Imperial College London

PHP Aspis: Using Partial Taint Tracking To Protect Against Injection Attacks

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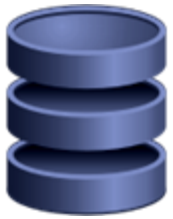
Injection Vulnerability Example

```
<?php
$name=$GET['name'];


$sql =
    "SELECT *
     FROM USERS
     WHERE user=".
     $name;


mysql_query($sql);
?>
```



Injection Vulnerability Example

http://…?name=**Yiannis**

```
<?php
$name=$GET['name'];


$sql =
    "SELECT *
     FROM USERS
     WHERE user=".
     $name;


mysql_query($sql);
?>
```

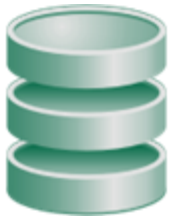
Sanitisation

http://…?name=Yiannis

```
<?php
$name=$GET['name'];


$sql =
    "SELECT *
     FROM USERS
     WHERE user=".
     sanitise_sql($name);


mysql_query($sql);
?>
```



Taint Tracking

taint data in entry points 1

propagate taint 2

use taint to guide sanitisation 3

```
<?php
$name=$GET['name'];


$sql =
    "SELECT *
     FROM USERS
     WHERE user=".
     $name;


mysql_query($sql);
?>
```

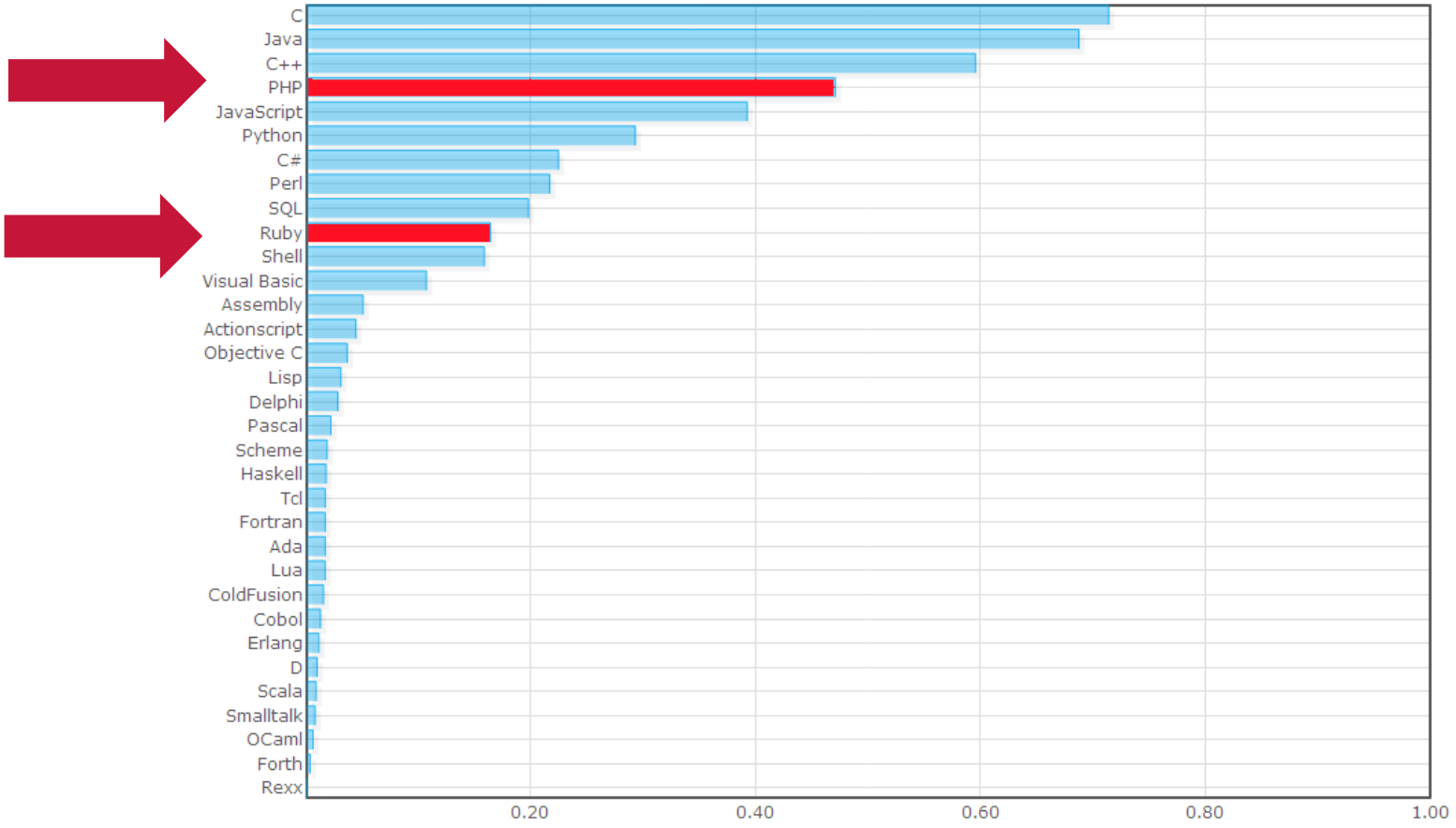
Taint Tracking ~~in PHP~~

No support

1. Suggested but ignored [Venema06]
2. Custom research interpreters [Yip09, Pietraszek06]

> *"modifications to the Zend engine should be avoided.* ***Changes here result in incompatibilities with the rest of the world, and hardly anyone will ever adapt to specially patched Zend engines.*** *… Therefore, this method is generally considered bad practice"*
>
> *The PHP Manual*

PHP is popular



data provided by langpop.com

PHP Aspis Contributions

1. Source-to-source transformations
2. Partial Taint Tracking

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2. Partial Taint Tracking

1 Why source transformations?

- ~~Adopt officially~~
- ~~Custom Runtime~~
- Source code transformations
  - ✓ On demand
  - ✓ Portable

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- ~~Adopt officially~~
- ~~Custom Runtime~~
- Source code transformations
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Challenges:

1. Not everything is an object
   (how can you attach taint to strings?)

2. The interpreter cannot be edited
   (no metaprogramming)

2 What is the performance overhead?

Partial taint tracking: Code is not equally vulnerable

Third-party plugin code

year	WordPress	WordPress Plugins
2009	2	13
2010	2	10

CVE WordPress-Platform Injection Vulnerabilities

Code that handles user data

CVE #	Functionality
2009-2851	Display user comments
2009-3891	File upload handler
2010-4257	Trackback handling
2010-4536	Display user comments

