- On failure you can just fall back to a probabilistic approach

zalloc() Timing Attack: A practical use case

- In some rare cases extremely precise heap layout control is required to have any form of meaningful reliability
- An example is IOHIDFamily’s CVE-2015-6974
- Fixed in 10.11.1, found independently by multiple parties*
- Used by Pangu9 and npwn
- Required uid=0 on OS X, container sandbox escape on iOS.
- Terminating an IOHIDUserDevice after creating one drops the reference count without setting pointers to it to NULL

*so far I’m aware of me, @panguteam and @cererdlong

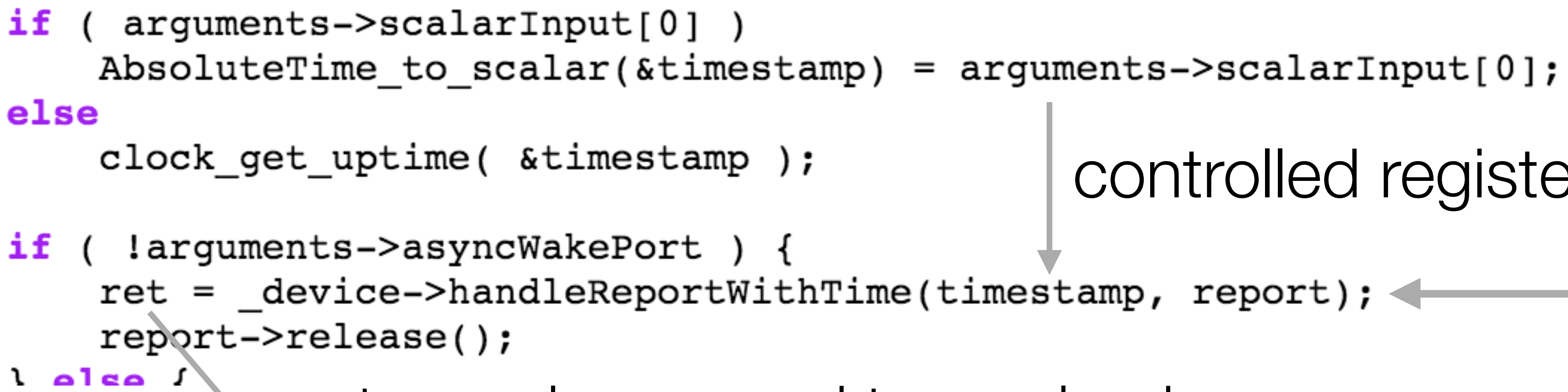
CVE-2015-6974: A textbook Use-After-Free



```
IOReturn IOHIDResourceDeviceUserClient::terminateDevice()
{
    if (_device) {
        _device->terminate();
    }
    OSSafeRelease(_device);

    return kIOReturnSuccess;
}
```

Free



```
if ( arguments->scalarInput[0] )
    AbsoluteTime_to_scalar(&timestamp) = arguments->scalarInput[0];
else
    clock_get_uptime( &timestamp );

if ( !arguments->asyncWakePort ) {
    ret = _device->handleReportWithTime(timestamp, report);
    report->release();
} else {
```

controlled register

Use

return value passed to userland

```
        return ret;
```

Both of these functions are IOExternalMethods

CVE-2015-6974: OS”notso”SafeRelease

```
IOReturn IOHIDResourceDeviceUserClient::terminateDevice()
{
    if (_device) {
        _device->terminate();
    }
    OSSafeRelease(_device);

    return kIOReturnSuccess;
}
```

what Apple did

```
/*! @function OSSafeRelease
 *  @abstract Release an object if not <code>NULL</code>.
 *  @param    inst  Instance of an OSObject, may be <code>NULL</code>.
 */
#define OSSafeRelease(inst)       do { if (inst) (inst)->release(); } while (0)

/*! @function OSSafeReleaseNULL
 *  @abstract Release an object if not <code>NULL</code>, then set it to <code>NULL</code>.
 *  @param    inst  Instance of an OSObject, may be <code>NULL</code>.
 */
#define OSSafeReleaseNULL(inst)   do { if (inst) (inst)->release(); (inst) = NULL; } while (0)
```

