Cross-Origin State Inference (COSI) Attacks: Your Browser is Leaking Your Secrets

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Juan Caballero

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COSI Attack

A malicious web site infers the state of a user (the victim) at another web site

Alice
(victim)

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Web Browser

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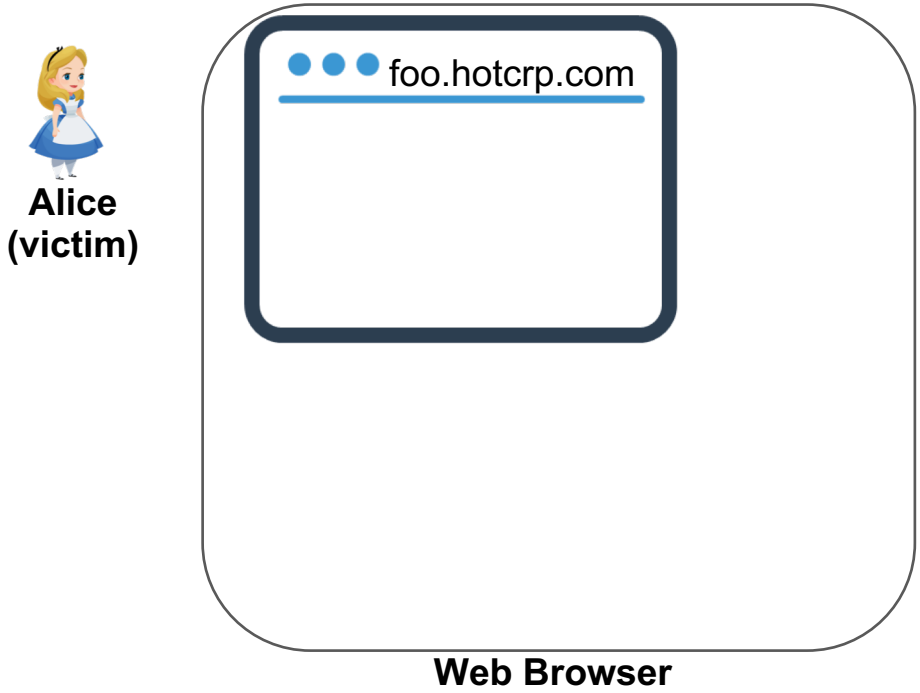

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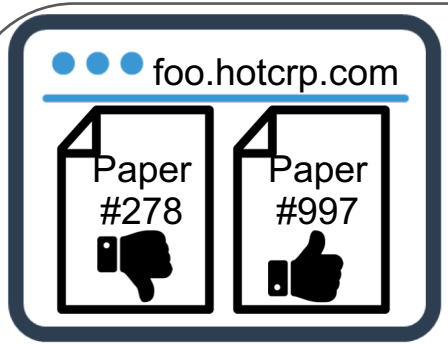

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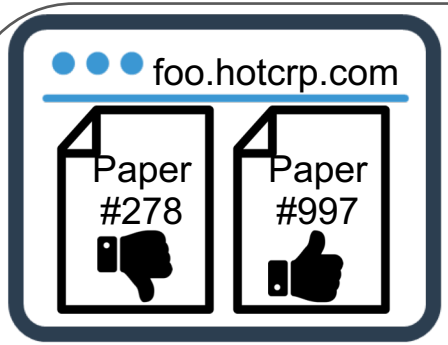

Malice (Attacker)