CVE WordPress-Core Injection Vulnerabilities

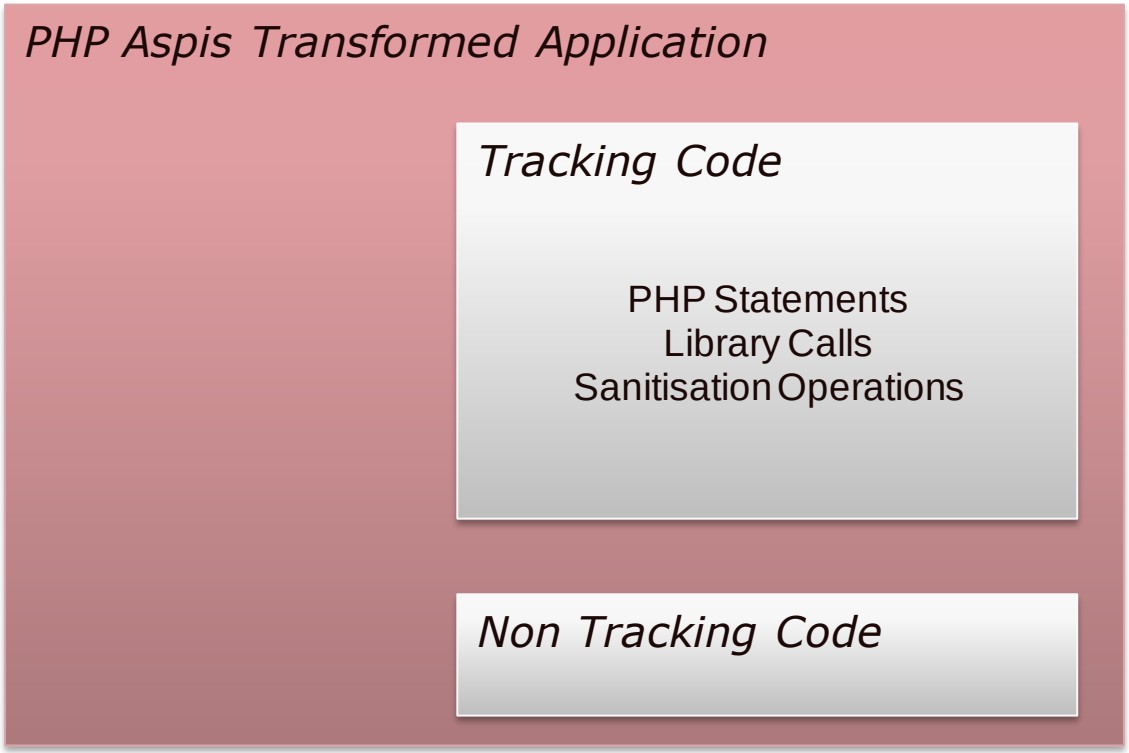
~~1. Introduction~~

2. DESIGN

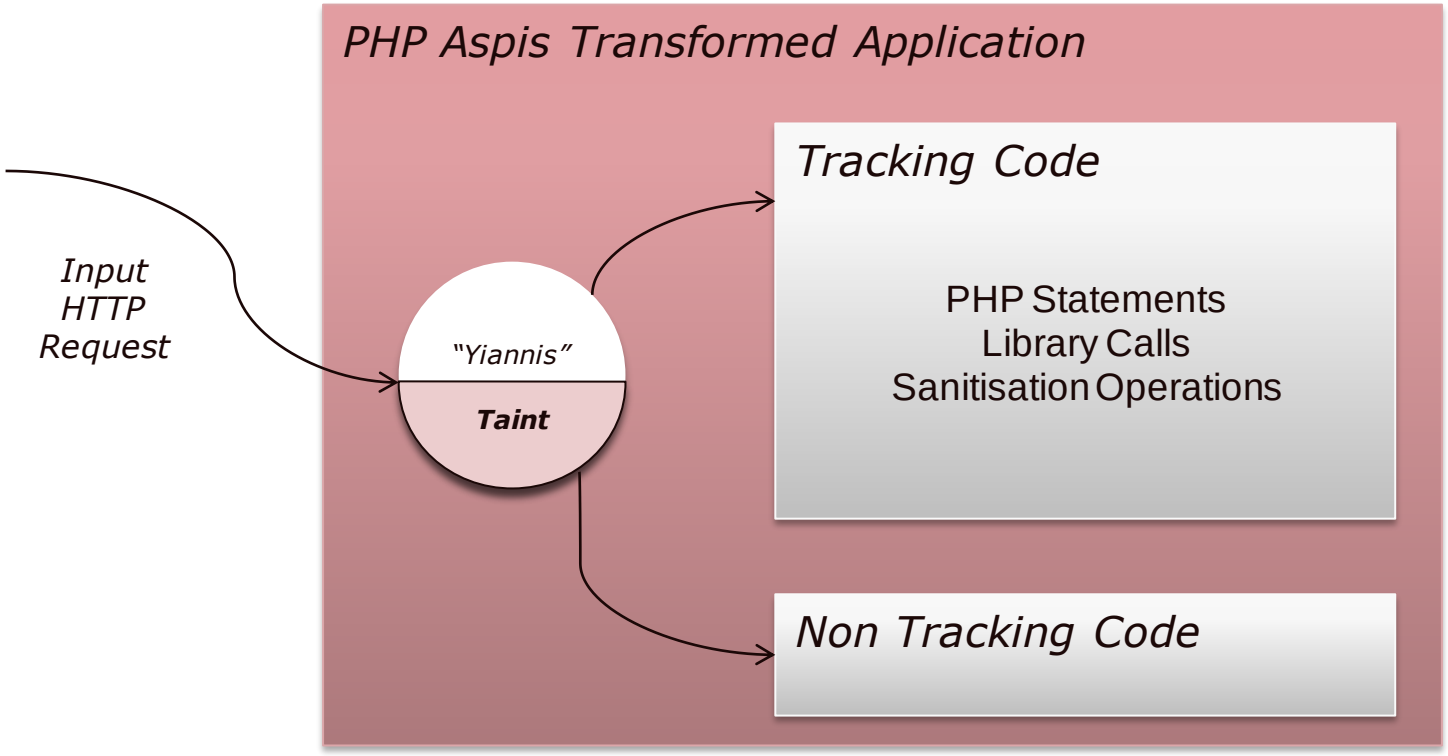
3. Implementation

4. Evaluation

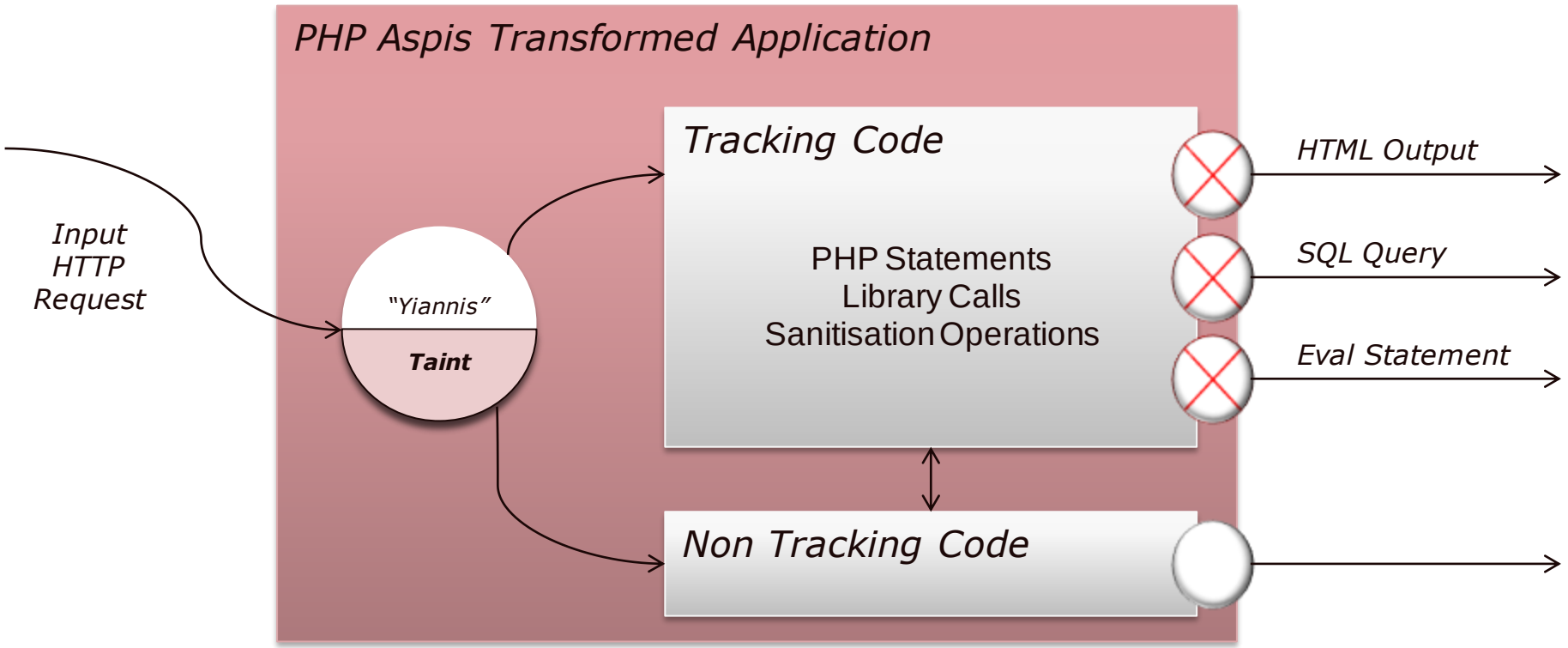
PHP Aspis Overview



PHP Aspis Overview



PHP Aspis Overview



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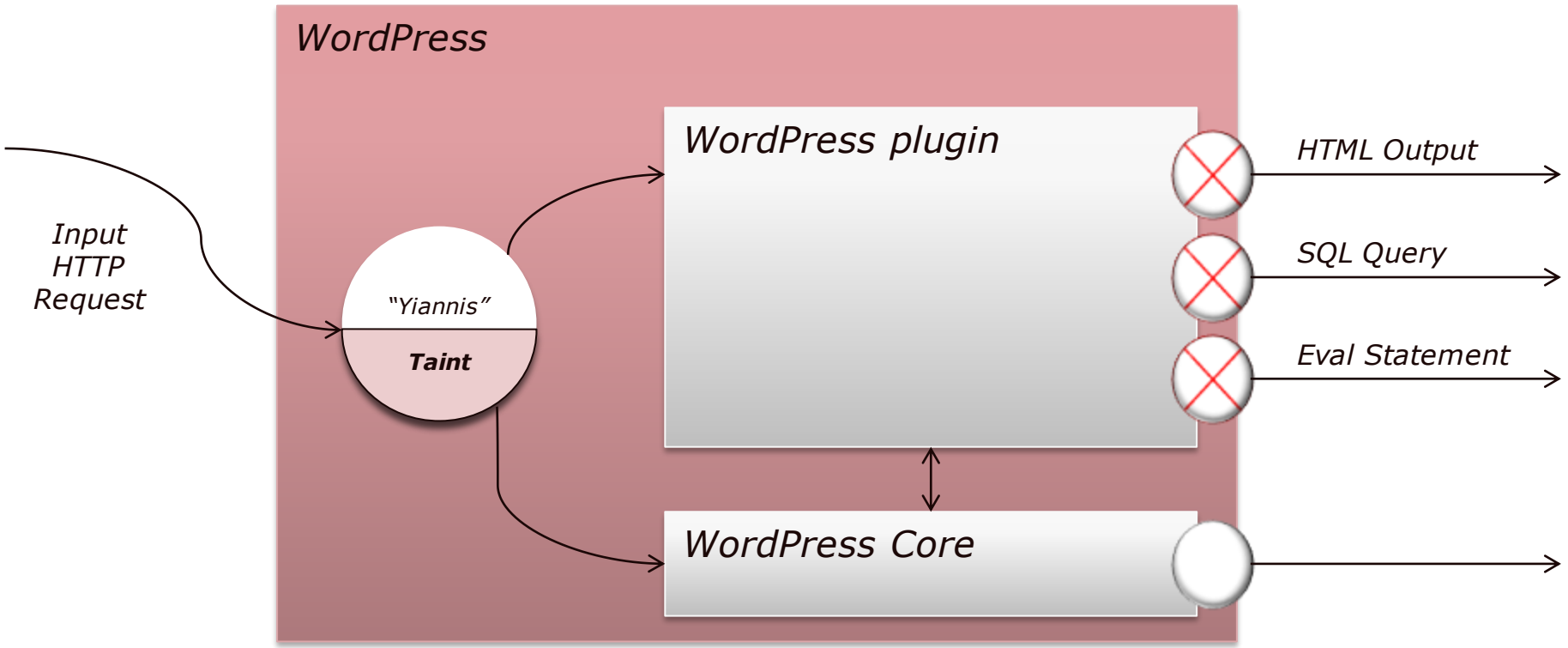