what Apple really wanted to do

CVE-2015-6974

```
ret = _device->handleReportWithTime(timestamp, report);
```

vcall on free’d object at vtable+0x948

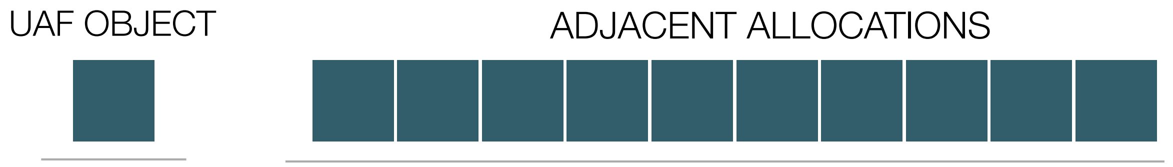
The bug allows you to control the vtable pointer used for this call
1st argument: pointer to UaF’d allocation
2nd argument: controlled 64 bit value

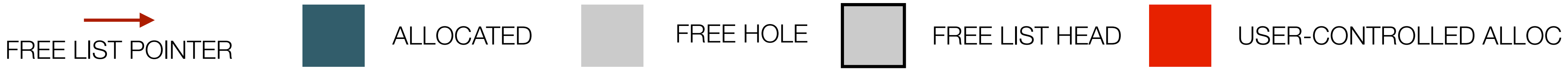
By controlling the vtable pointer you can get code exec easily with these constraints:

- on non-SMEP OS X you can point the vtable in userland and jump to user memory
- on non-SMAP OS X you can point the vtable in userland and ROP with a kASLR info leak
- on iOS and SMAP OS X you need to use an heap info leak as well as a kASLR info leak

CVE-2015-6974

An alternate avenue for exploitation for SMAP / iOS requires a **tightly controlled heap layout**.
The vtable index for the vcall is 0x948 and the object lives in kalloc.256.





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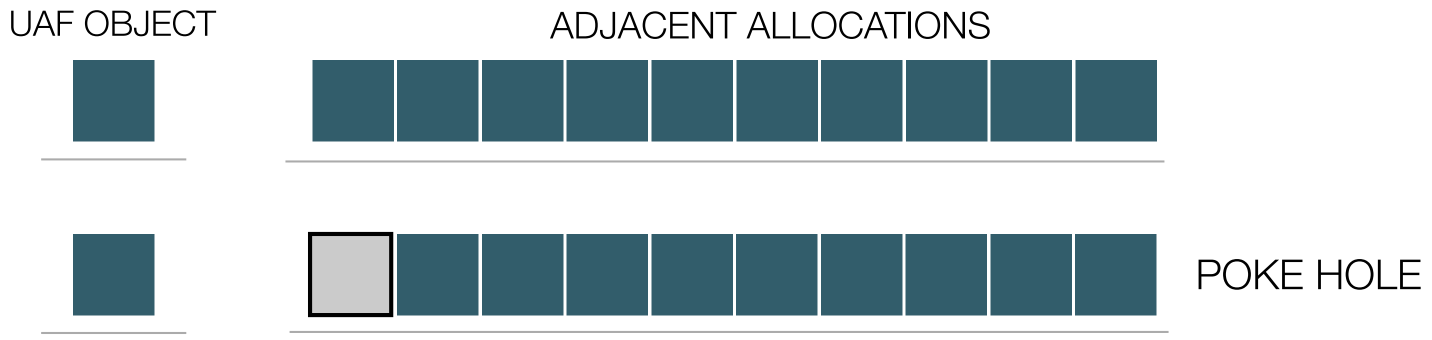

