Detecting Logic Vulnerabilities in E-Commerce Applications

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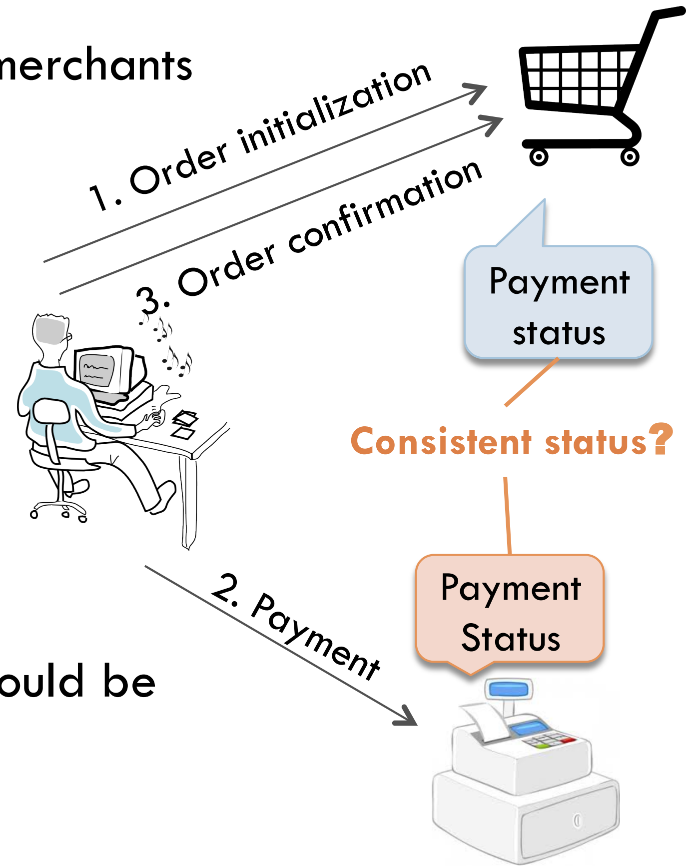
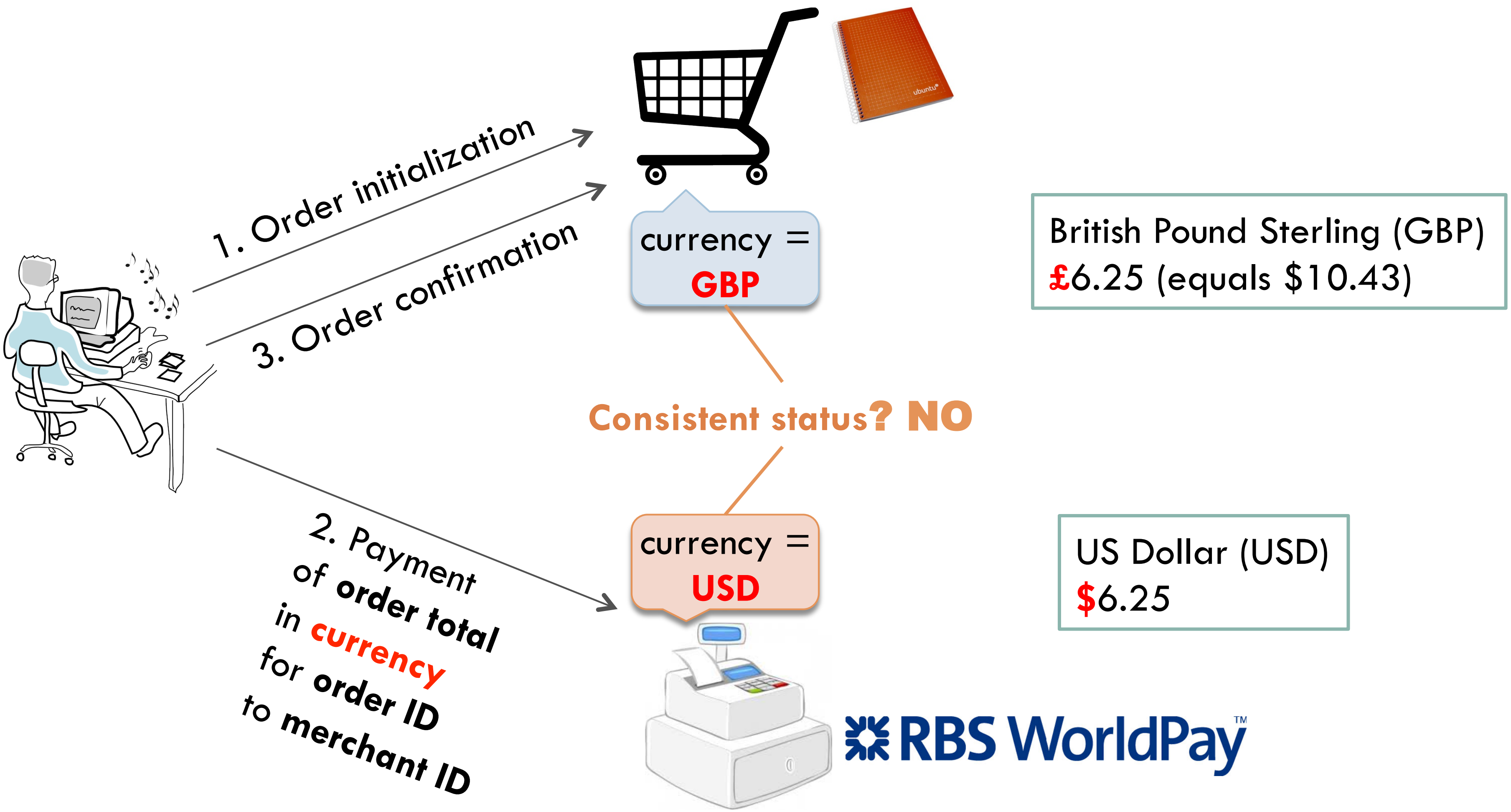
Logic Vulnerabilities in E-Commerce Web Applications