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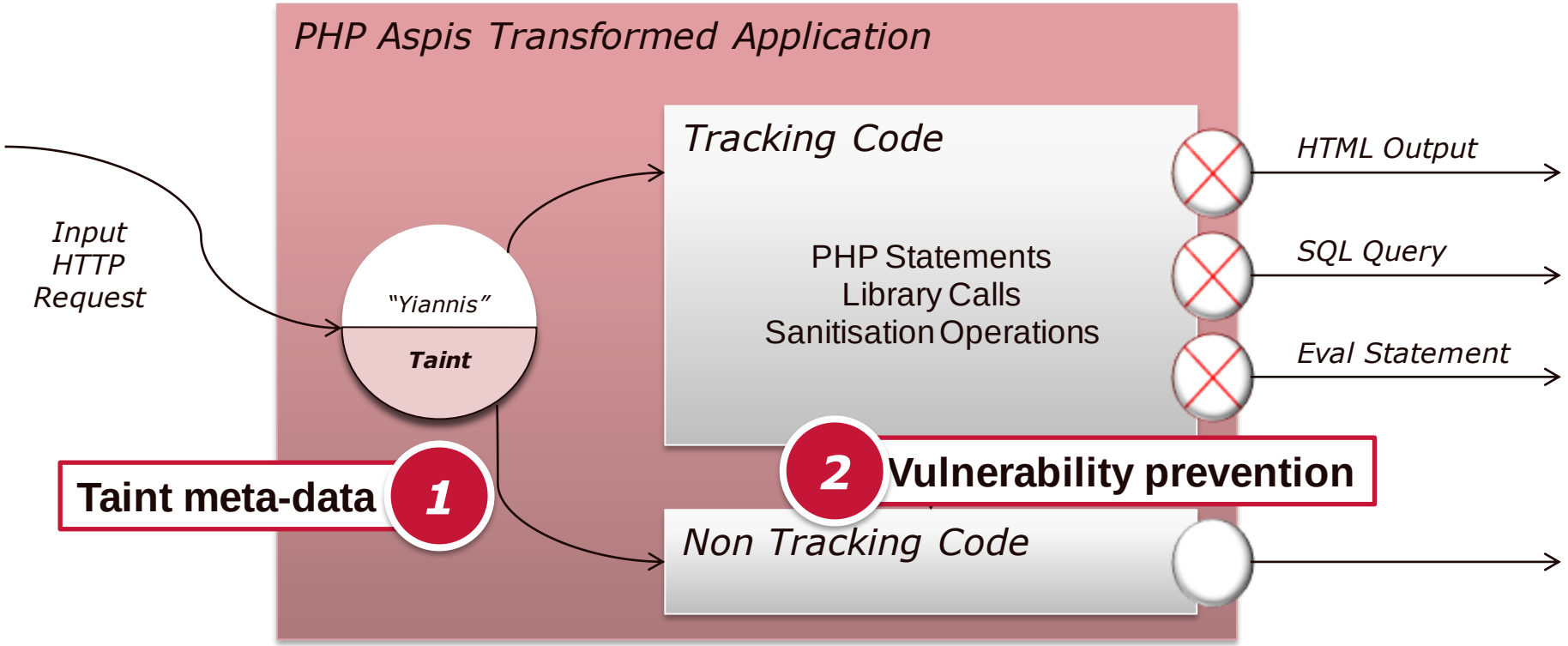
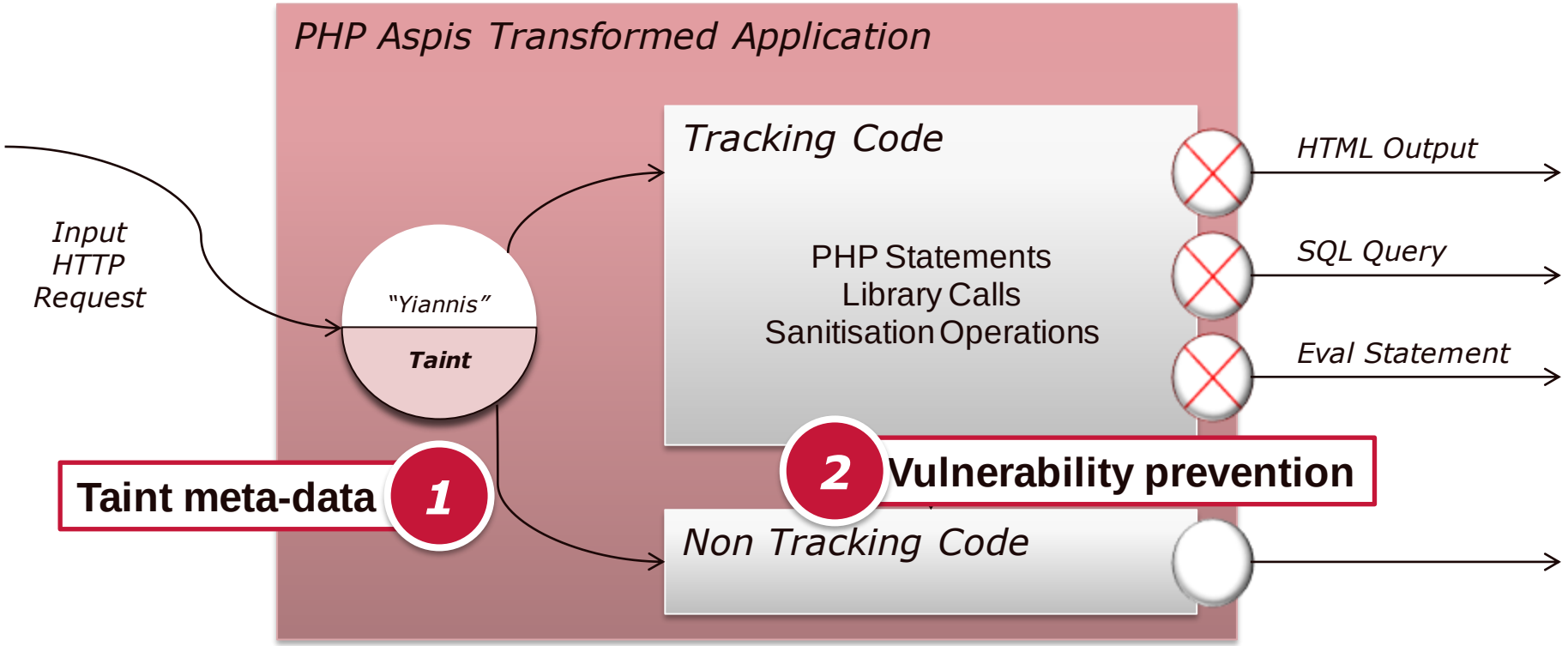
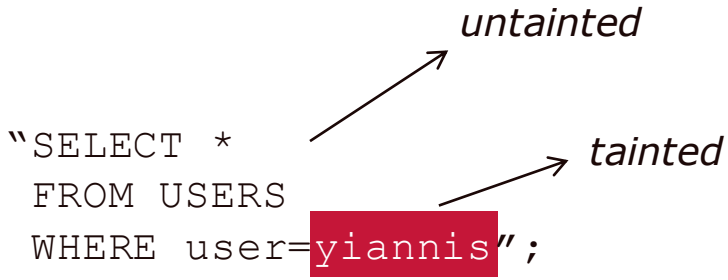