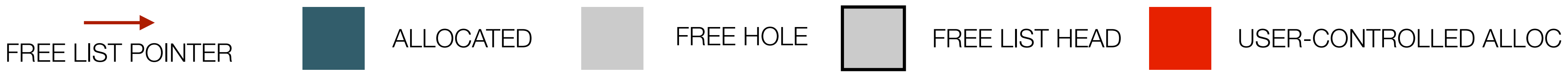

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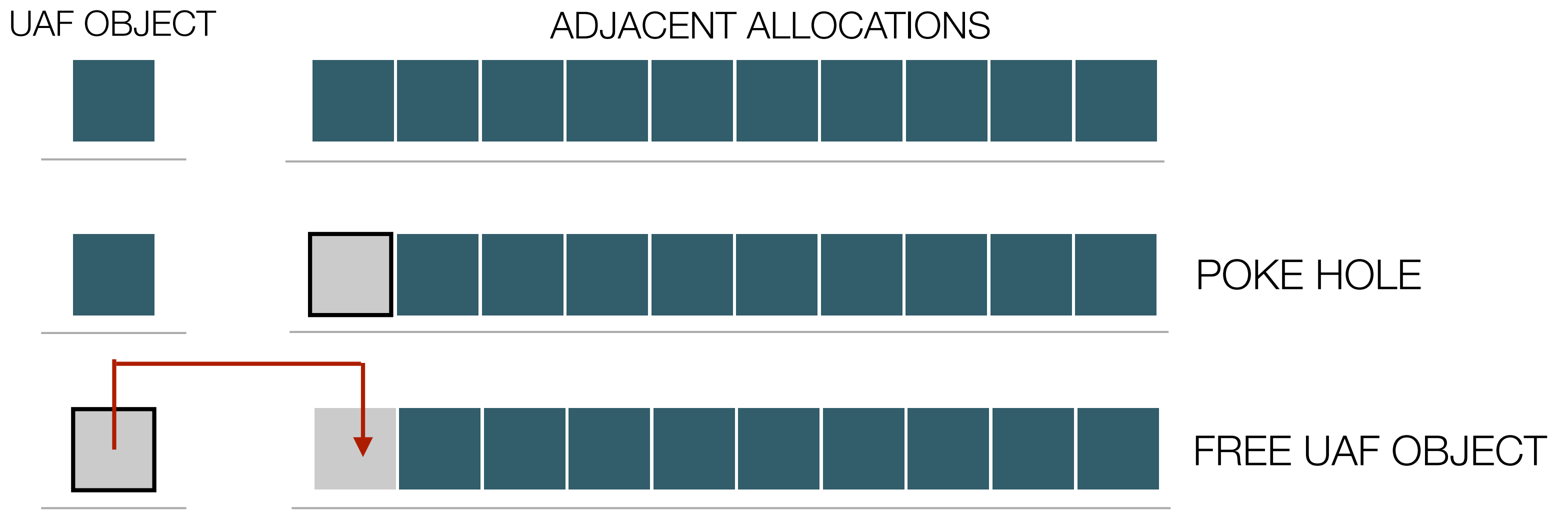

