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Analyzing Information Flow in JavaScript-based Browser Extensions

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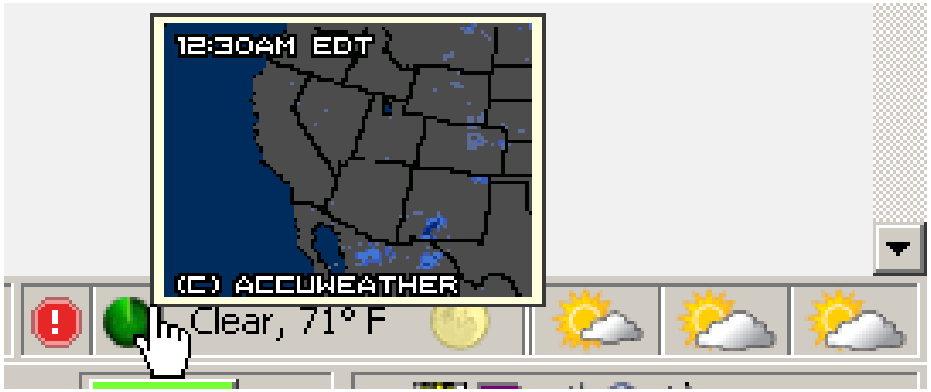
JavaScript-based Extensions (JSEs)

- Modern browsers support extensions
  - JavaScript-based Extensions



- Hugely popular
  - 1.5 bn JSEs downloaded, 150 - 190 mn used daily

[Mozilla Add-ons Statistics Dashboard]

JSEs – A Security Risk

- Unrestricted access to system resources

- Hard to detect malicious code
- Inadequate sandboxing of JSE actions
- Lack of good development and debugging tools for JSE

Outline

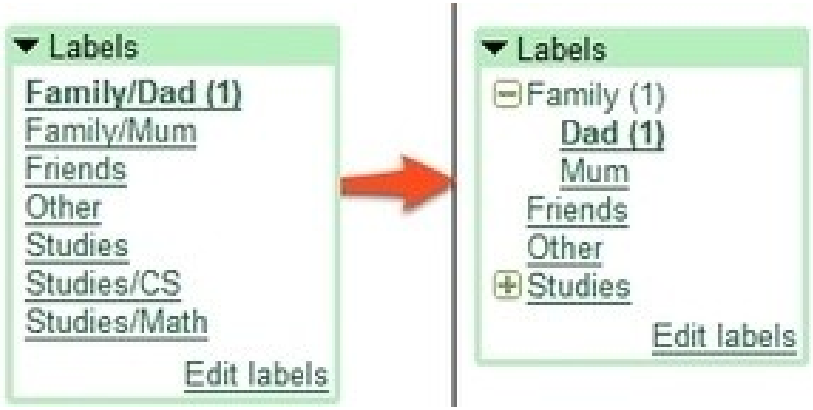
- Introduction
- **Motivating Example**
- **Solution**
- **Evaluation**
- **Conclusion**

GreaseMonkey

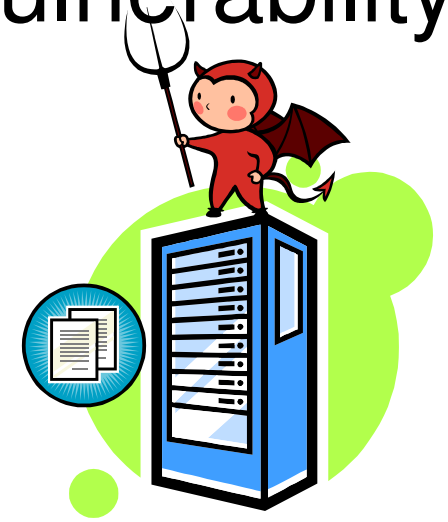
- Highly popular Firefox extension
  - nearly 3 million active daily users

[Mozilla Add-ons Statistics Dashboard]

- Exports a set of APIs for users to customize and program the way web pages look and function