PHP Aspis Overview



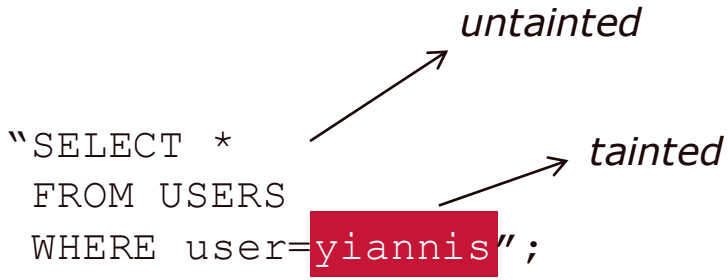
1 Taint Meta-data



✘ Variable Level
- Leads to false positives

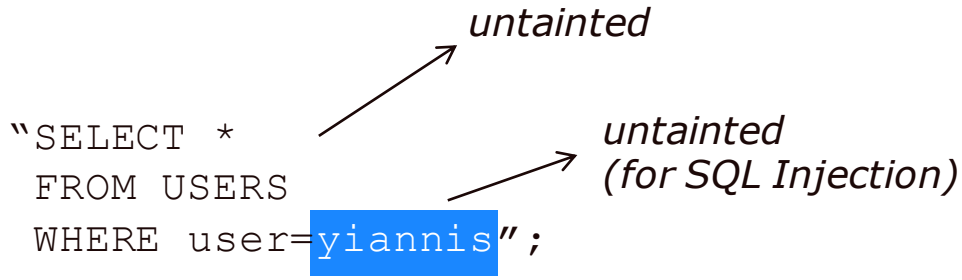
✔ Character Level
- Precise information

1 Taint Meta-data



- ✗ Variable Level
  - Leads to false positives
- ✓ Character Level
  - Precise information

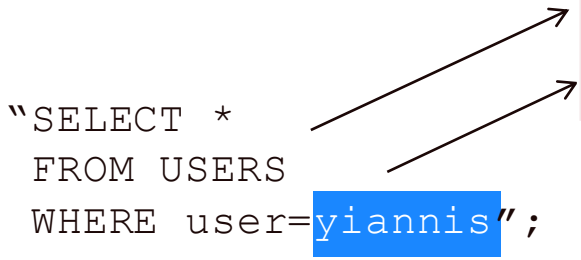
- Partial sanitisation (e.g. `sanitise_sql($name)`)



- More than 1 bit of taint meta-data is required

1 Taint Categories

- Example



Taint Category		
SQL Injection	*XSS*	*Eval Injection*
untainted	untainted	untainted
	tainted	tainted

1 Taint Categories

- Example

```
"SELECT *
 FROM USERS
 WHERE user=yiannis";
```

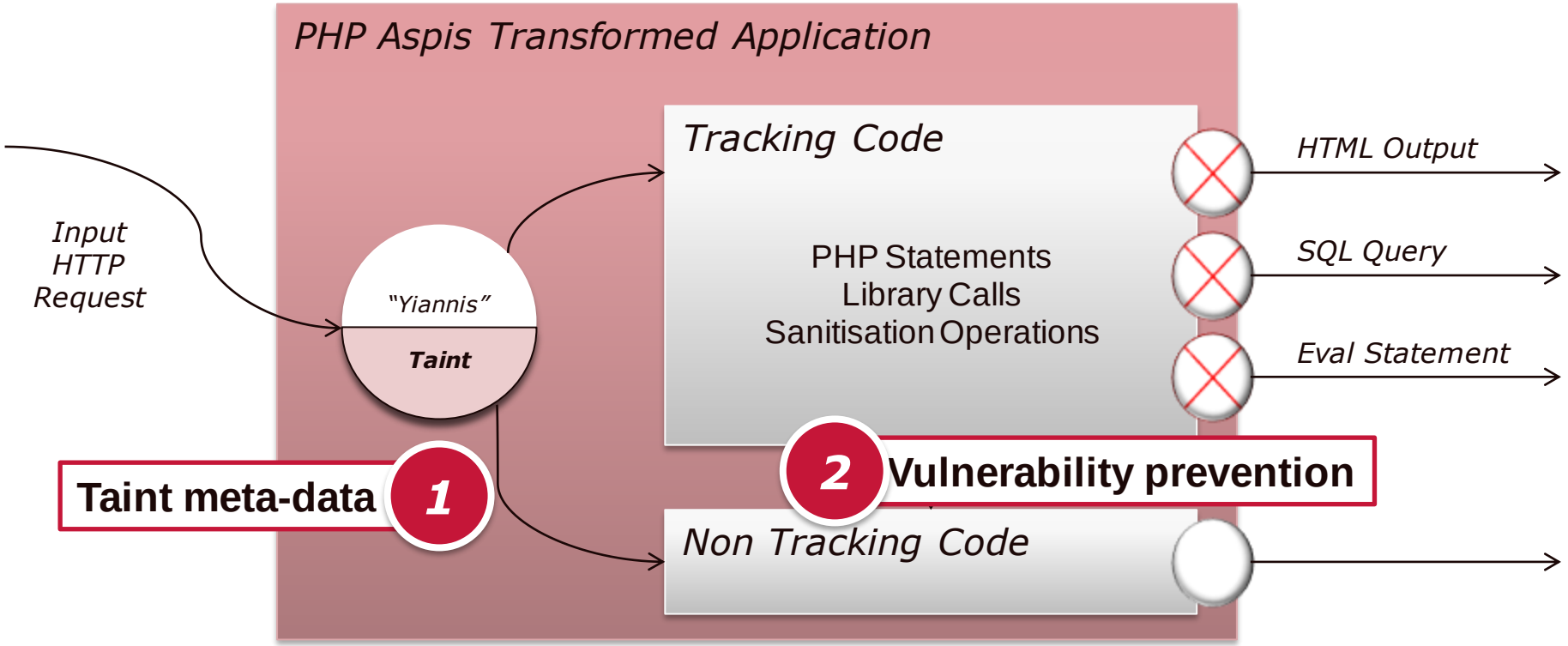
Taint Category		
SQL Injection	*XSS*	*Eval Injection*
untainted	untainted	untainted
	tainted	tainted

- Generic way to define:
  - How an application ***is supposed to*** sanitise
  - What to do if it doesn't

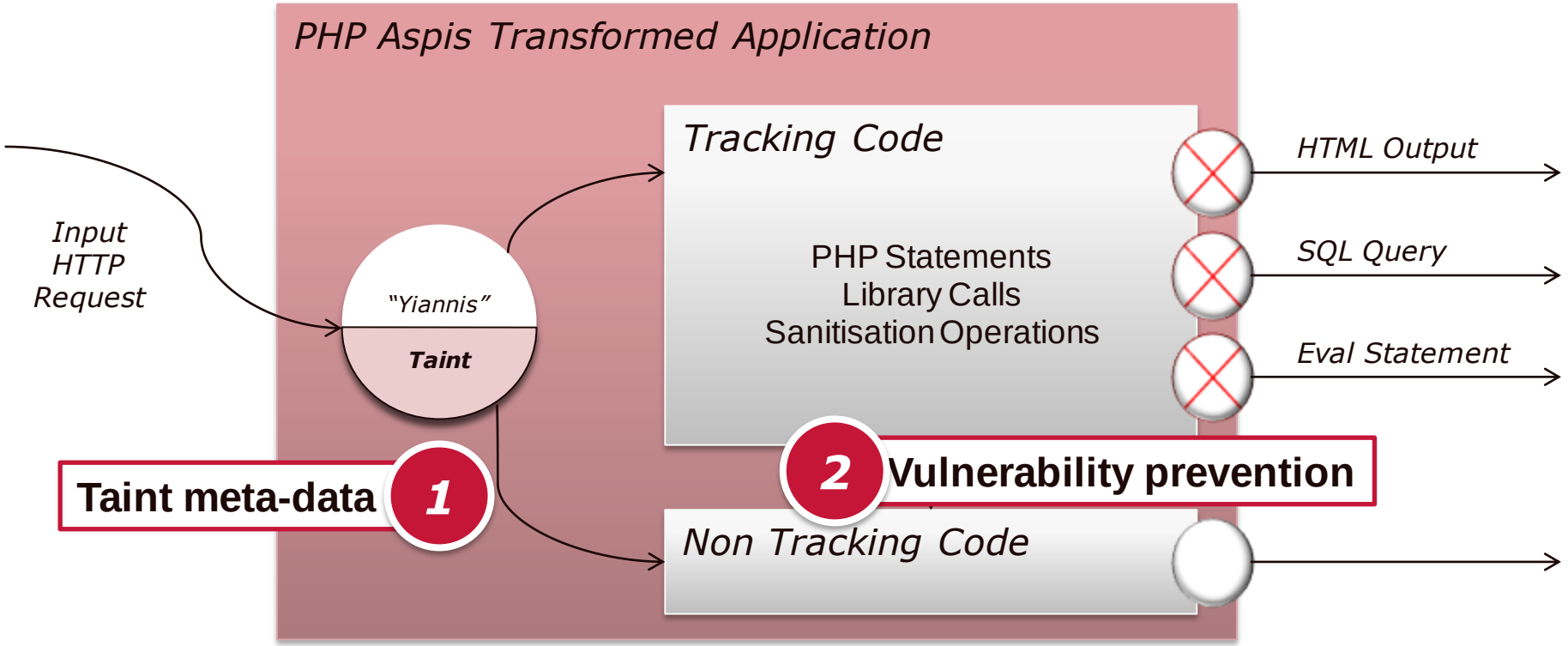
Sanitisation Functions	**htmlentities()** **htmlspecialchars()**
Guarded Sinks	**echo()→AspisAntiXSS()** **print()→AspisAntiXSS()** **…**