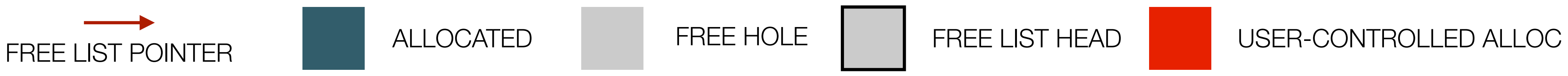

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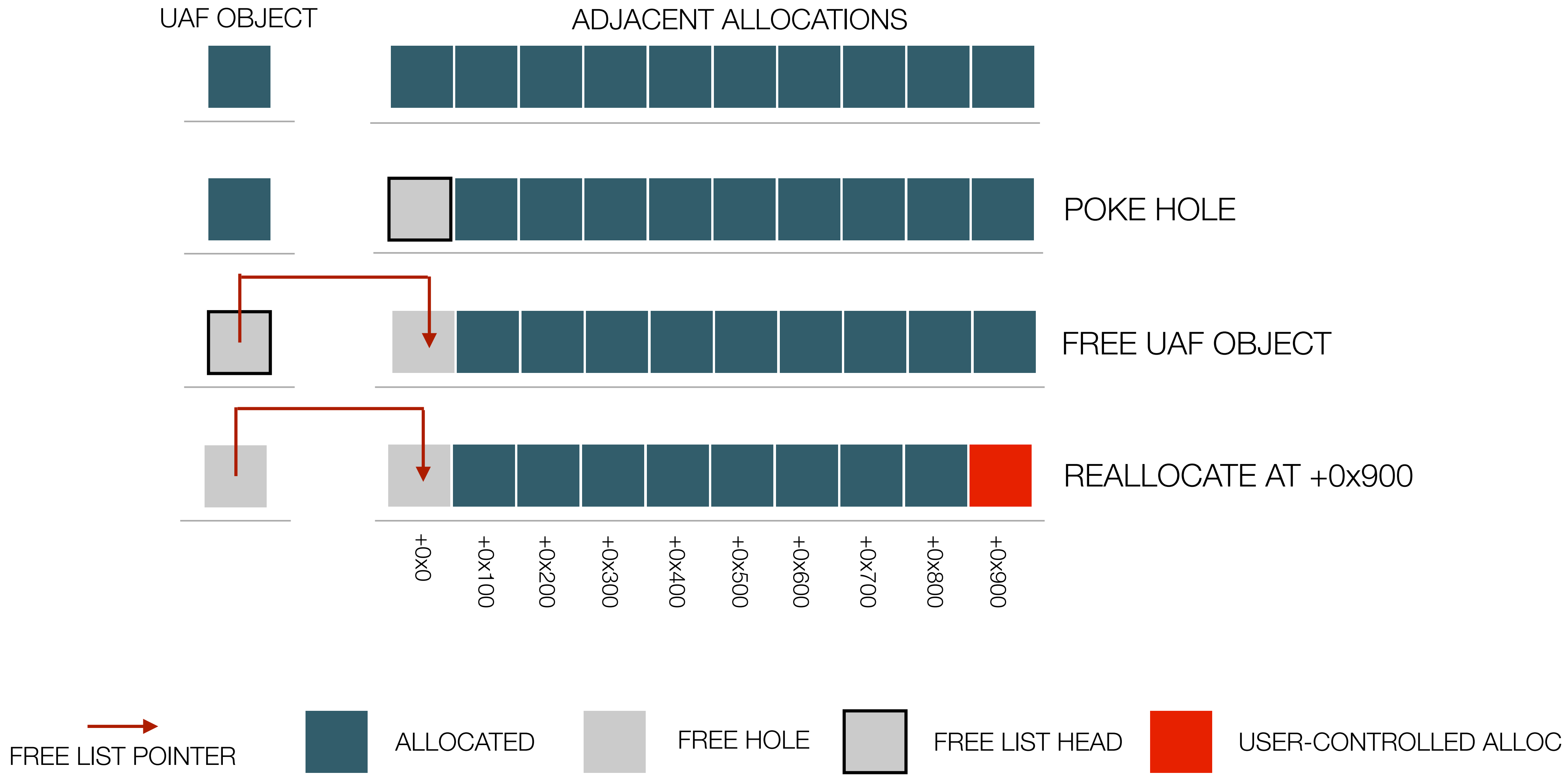