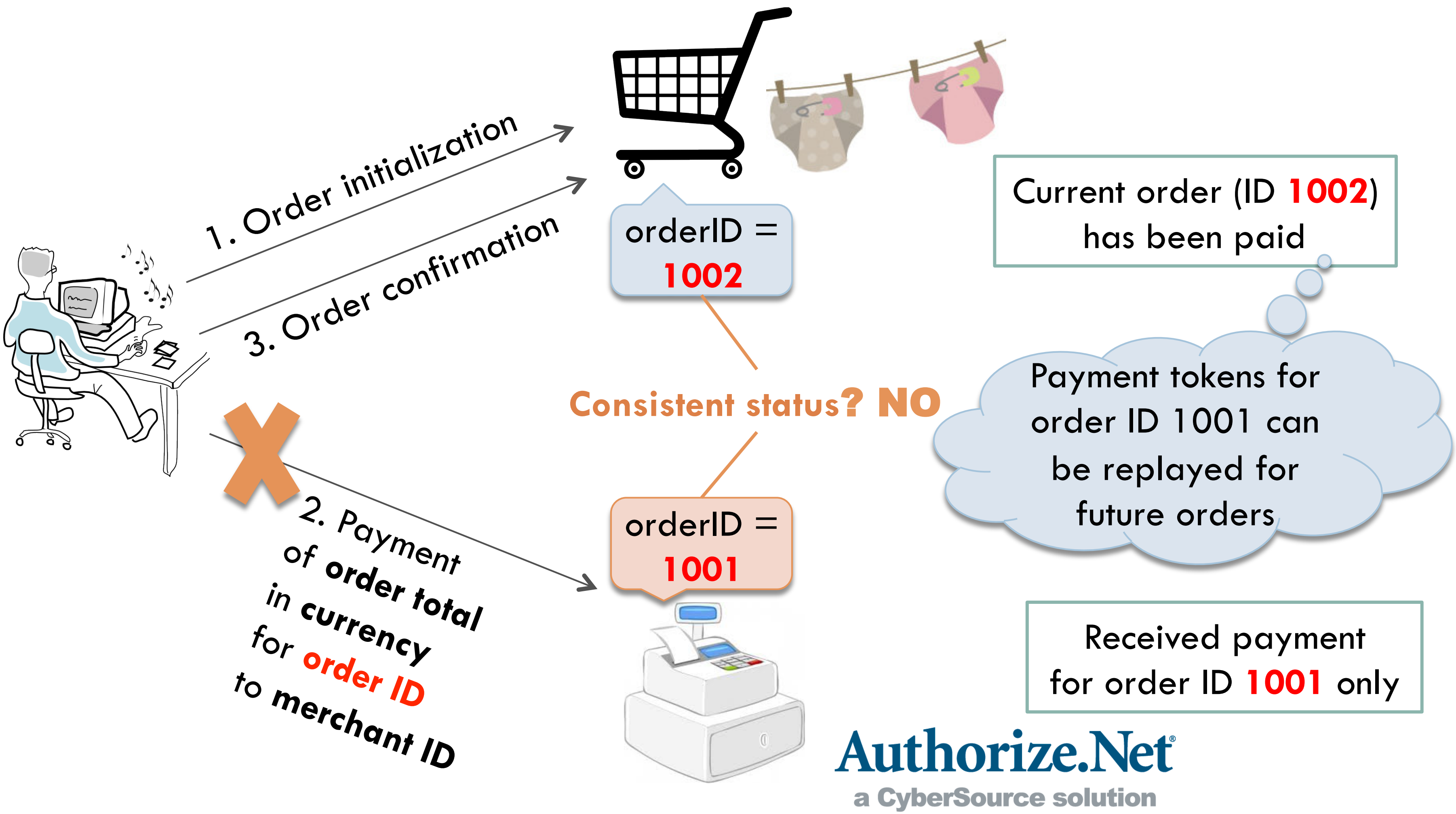
- Third-party cashiers
  - Bridge the trustiness gap between customers and merchants
  - Complicate logic flows during checkout
- Logic vulnerabilities in e-commerce web applications
  - Abuse application-specific functionality
  - Allow attackers to purchase products or services with incorrect or no payment
  - Have multiple attack vectors
    - Assumptions of **user inputs** and **user actions** should be explicitly checked
  - Example
    - CVE-2009-2039 is reported for Luottokunta (v1.2) but the patched Luottokunta (v1.3) is still vulnerable