XSS taint category excerpt

PHP Aspis Overview



PHP Aspis Overview



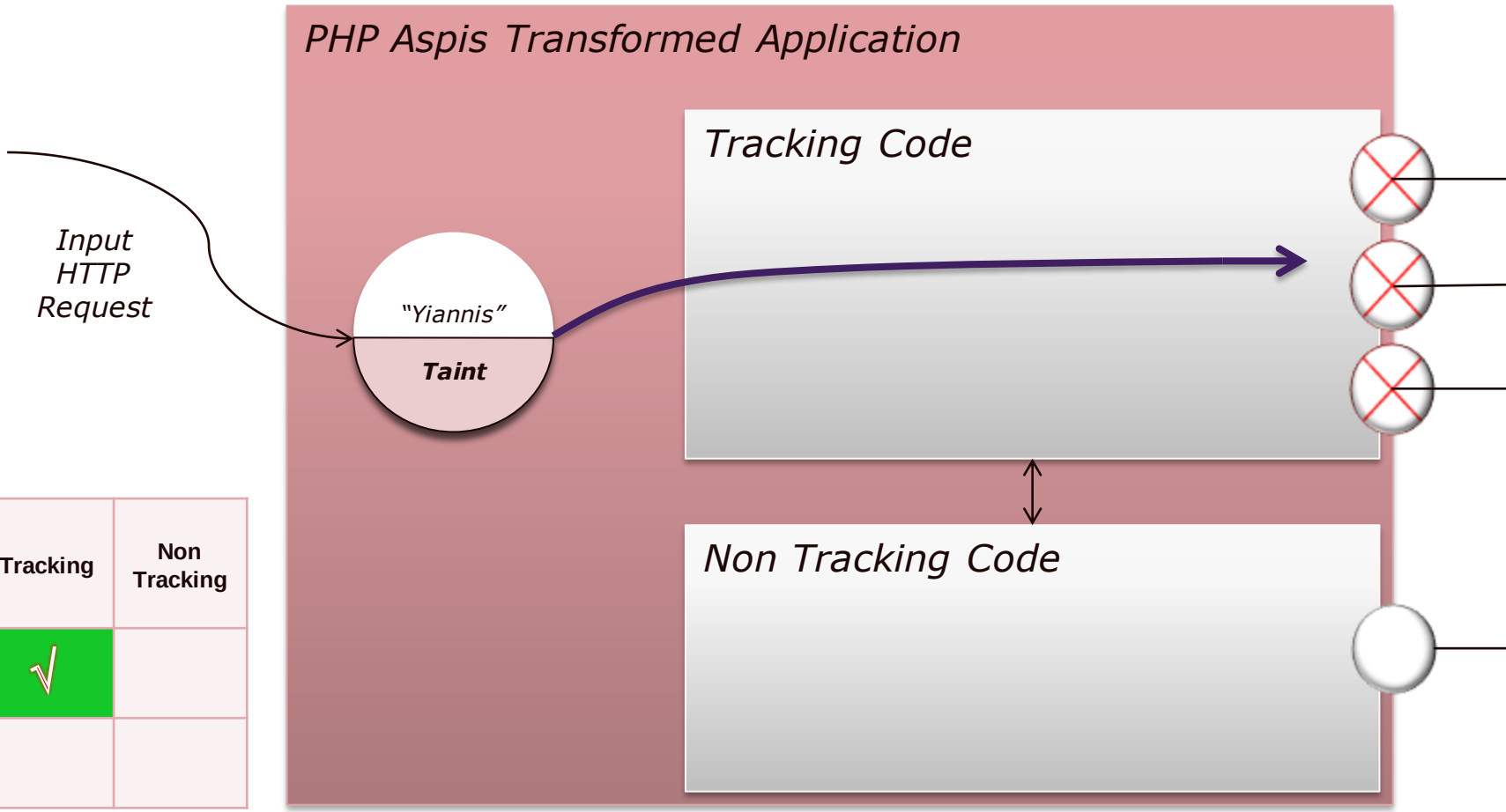
2 Which vulnerabilities can be prevented?