Web Browser

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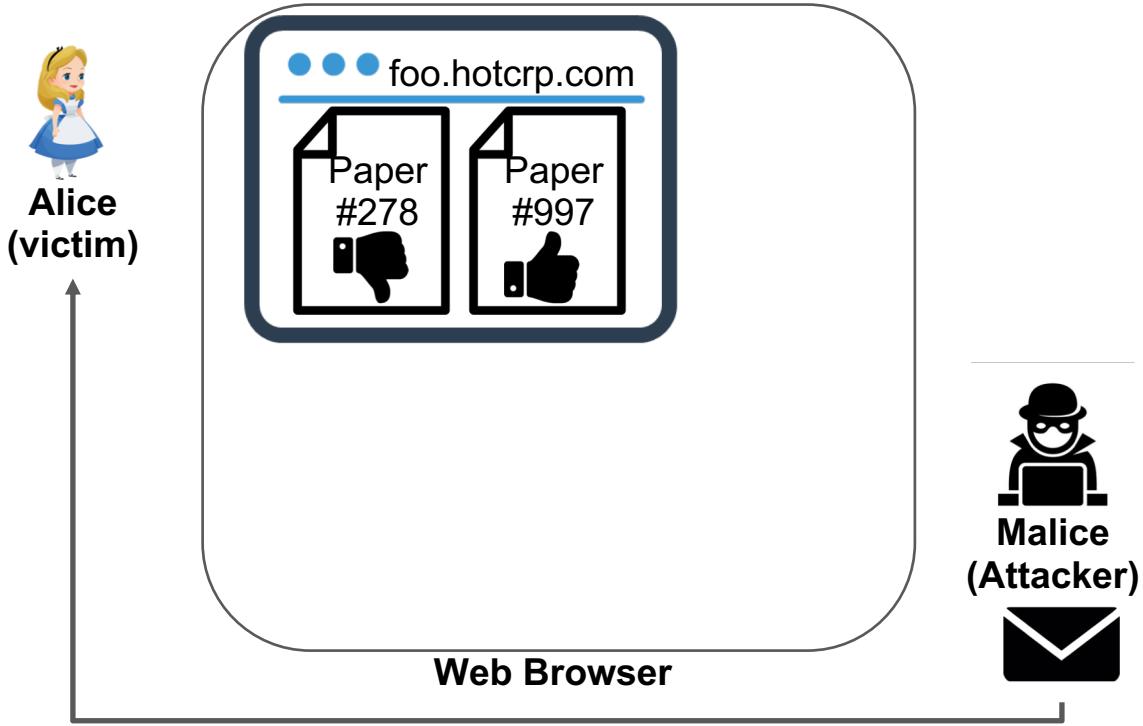

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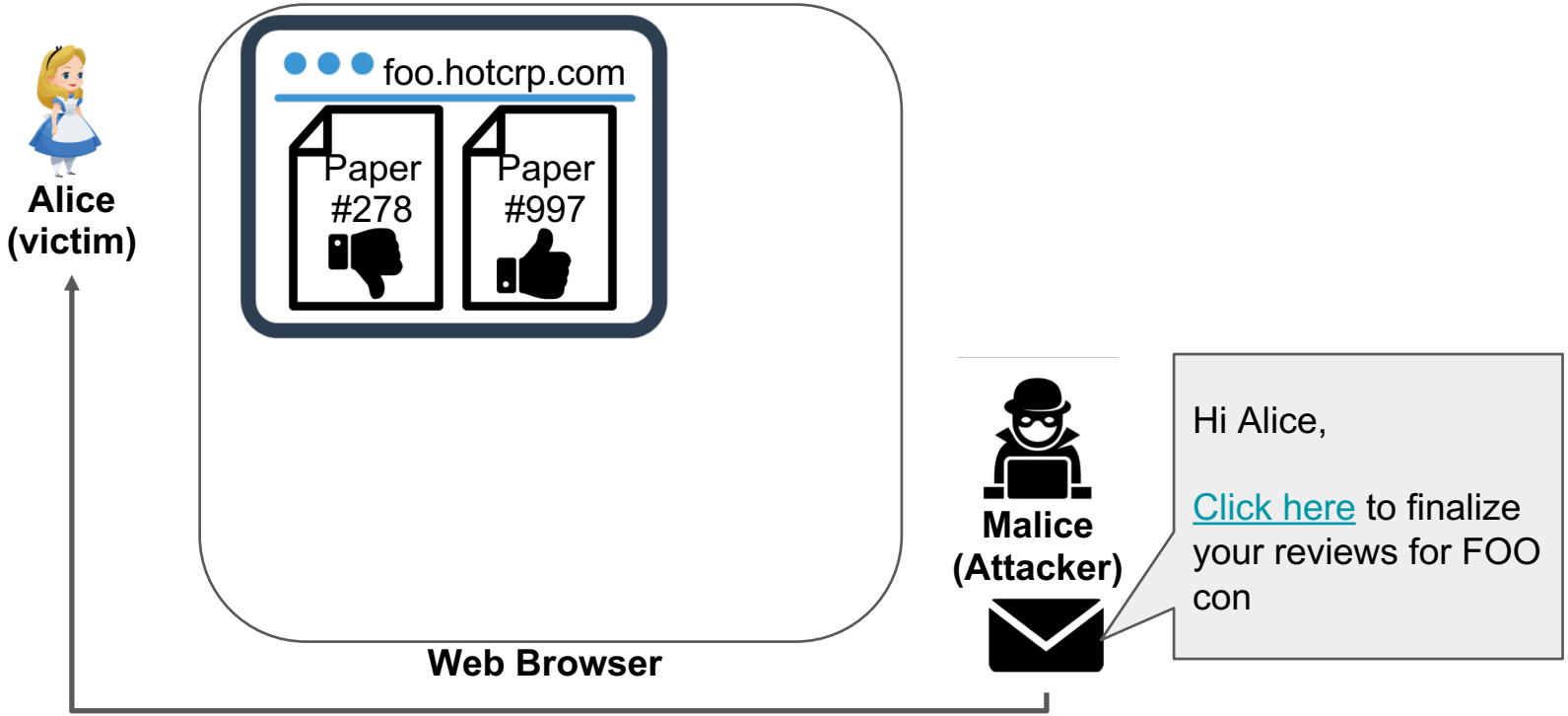