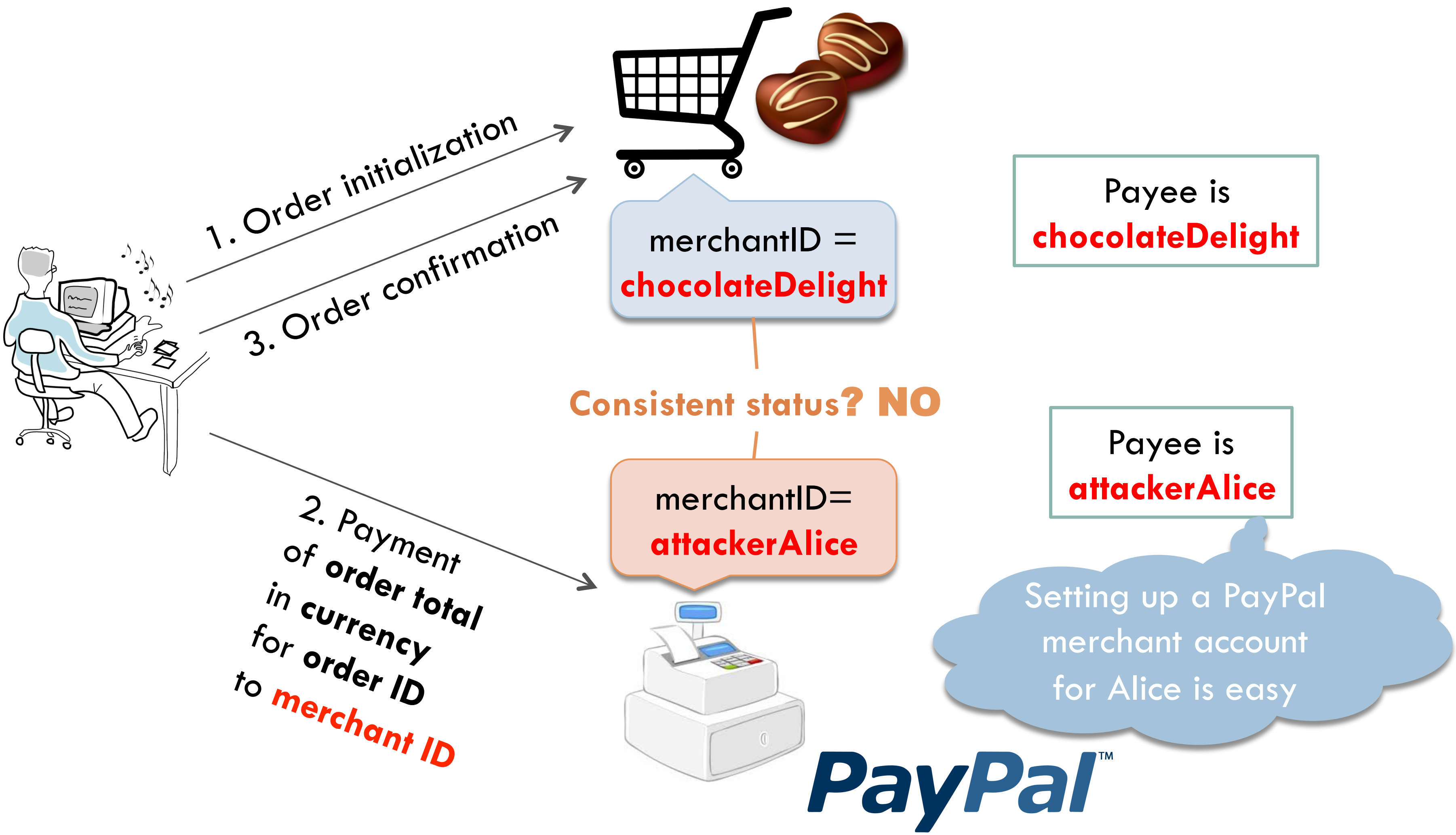
Attack on Currency



Attack on Order ID



Attack on Merchant ID



Key Challenge

- Logic vulnerabilities in e-commerce web applications are application-specific
  - Thorough code review of all possible logic flows is non-trivial
  - Various application-specific logic flows, cashier APIs and security checks make automated detection difficult