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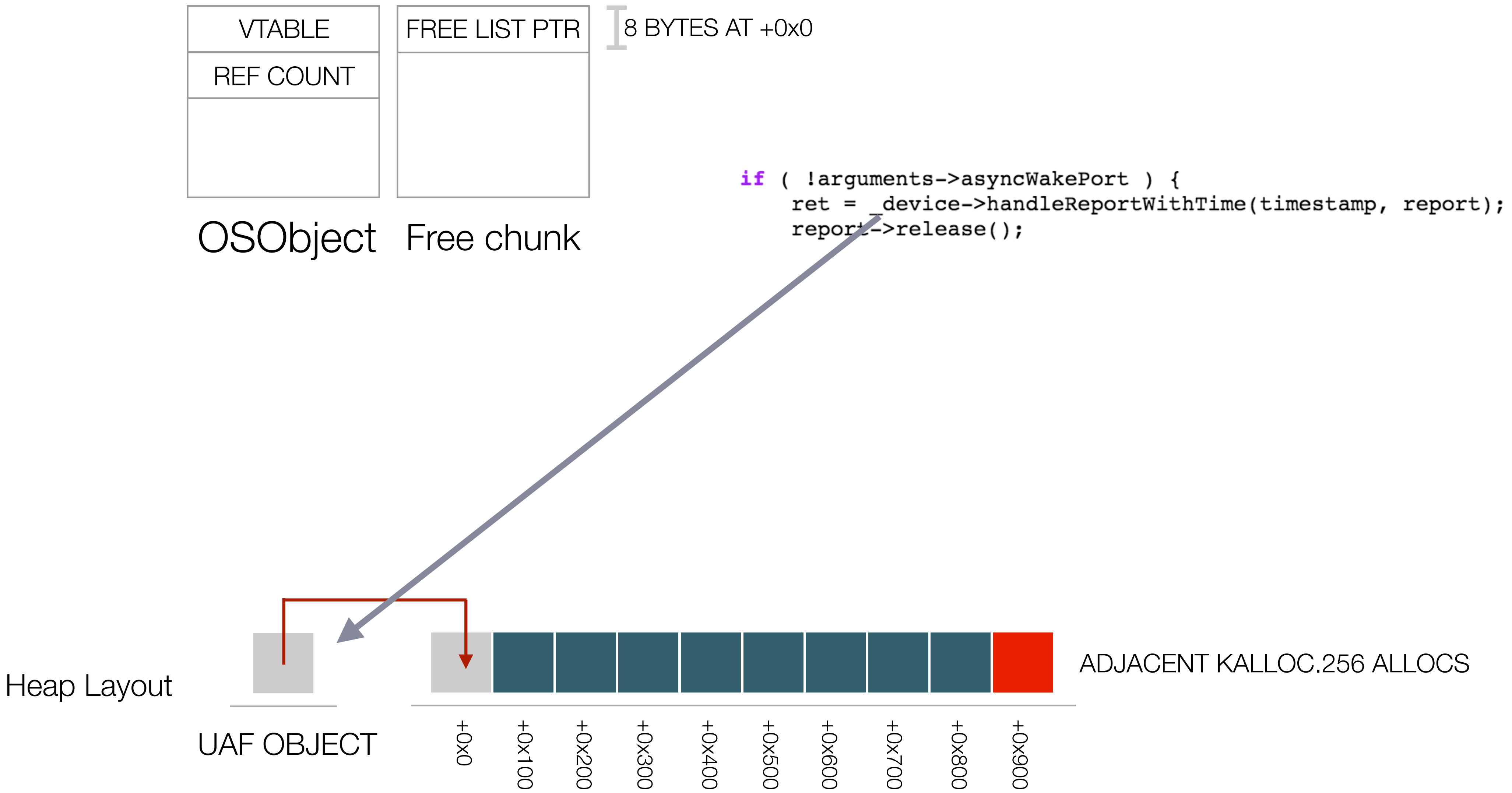

```
if ( !arguments->asyncWakePort ) {
    ret = _device->handleReportWithTime(timestamp, report);
    report->release();
```