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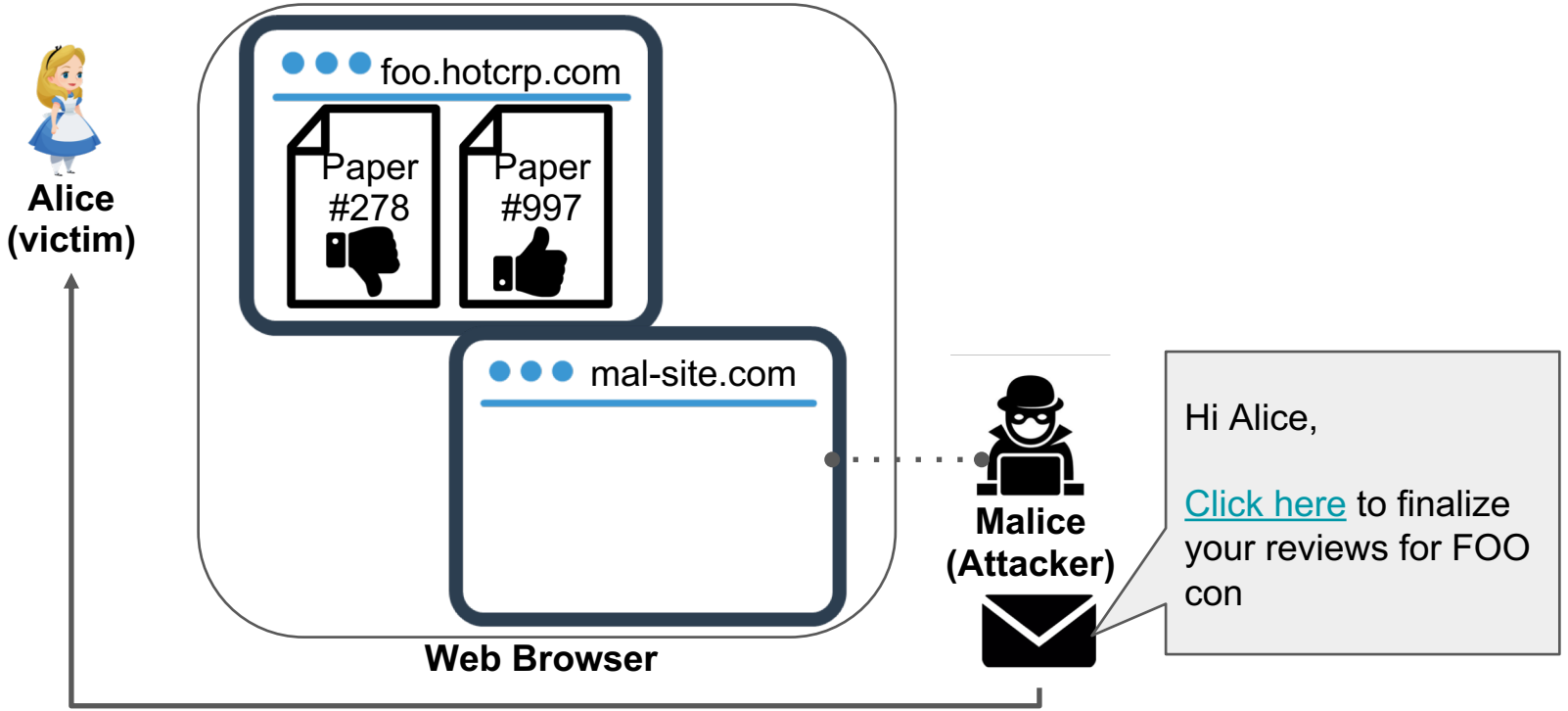