- Key challenge of automated detection

> The lack of a general and precise notion of **correct payment logic**

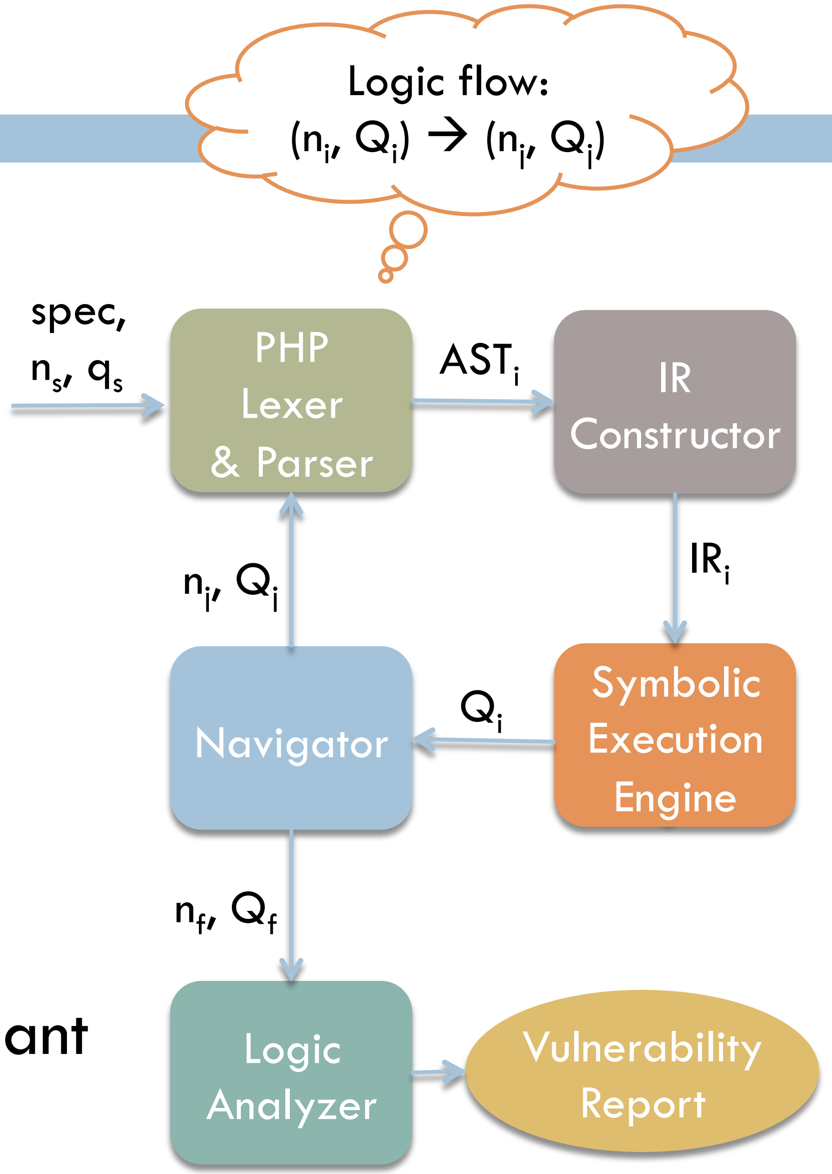
Key Insight

- A **common invariant** for automated detection

A checkout is secure when it guarantees the **integrity** and **authenticity** of critical payment status (order ID, order total, merchant ID and currency)

Our Approach

- A symbolic execution framework that explores critical control flows exhaustively
- Tracking taint annotations across checkout nodes
  - Payment status
  - Exposed signed token (signed with a cashier-merchant secret)



Taint Removal Rules

- Conditional checks of (in)equality
  - When an untrusted value is verified against a trusted one
  - Example of removing taint from order total

```
md5(SECRET . $_SESSION['order']→info['total']) == md5(SECRET . $_GET['oTotal'])
```

- Writes to merchant databases
  - When an untrusted value is included in an INSERT/UPDATE query
  - Merchant employee can easily spot tampered values

- Secure communication channels (merchant-to-cashier cURL requests)
  - Remove taint from order ID, order total, merchant ID or currency when such components are present in request parameters

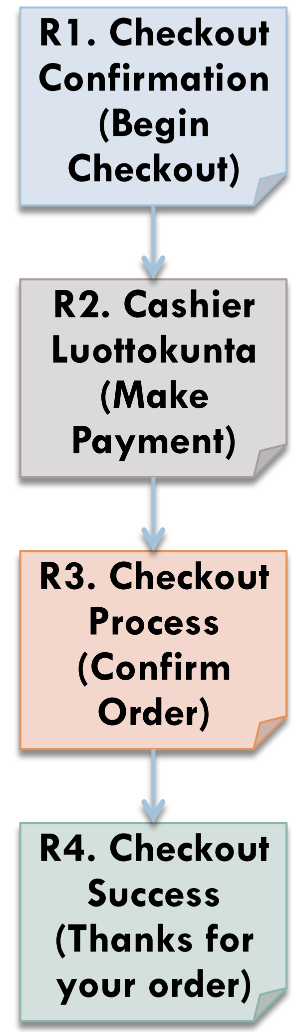
Taint Addition Rule

- Add an exposed signed token when used in a conditional check of a cashier-to-merchant request