CVE-2015-6974

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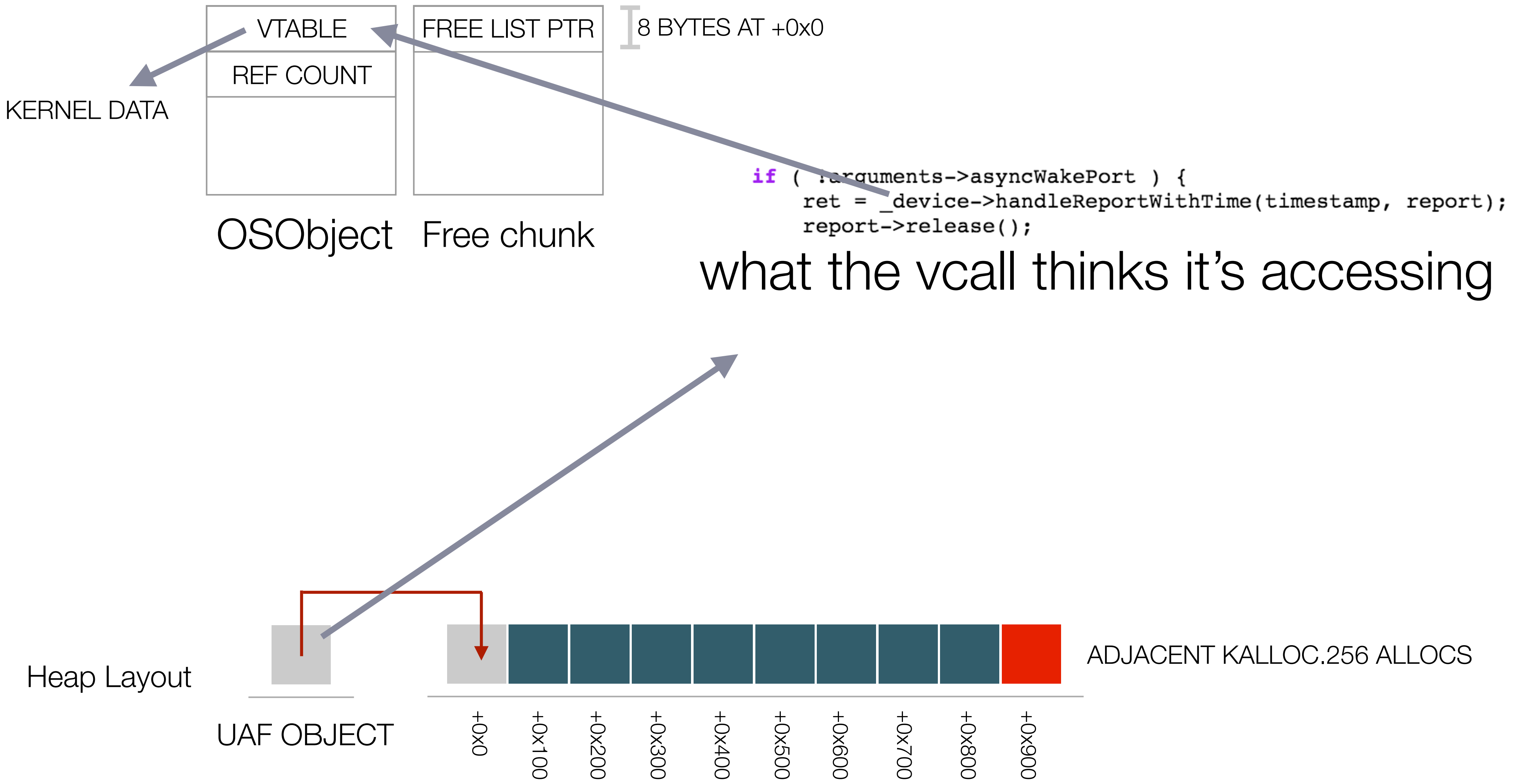