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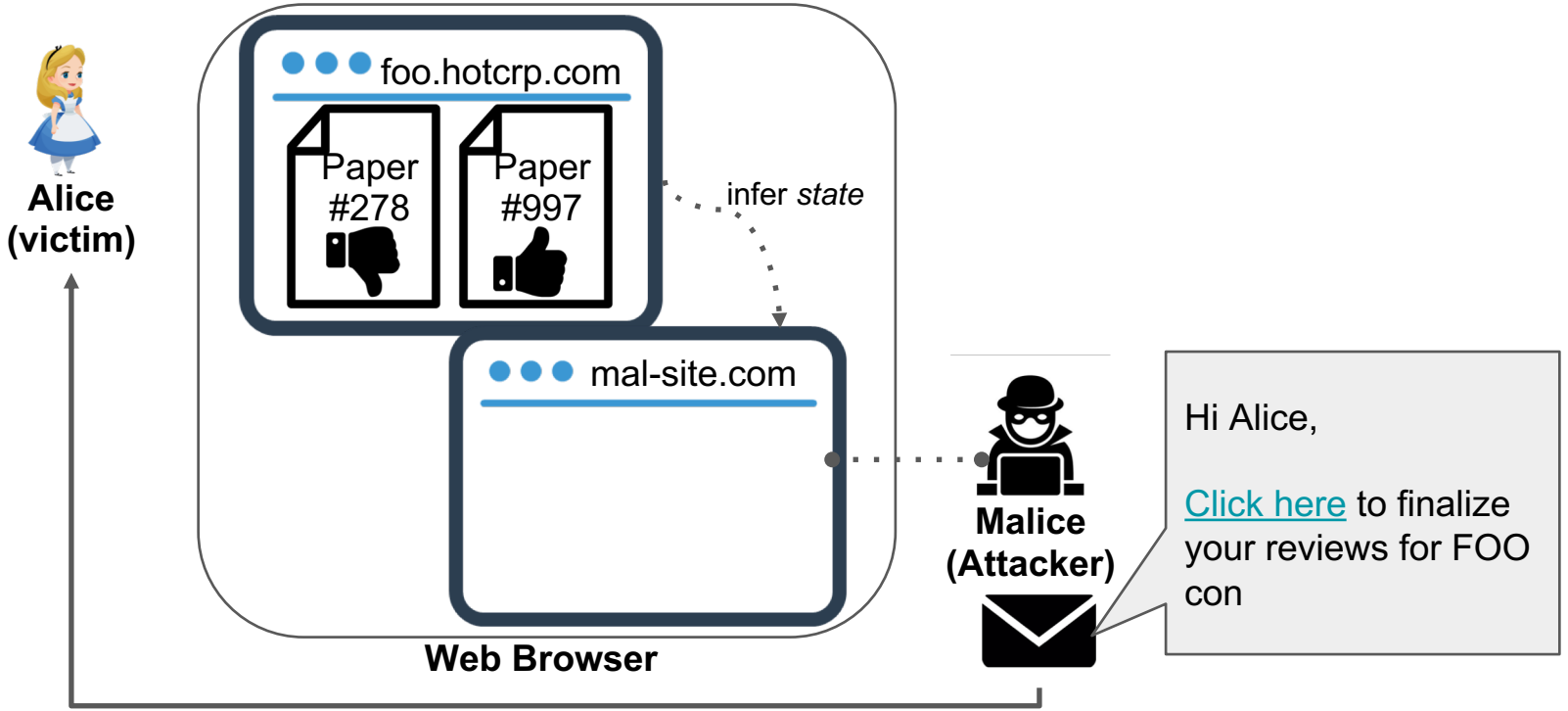