  - Security by obscurity is insufficient

- Example
  - Hidden HTML form element: md5($secret . $orderId . $orderTotal)
  - $_GET['hash'] == md5($secret . $_GET['oId'] . $_GET['oTotal'])
  - This exposed signed token md5($secret . $orderId . $orderTotal) nullifies checks on order ID and order total

Vulnerability Detection Example

- R1. User → Merchant(checkoutConfirmation.php)
  - Symbolic HTML form contains two URLs: cashier URL and return URL(checkoutProcess.php).
- R2. User → Cashier(https://dmp2.luottokunta.fi)
  - Modeling cashier as trusted black box
- R3. User → Merchant(checkoutProcess.php), redirection
  - Representing all possible cashier responses with symbolic inputs
- R4. User → Merchant(checkoutSuccess.php), redirection
  - Analyzing logic states at this destination node (end of checkout) to detect logic vulnerabilities



Luottokunta (v1.3)

```
1.  function before_process() {
2.    if (!isset($_GET['orderID'])) {
3.      tep_redirect(FILE_PAYMENT);
4.    } else {
5.      $orderID = $_GET['orderID'];
6.    }

7.    $price = $_SESSION['order']->info['total'];
8.    $tarkiste = SECRET_KEY . $price
9.                       . $orderID . MERCHANT_ID;
10.   $mac = strtoupper(md5($tarkiste));

11.   if (($_POST['LKMAC'] != $mac)
12.        && ($_GET['LKMAC'] != $mac)) {
13.     tep_redirect(FILE_PAYMENT);
14.   } else {
15.     ...
16.}
17.}
```