GreaseMonkey / Firefox Vulnerability



www.evil.com

GreaseMonkey

HTTP

Sensitive

Firefox with GreaseMonkey

Alice

Exploited JSEs can lead to disclosure of confidential data

Firefox Sniffer (FFsniFF) – A Malicious JSE

Sniffs all form fields

Emails them to the attacker

Firefox with FFsniFF

Submit to the website

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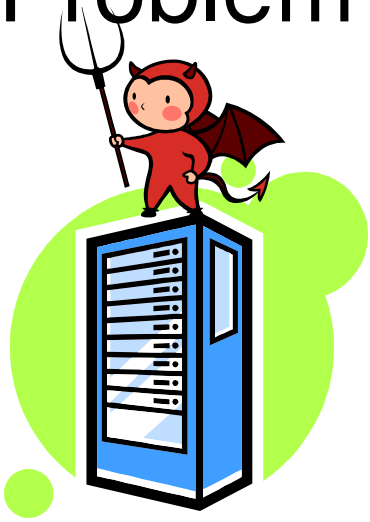
Solving the GreaseMonkey Problem



www.evil.com

GreaseMonkey

Firefox with GreaseMonkey

Alice

1. **Mark data as sensitive**
2. **Take action when sensitive data is sent out**

Our Solution

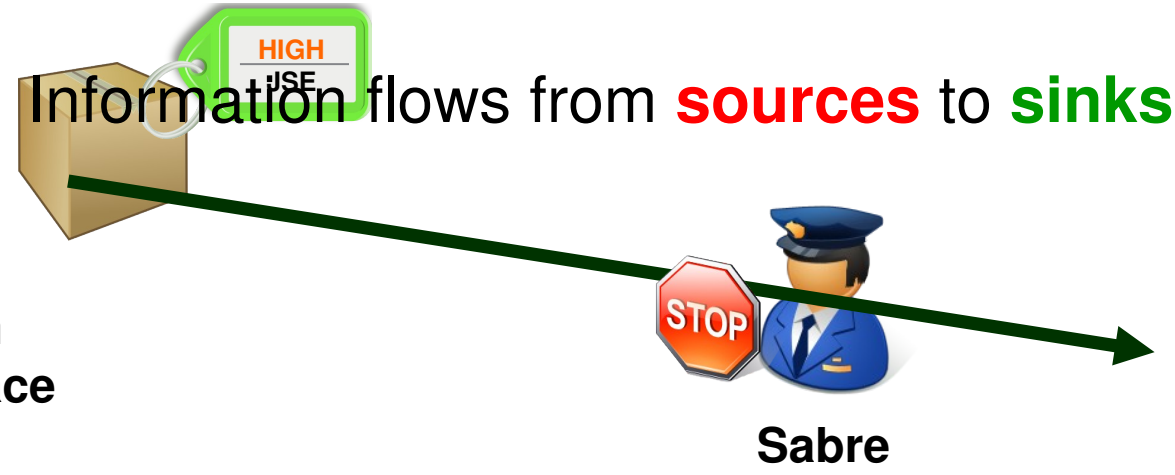
- ***S***ecurity ***A***rchitecture for ***Br***owser ***E***xtensions (Sabre)

Enhance browser with JavaScript information flow analysis

- Attach **security labels** with each JavaScript object
- Track the propagation of these labels
- Take action when a sensitive object is externalized

Security Labels

- **File System**
- **User Interface**



Information flows from **sources** to **sinks**.

- **Network**
- **File System**

Sabre

Please see the paper for the list of sources and sinks.