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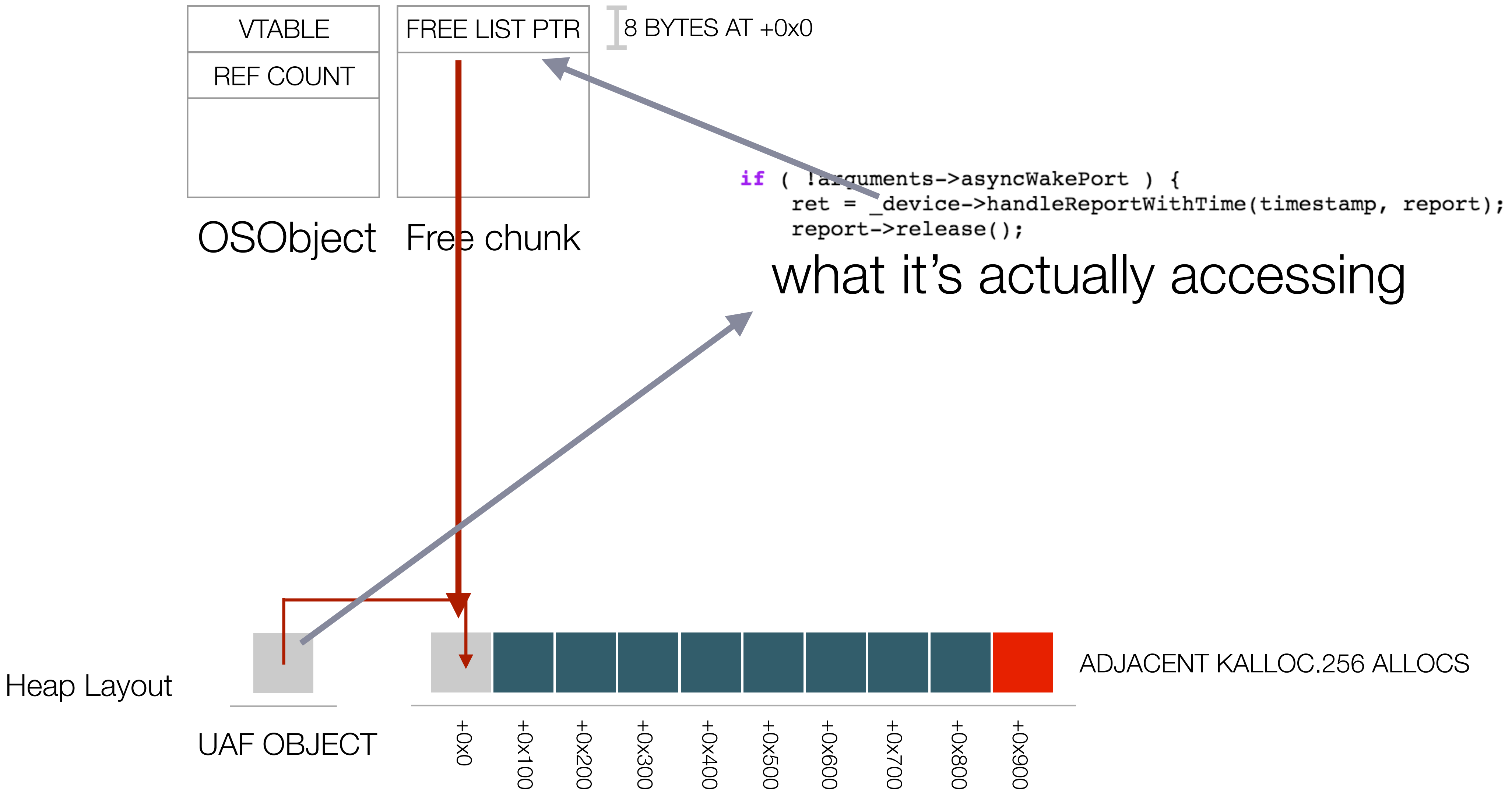