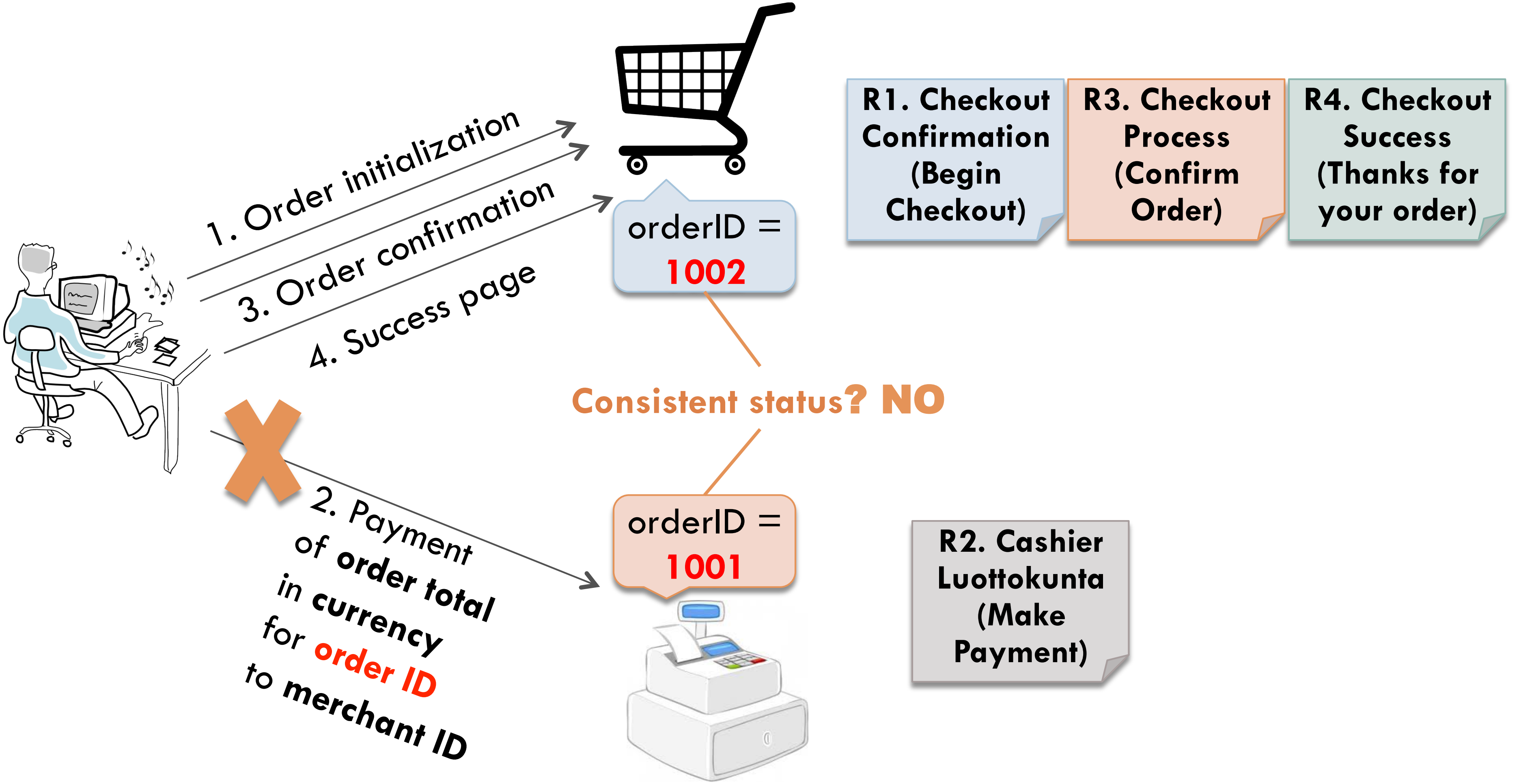
R3. Checkout Process (Confirm Order)