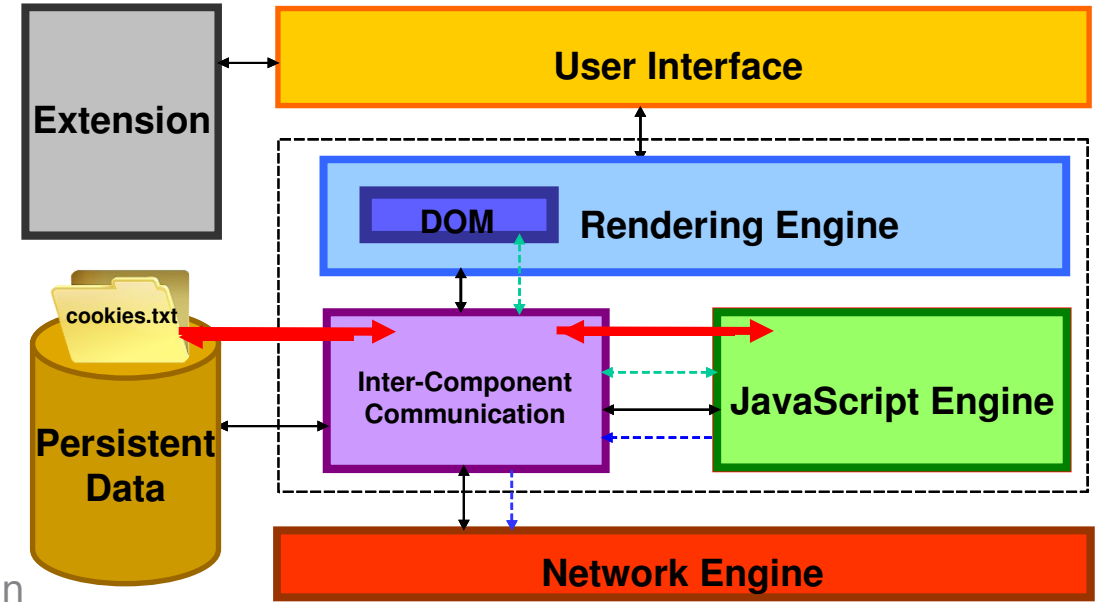
Challenges in Real JSEs

1. Cross - Domain Flows
2. Implicit Flows
3. Benign Flows
4. Provenance

Challenge 1 : Cross – Domain Flows

- JavaScript in a JSE can interact with other browser sub-systems

```
var cookieMgr = Components.classes.["@mozilla.org/cookiemanager;1"].
                    getService(Components.interfaces.nsICookieManager);
```



Challenge 1 : Cross – Domain Flows (Object Access)

```
var cookieMgr = Components.classes.["@mozilla.org/cookiemanager;1"].
                    getService(Components.interfaces.nsICookieManager);
```

Problem : Label propagation for objects and properties not managed by JavaScript

Solution : Assign sensitivity label of component to JavaScript objects

- JavaScript can interact and store data in the DOM
  - Modify the DOM to store security labels also

Challenge 2 : Implicit Flows

```
 1: x = false;
 2: y = false;
 3: if (document.cookie == "abc") {
 4:   x = true;
 5: } else {
 6:   y = true;
 7: }
 8: if (x == false) {
 9:   // Line 6 was executed, and x is not tainted
10: }
11: if (y == false) {
12:   // Line 4 was executed, and y is not tainted
13: }
```

Problem : How to handle direct control dependency?

Solution : Labeled Scope

L(lhs) = L(rhs) U L(scope)

Challenge 2 : Implicit Flows (contd.)

```
 1: x = false;
 2: y = false;
 3: if (document.cookie == "abc") {
 4:   x = true;
 5: } else {
 6:   y = true;
 7: }
 8: if (x == false) {
 9:   // Line 6 was executed, and x is not tainted
10: }
11: if (y == false) {
12:   // Line 4 was executed, and y is not tainted
13: }
```

Problem : How to deal with all implicit flows?