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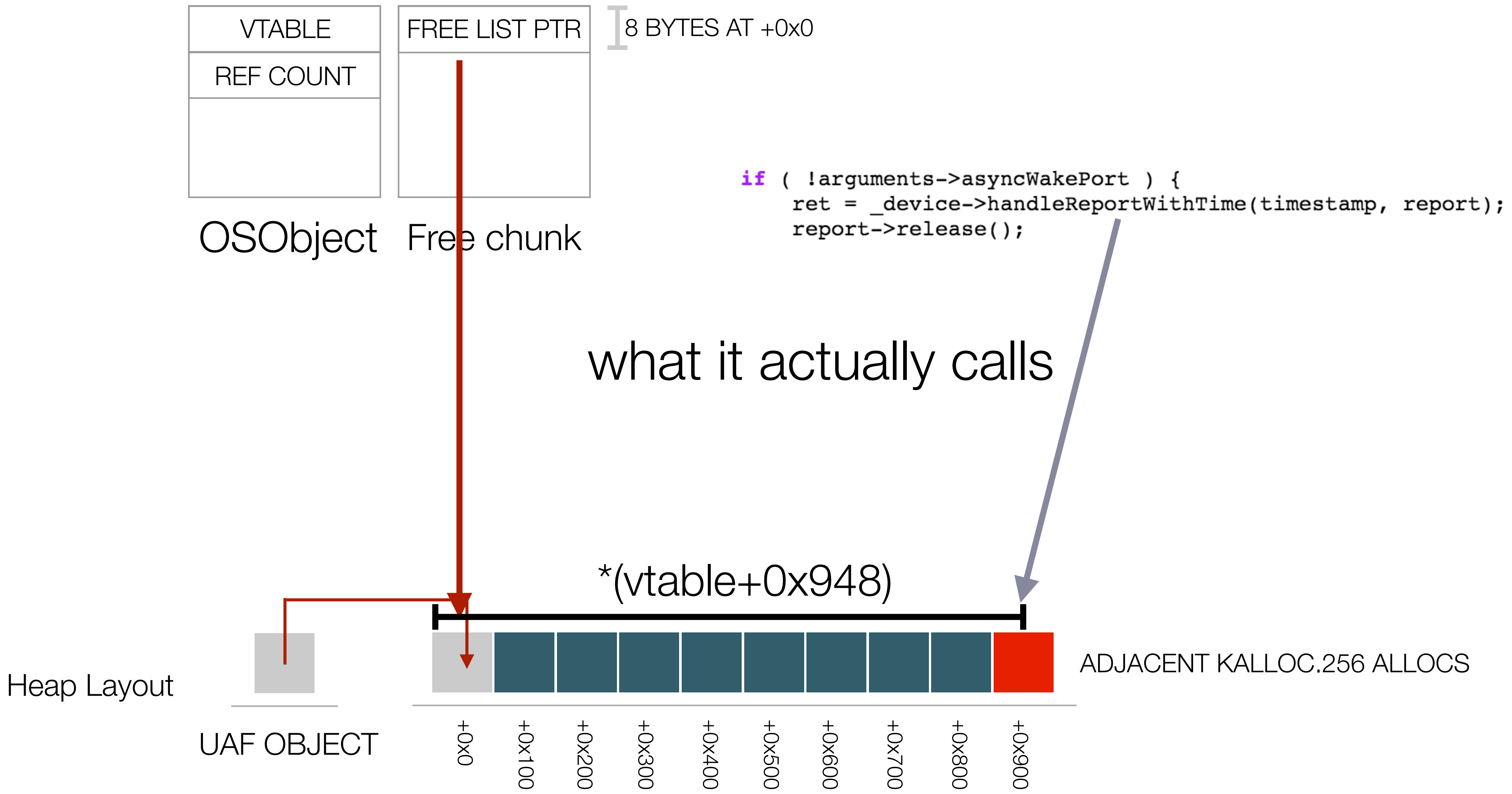

```
if ( !arguments->asyncWakePort ) {
    ret = _device->handleReportWithTime(timestamp, report);
    report->release();
```

CVE-2015-6974

- We can now control the instruction pointer and the 2nd argument
- First argument is a pointer to the UaF’d allocation
- kASLR slide not leaked yet
    - In npwn I used “kas_info”, which could be considered cheating but is still allowed on SIP-protected 10.11.1
    - Alternative kASLR leaking strategy (used by Pangu9): abuse the UaF like a type confusion

Disabling System Integrity Protection

- Pedro Vilaça (@osxreverser) discussed _csr_set_allow_all for his “rootfool” kernel extension
- We can just redirect the vcall to _csr_set_allow_all
- As long as the first argument is non-NULL, it’ll disable SIP for good
- ROP is not needed at all

Demo!

Black Hat Sound Bytes

- The rapid growth in use of sandboxing technology is pushing many attackers to kernel attacks.
- Apple has been trying to harden the kernel heap for years now but it’s still fairly easy to carry out attacks.
- The zalloc timing attack can prove useful in many situations

Questions?

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Mail: me at qwertyoruiop dot com

Thanks to:

- windknown (@windknown) & Pangu Team (@PanguTeam)
  - Pangu9 was amazing stuff!
- Steven De Franco (@iH8sn0w)
- Filippo Bigarella (@FilippoBiga)
- Joshua Hill (@p0sixninja)
- Nicholas Allegra (@comex)
- Jonathan Levin (@Technologeeks / http://newosxbook.com/)
- Stefan Esser (@i0n1c)
  - Make sure you've read his XNU exploitation papers!
- Pedro Vilaça (@osxreverser)
- Mark Dowd (@mdowd)
- Tarjei Mandt (@kernelpool)