Path condition for 'else branch' (line 15):

```
[ or
  ($_POST['LKMAC'] =
      strtoupper(md5(SECRET_KEY
    . $_SESSION['order']->info['total']
    . $_GET['orderID'] . MERCHANT_ID)));

  ($_GET['LKMAC'] = ...);
]
```

- Remove taint from **order total** ($_SESSION['order']->info['total']) and **merchant ID** (MERCHANT_ID).
- **Order ID** and **currency** are still tainted: $_GET['orderID'] is an untrusted user input.
- 'If' branch is a backward logic flow; 'else' branch is a forward logic flow



R3 for order ID **1002**: http://merchant.com/checkoutProcess.php?orderID=**1001**&LKMAC=**SecretMD5For1001**

Evaluation

- Subjects: 22 unique payment modules of osCommerce
  - More than 14,000 registered websites, 928 payment modules, 13 years of history (osCommerce v2.3)
  - **20** out of 46 default modules with distinct CFGs
  - **2** Luottokunta payment modules (v1.2 & v1.3)

- Metrics
  - Effectiveness: Detected 12 logic vulnerabilities (11 new) with no false positives
  - Performance

Logic Vulnerability Analysis Results

Payment Module	Safe	Payment Module	Safe
2Checkout	✗	PayPal Pro - Direct Payments	✔
Authorize.net CC AIM	✔	PayPal (Payflow) - Direct Payments	✔
Authorize.net CC SIM	✗	PayPal (Payflow) - Express Checkout	✔
ChronoPay	✗	PayPal Standard	✗
inpay	✔	PayPoint.net SECPay	✗
iPayment (Credit Card)	✗	PSiGate	✗
Luottokunta (v1.2)	✗	RBS WorldPay Hosted	✗
Luottokunta (v1.3)	✗	Sage Pay Direct	✔
Moneybookers	✓	Sage Pay Form	✗
NOCHEX	✗	Sage Pay Server	✔
PayPal Express	✔	Sofortüberweisung Direkt	✔*

Taint Annotations of 12 Vulnerable Payment Modules

Payment Module	Order Id	Order Total	Merchant Id	Currency	Signed Tokens
2Checkout	✗	✗	✗	✗	
Authorize.net SIM	✗			✗	
ChronoPay	✗	✗	✗	✗	✗
iPayment (Credit card)	✗				
Luottokunta (v1.2)	✗	✗	✗	✗	
Luottokunta (v1.3)	✗			✗	
NOCHEX	✗	✗	✗	✗	
PayPal Standard			✗		
PayPoint.net SECPay	✗	✗		✗	
PSiGate	✗	✗	✗	✗	
RBS WorldPay Hosted				✗	✗
Sage Pay Form		✗		✗	
Total	**9**	**7**	**6**	**10**	**2**

Performance Results of 12 Vulnerable Payment Modules

Payment Module	Files	Nodes	Edges	Stmts	States	Flows	Time(s)
2Checkout	105	5,194	6,176	8,385	40	4	16.04
Authorize.net SIM	105	5,221	6,221	8,435	46	4	16.89
ChronoPay	99	5,013	5,969	8,084	69	5	31.51
iPayment (Credit card)	99	4,999	5,932	7,918	38	5	21.86
Luottokunta (v1.2)	105	5,158	6,127	8,291	34	4	15.33
Luottokunta (v1.3)	105	5,164	6,135	8,308	35	4	15.33
NOCHEX	105	5,145	6,111	8,237	33	4	15.03
PayPal Standard	99	5,040	6,006	8,170	68	6	33.01
PayPoint.net SECPay	105	5,174	6,152	8,332	40	4	15.80
PSiGate	106	5,231	6,228	8,436	44	4	16.82
RBS WorldPay Hosted	99	5,019	5,977	8,121	79	5	36.12
Sage Pay Form	106	5,315	6,329	8,762	55	4	19.96
Average of 22	**102.73**	**5,173**	**6,162**	**8,376**	**67.27**	**5.05**	**31.43**

Conclusion

- First static detection of logic vulnerabilities in e-commerce applications
  - Based on an application-independent invariant
  - A scalable symbolic execution framework for PHP applications, incorporating taint tracking of payment status

- Three responsible proof-of-concept experiments on live websites

- Evaluated our tool on 22 unique payment modules and detected 12 logic vulnerabilities (11 are new)