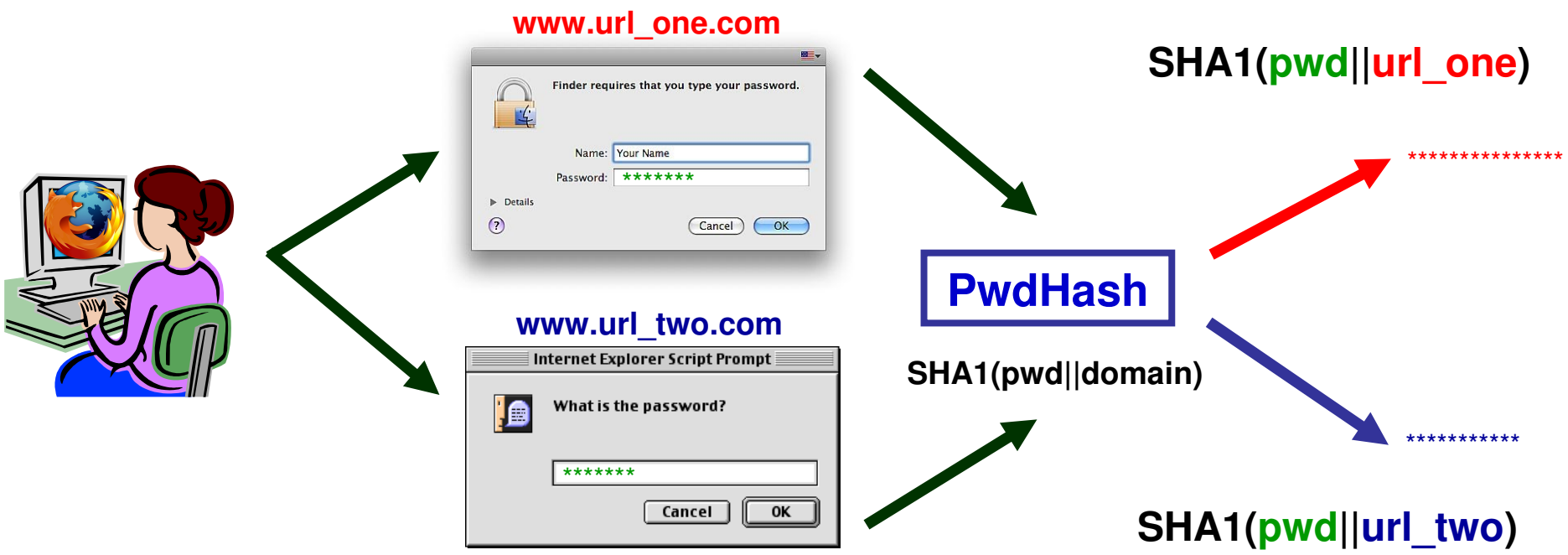
Solution : Static analysis

- Currently enhancing Sabre with support for static analysis

Challenge 3 : Benign Flows

- Benign JSEs may contain flow violations
  - PwdHash

[Usenix Security '05]



Challenge 3 : Benign Flows

- Disallowing them could render JSE dysfunctional

Problem : How to identify such flows?

  – Difficult to isolate malicious / benign behavior at runtime

Solution : Security analyst supplies a security policy to white-list trusted JSEs or declassify specific objects

- De-classification of password field in PwdHash

```
<declassify, stanford-pwdhash.js, finish, 330, field.value>
```

Challenge 4 : Provenance

- Origin of the script
  - Needs to be determined only once at the time of dispatching the script for execution
- JSEs contain overlays
  - Describe patches for the UI and contain JavaScript code
  - Event - driven and not explicitly dispatched for execution

Problem : Track provenance for "all" JavaScript including code in JSE overlay files

Solution : Per bytecode provenance tracking, or separately verify the overlay files

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Evaluation - Goals

- Effectiveness
  - Classify behavior of benign JSEs
  - Determine information flow violations in malicious JSEs
- Performance
  - Impact on JavaScript performance
  - Compare overhead due to per-bytecode provenance check for overlay code

Evaluation - Methodology

- Evaluated Sabre using a suite of 24 JSEs
  - Comprising over 120K lines of JavaScript code
- Enhance the browser with the JSE being tested and examine any flow violations
- Test Setup
  - Integrated Sabre with Firefox 2.0.0.9.
  - 2.33Ghz Intel Core2 Duo, 3GB RAM, Ubuntu 7.10

Results - Categorizing Benign JSEs

Behavior key: **(1)** HTML forms; **(2)** HTTP channels; **(3)** File system; **(4)** Loading URLS; **(5)** JavaScript events.