Possible Data Flows

from \ to	Tracking	Non Tracking
Tracking	1	5
Non Tracking	3	2

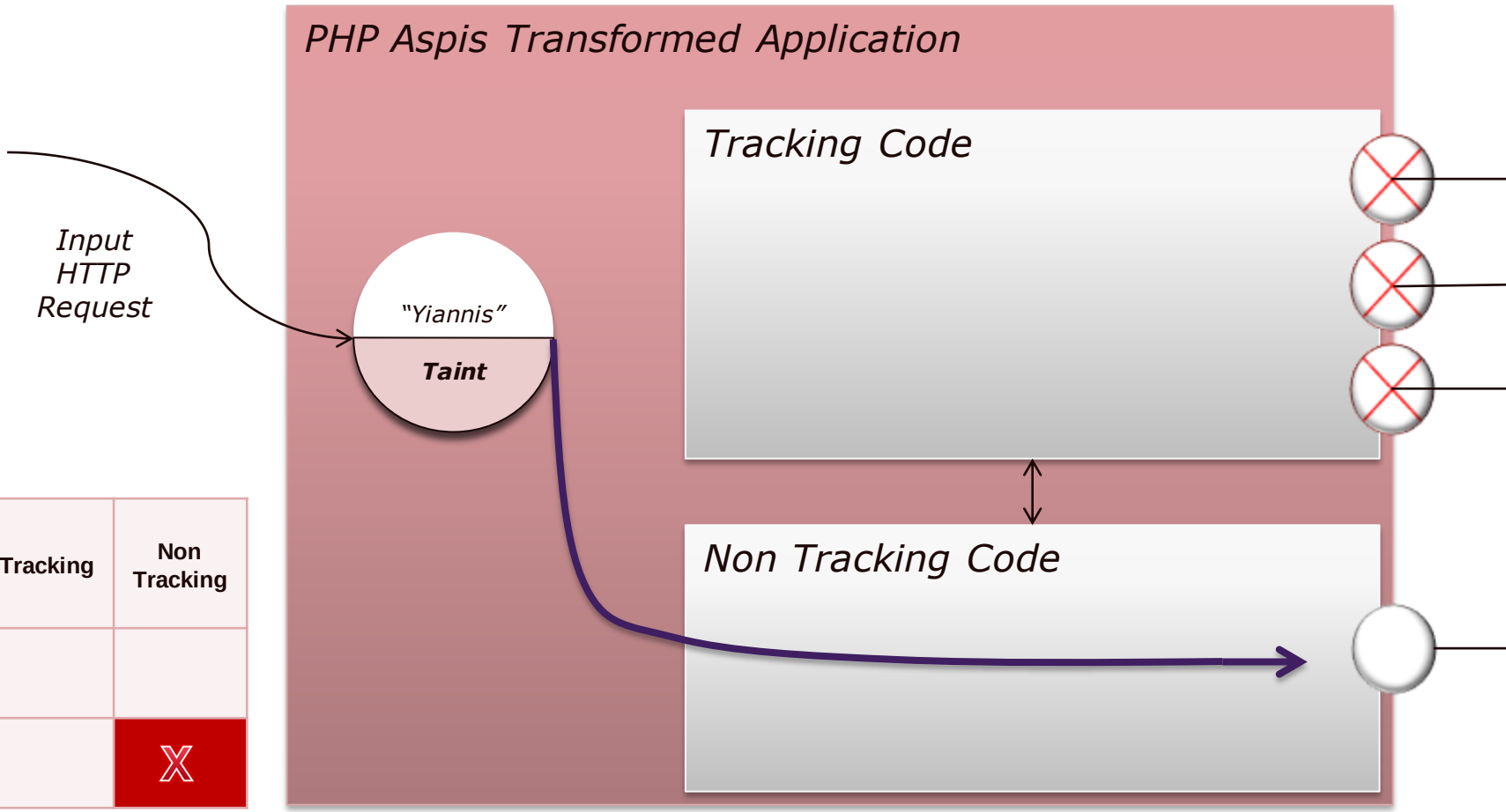
4

2 Tracking code only



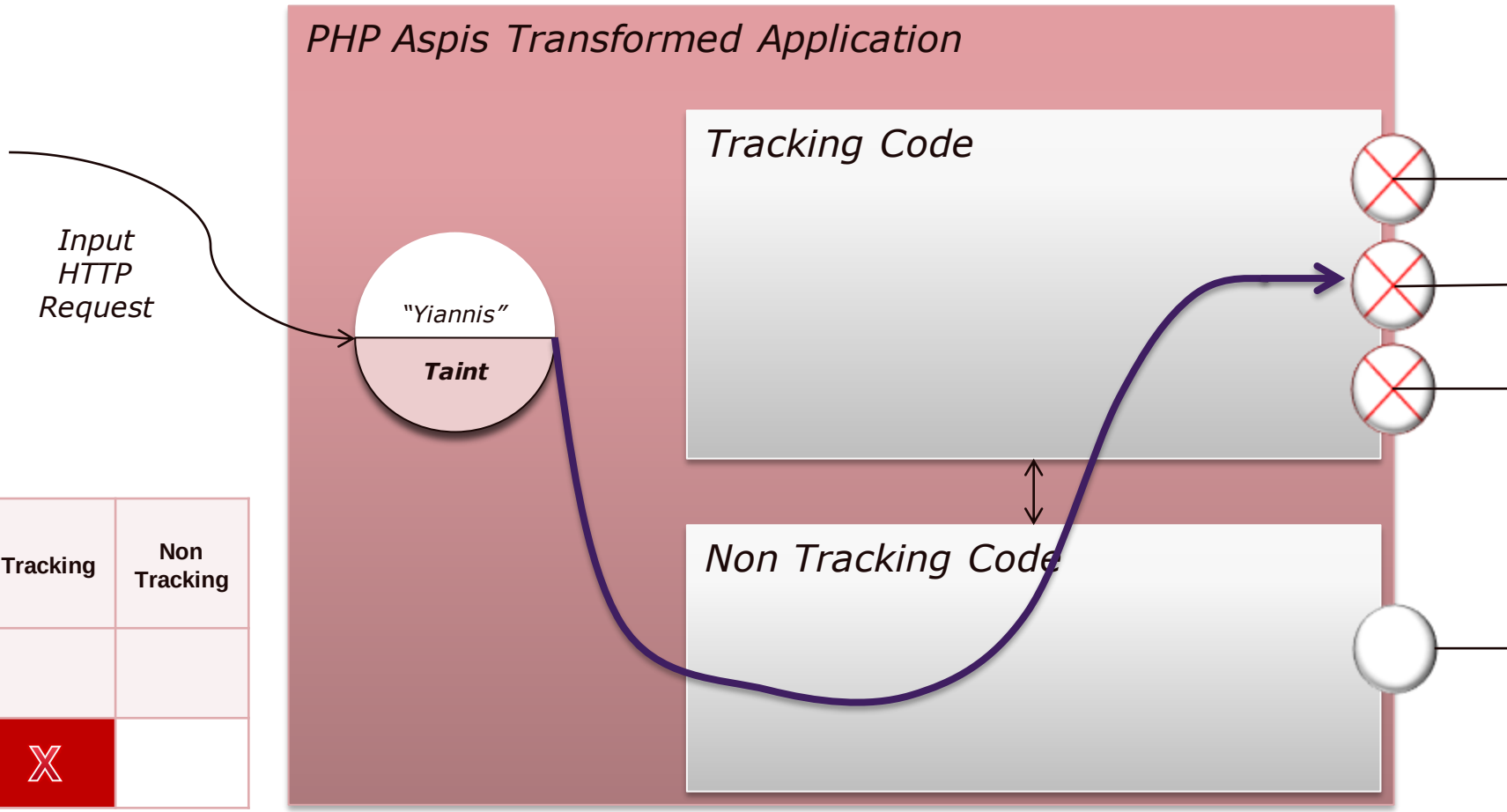
from \ to	Tracking	Non Tracking
Tracking	√	
Non Tracking		

2 Non Tracking code only



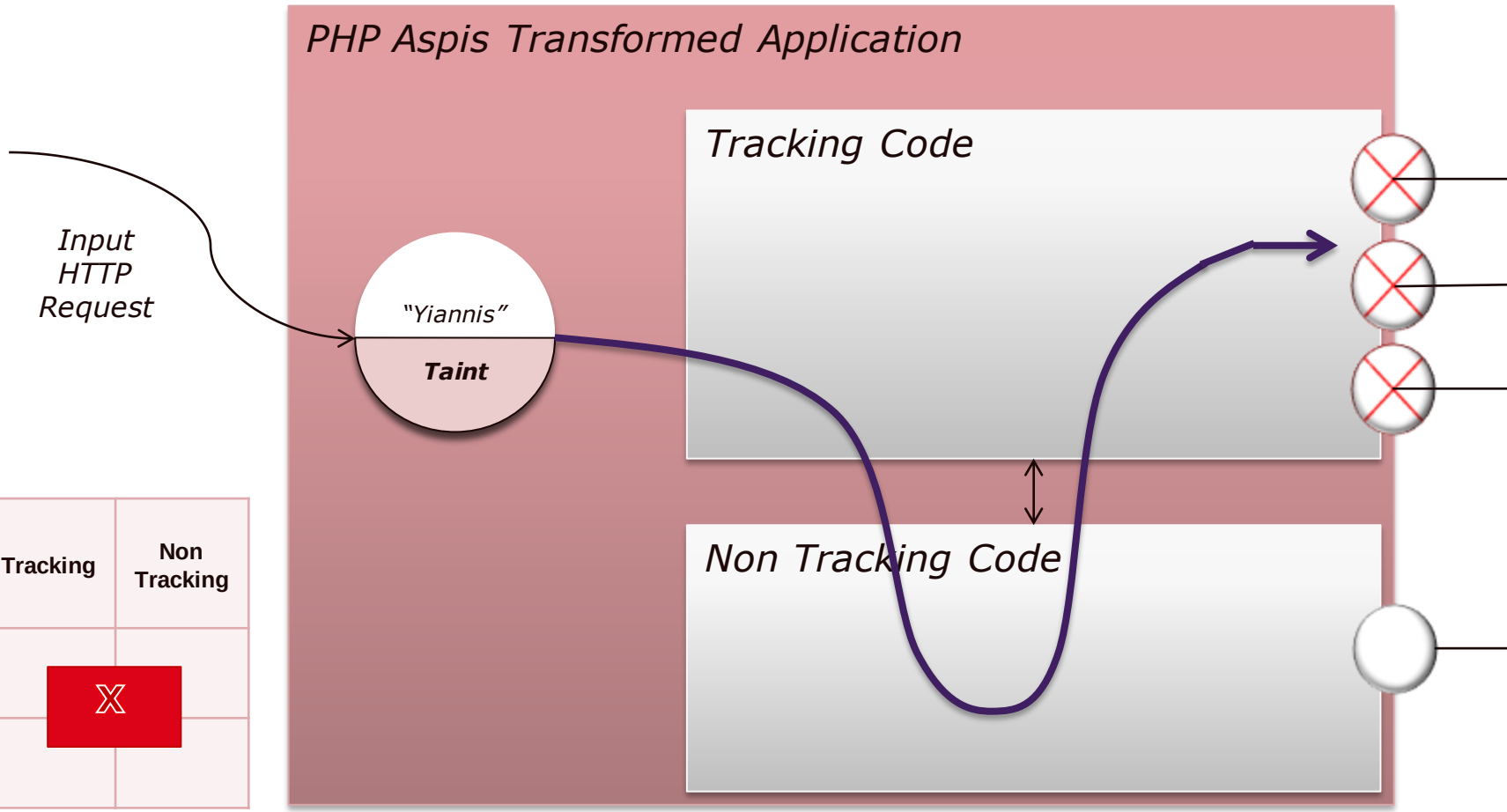
from \ to	Tracking	Non Tracking
Tracking		
Non Tracking		X

2 Non Tracking to Tracking



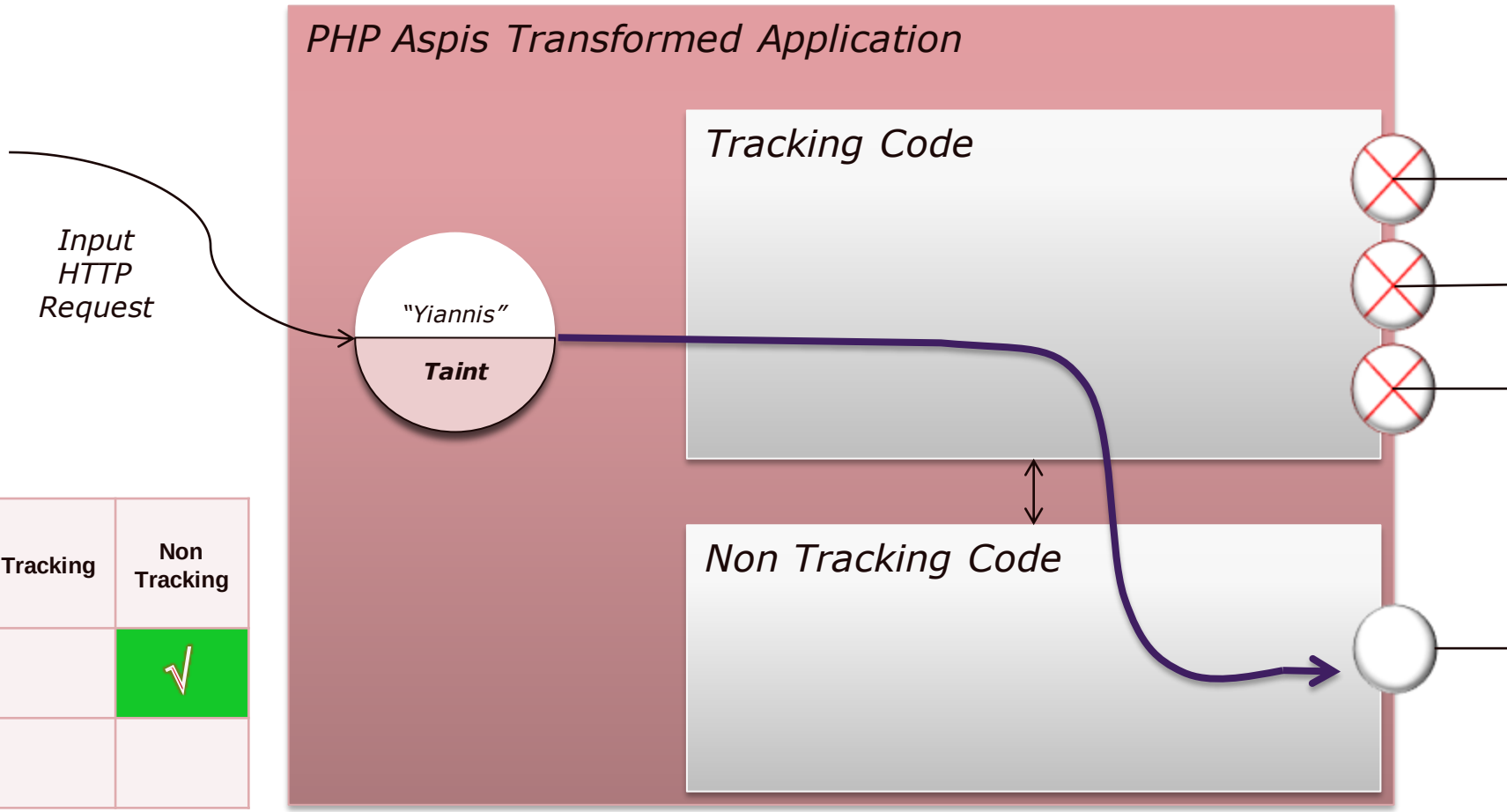
from \ to	Tracking	Non Tracking
Tracking		
Non Tracking	X	

2 Tracking/Non Tracking mixes



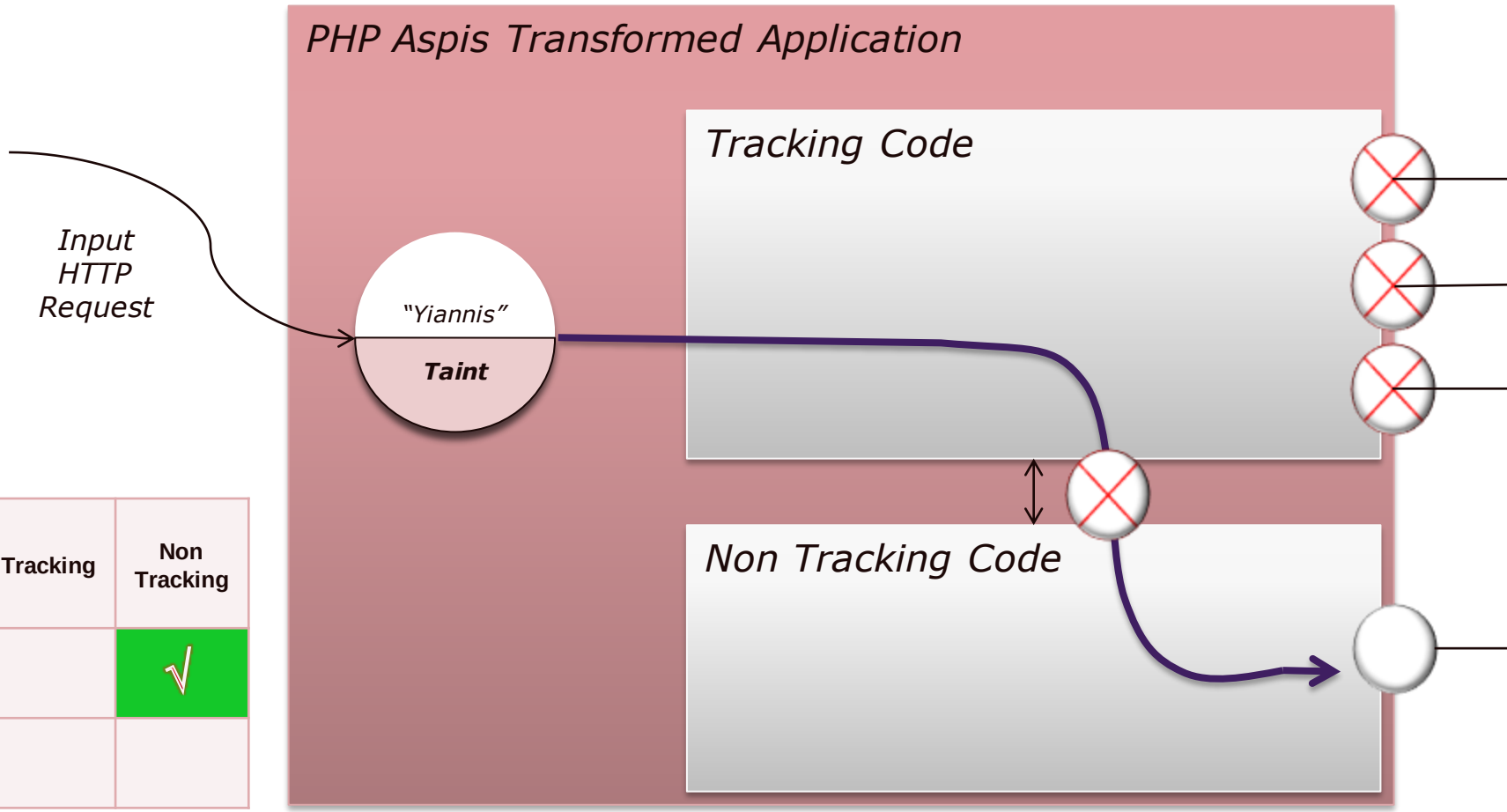
from \ to	Tracking	Non Tracking
Tracking	X	
Non Tracking		

2 Tracking to Non Tracking



from \ to	Tracking	Non Tracking
Tracking		√
Non Tracking		

2 Tracking to Non Tracking



from \ to	Tracking	Non Tracking
Tracking		√
Non Tracking		

2 Summary: Prevented Vulnerabilities

- Vulnerabilities Prevented
  - ✓ Tracking-code only
  - ✓ Tracking to non tracking

From \ to	Tracking	Non Tracking
Tracking	1	5
Non Tracking		

- Vulnerabilities Not Prevented
  - ✗ Non Tracking-code only
  - ✗ Non Tracking to Tracking
  - ✗ Tracking/Non Tracking mixes

from \ to	Tracking	Non Tracking
Tracking		
Non Tracking	3	2

~~1. Introduction~~

~~2. Design~~

3. IMPLEMENTATION

4. Evaluation

Storing Taint Meta-Data

Store taint *in place*

- ✓ Interoperation with non-tracking code

Use arrays

- ✓ 2-10x faster than object initialisation
- ✓ Scalar assignment semantics

Original value	*Aspis-protected value*
"Hello"	`array ( "Hello", TaintCats )`
12	`array ( 12, TaintCats )`

Taint Tracking Transformations

Statements & Expressions must

1. operate with Aspis-protected values
2. propagate taint correctly
3. return Aspis-protected values

Original expression	*Transformed Expression*
`$s.$t`	`concat($s,$t)`
`if ($v) {}`	`if ($v[0]) {}`
`$j = $i++`	`$j = postincr($i)`

PHP Function Library

- Library functions do not work with Aspis-protected values
  - ✓ use interceptors!

Default Interceptor	*Custom Interceptors*
✓ *strip input taint* ✓ *add empty output taint* ✓ *good as the default* ➡ `fclose(), fopen()`	✓ *guess the taint of the output* ➡ `substr()` ✓ *reimplement the function* ➡ `sort()`

- More custom interceptors, less false negatives
  - Default: drop taint, not abort the call
  - Support existing applications without developer intervention

The rest...