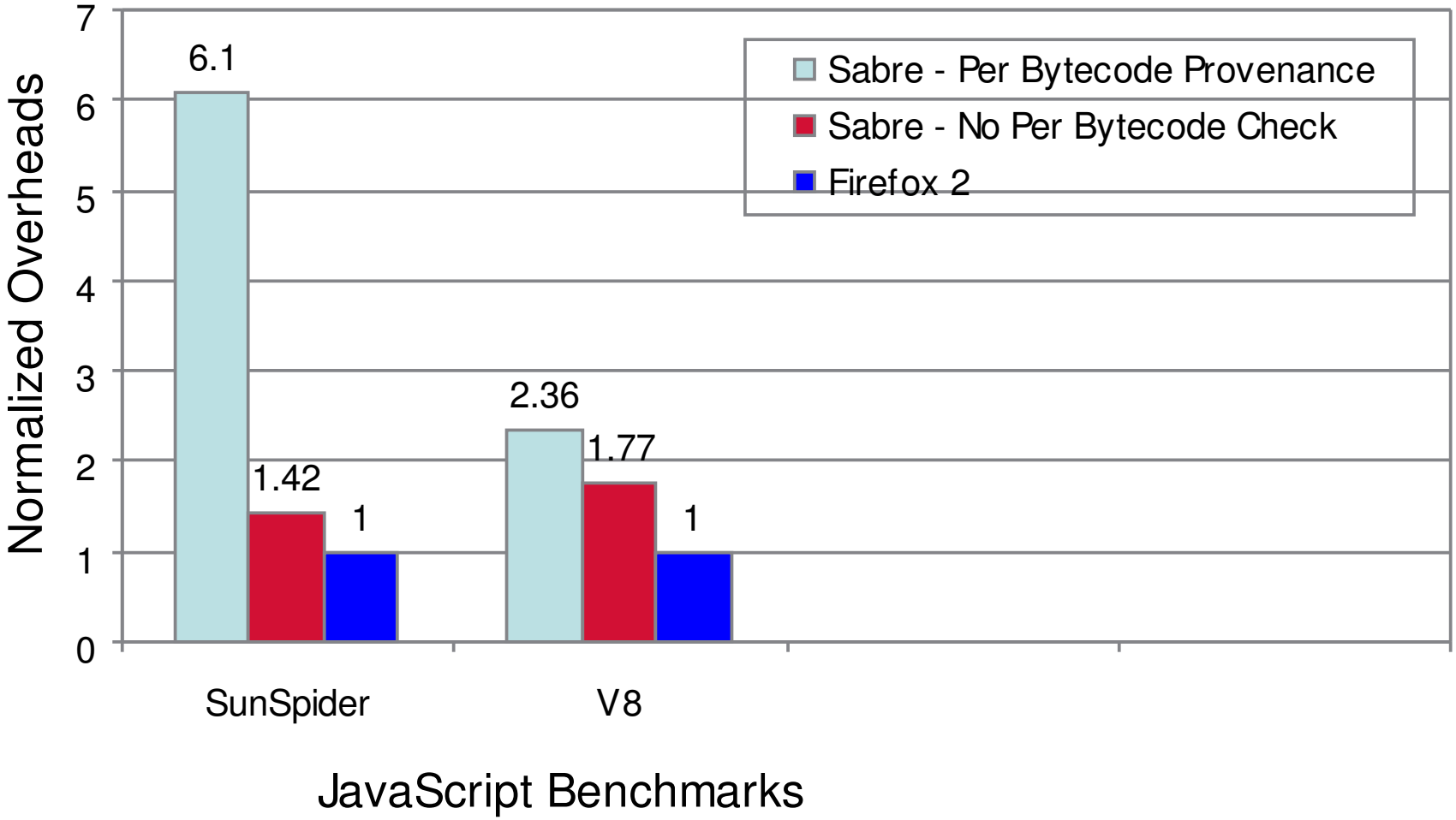
	JSE	1	2	3	4	5
1.	Adblock Plus		✓	✓		
2.	All-in-One-Sidebar			✓		
3.	CoolPreviews		✓	✓		
4.	Download Statusbar			✓		
5.	Fast Video Download				✓	
6.	Forecastfox		✓	✓	✓	
7.	Foxmarks Synchronizer		✓	✓		
8.	Ghostery			✓		
9.	GooglePreview		✓	✓		
10.	Greasemonkey (0.8.1)		✓	✓		
11.	NoScript		✓	✓		
12.	PDF Download		✓	✓	✓	
13.	Pwdhash	✓				
14.	SpeedDial			✓	✓	
15.	StumbleUpon		✓	✓	✓	
16.	Stylish		✓	✓	✓	✓
17.	Tab Mix Plus			✓	✓	
18.	User Agent Switcher			✓		
19.	Video DownloadHelper		✓	✓		
20.	Web-of-Trust		✓	✓	✓	

White-listing / De-classification of trusted JSEs is essential.

Results - Accuracy

- **Vulnerable & Malicious JSEs**
  - GreaseMonkey v0.3.3
  - Firebug v1.01
  - FFsniFF
  - BrowserSPY
- **Result**
  - Precisely identified all flow violations
  - No false positives during normal web browsing

Results - Performance Overheads



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Conclusion

- Exploited JSEs can cause loss of sensitive information
- Policy-based access control is coarse grained and overly restrictive
- Sabre uses information flow tracking across browser sub-systems to prevent security violations in untrusted JSE code