- Taint representation
- Expressions
- Statements
- PHP Library Function Calls
- Taint initialisation
- Tracking/Non Tracking Calls
- Calls to sanitisation functions
- Calls to sinks
- Variable variables
- Variable function calls
- Include Statements
- Dynamic code generation

1. ~~Introduction~~
2. ~~Design~~
3. ~~Implementation~~

4. EVALUATION

Goals

1. Is PHP Aspis **effective** in preventing injection attacks?
2. What is the **performance overhead**?

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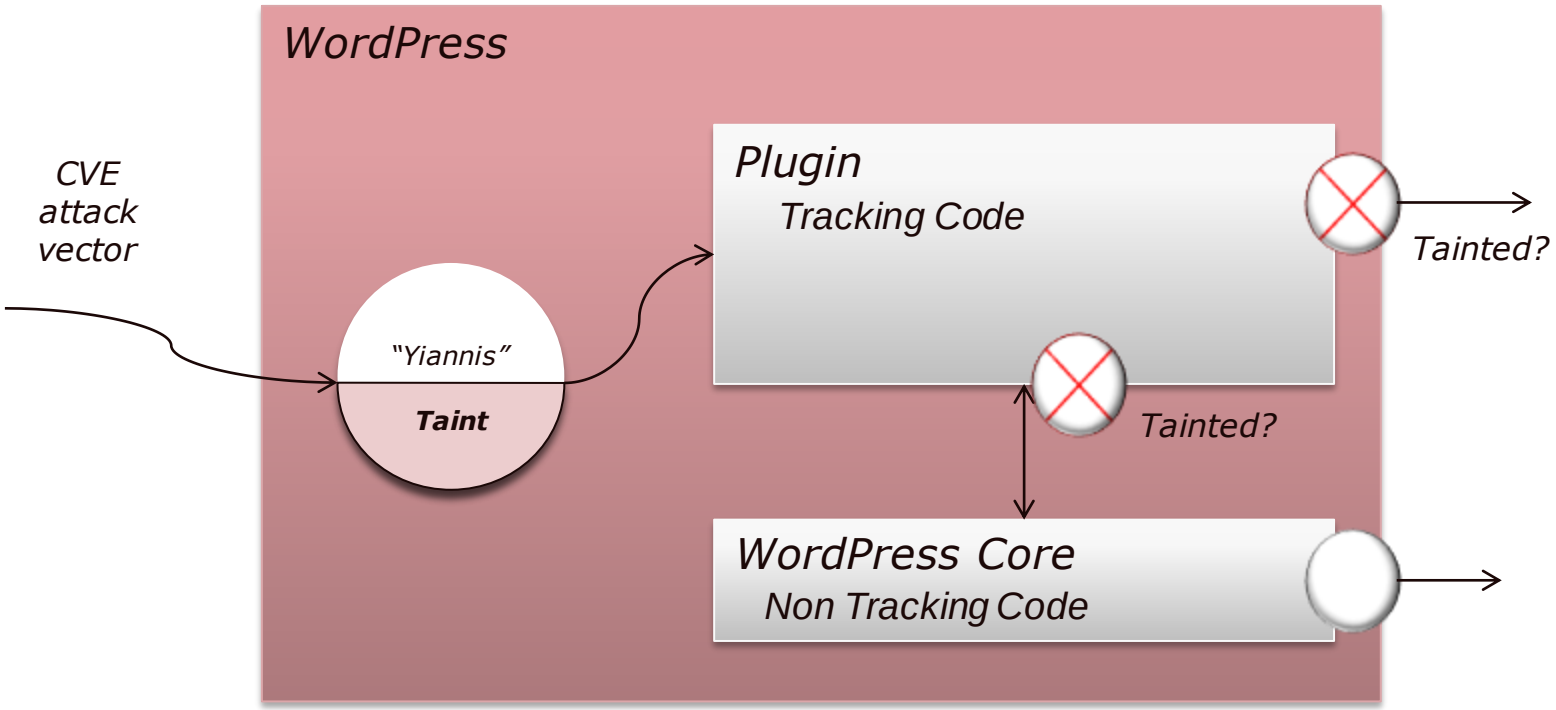
1. Is PHP Aspis **effective** in preventing injection attacks?
2. What is the **performance overhead**?

1 Evaluation methodology

- Use all reported WordPress plugins to the CVE since 1/1/2010
- Replay the provided attack vectors where possible

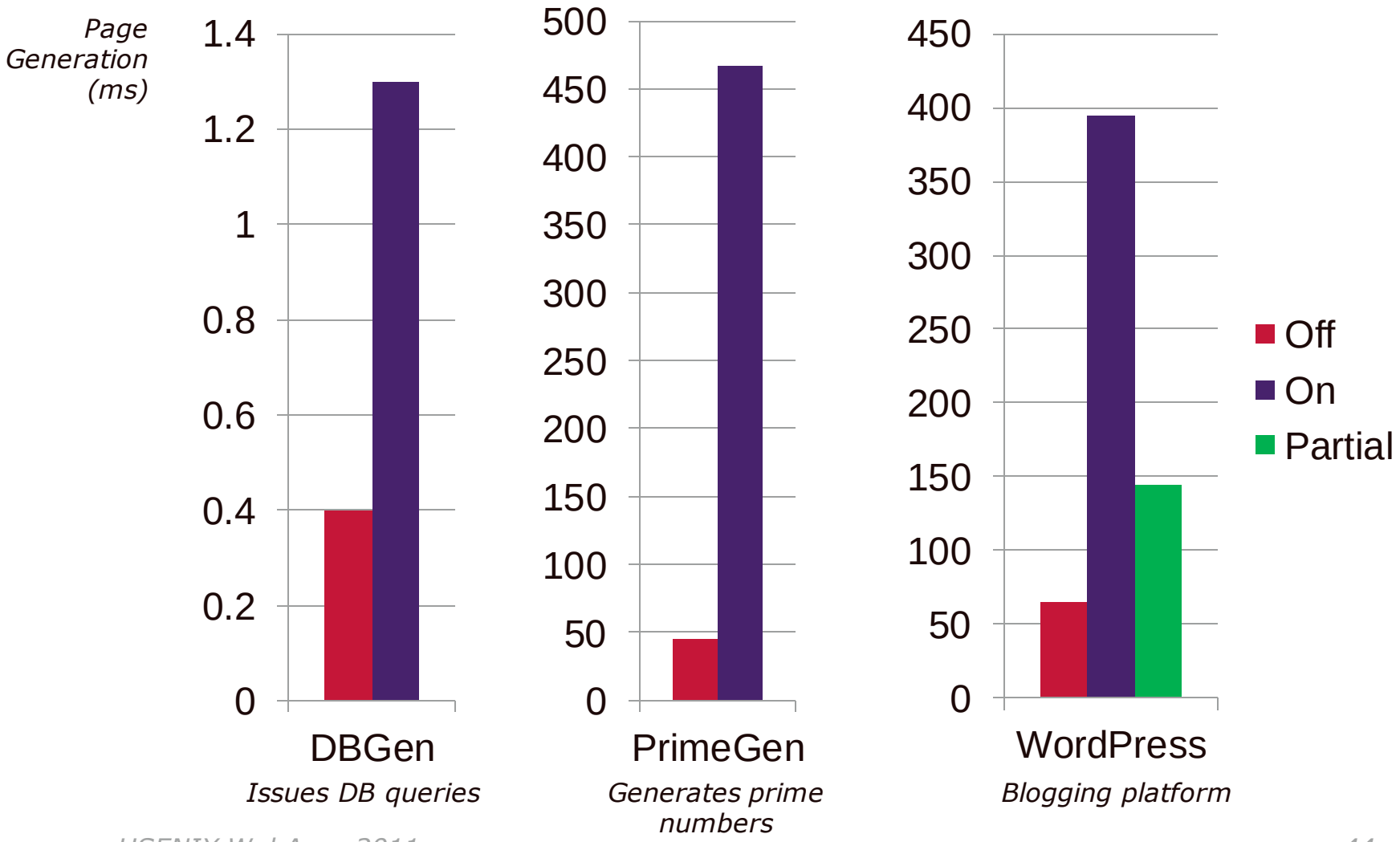


1 WordPress Plugins Results

- Total plugins with injection vulnerabilities: **15**
- Tested plugins: **14**
  - 1 plugin was not publicly available
- Vulnerabilities prevented: **12**
  - 10 XSS cases
  - 2 SQL Injection cases
- Vulnerabilities not prevented: **2** (false negatives)
  - Stored XSS attacks
  - PHP Aspis does not track taint in the database

✓ No observed false positives

2 PHP Aspis Overhead



Conclusion

- Partial taint tracking
  - Can be applied by source code transformations
  - Is suitable for applications that support plugins
  - Is effective for real world plugin vulnerabilities
- PHP Aspis design favours false negatives
  - False negatives are a consequence of partial taint tracking
  - False positives break existing applications
- "Reasonable" performance overhead
  - Suitable for deployments where security is more important than performance
  - Partial taint tracking for the WordPress case: 2.2x slowdown

The End

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```
$git clone git://github.com/jpapayan/aspis.git
```

ip108@doc.ic.ac.uk

References

[1] Venema, W. Runtime taint support proposal. In PHP Internals mailing list (2006)

[2] Yip, A. Wang X., et all. Improving application security with data flow assertions. In SOSP 2009

[3] Pietraszek, T and Berghe, C. Defending against injection attacks through context sensitive string evaluation. In Recent Advances in Intrusion Detection (2006)