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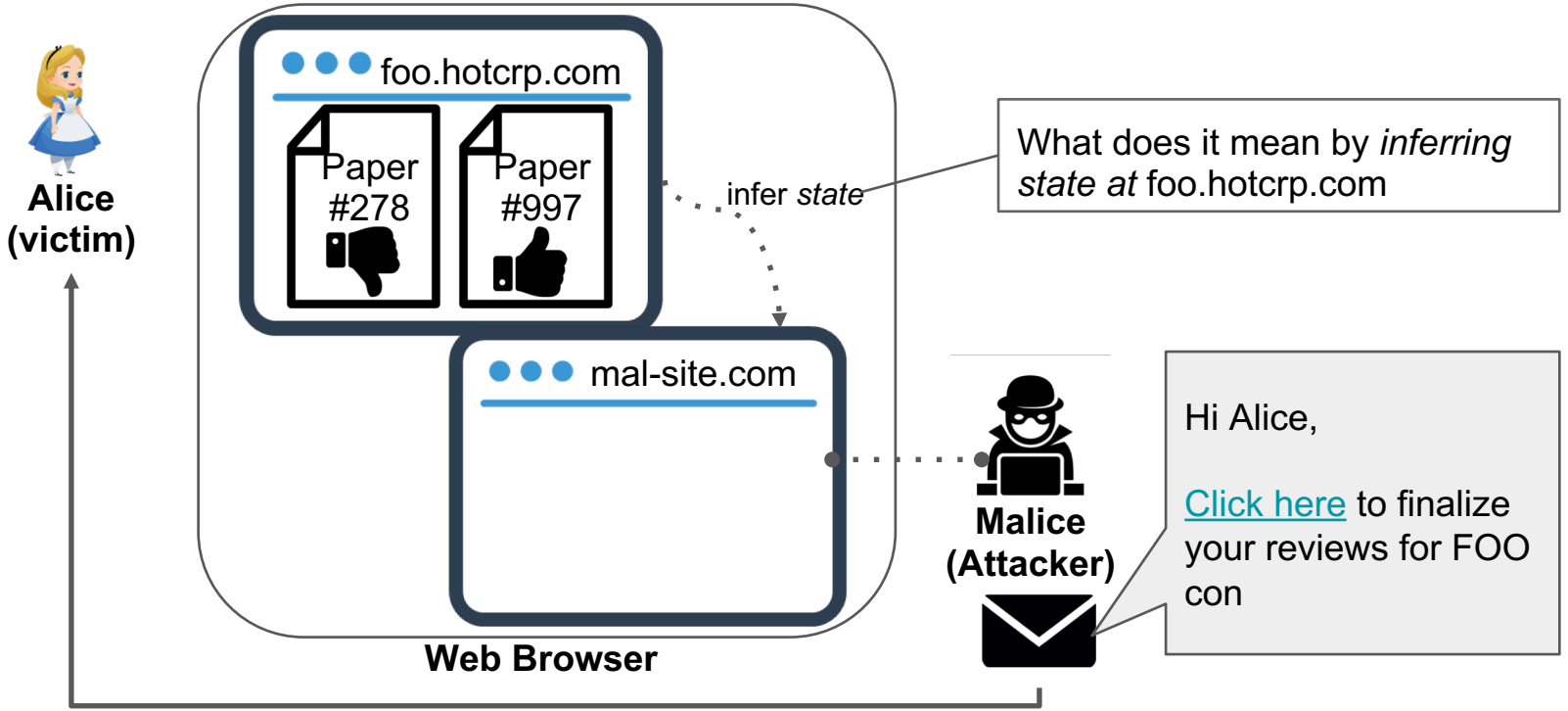
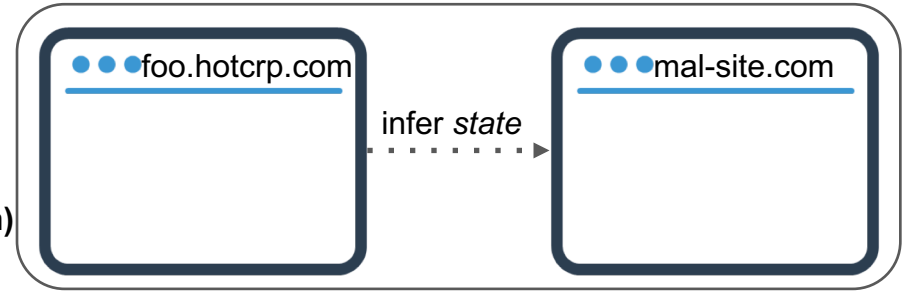


States

Alice (victim)



Web Browser

COSI Attack:
- Attacker's goal: infer states
- Known by different names

Login	Logged In / Logged Out	Login Detection, Login Oracle
Account Type	Reviewer / Author / Admin	
Content Ownership	Owns a review of paper #278 / Does not own a review of paper #278	
Account Ownership	Owns the account *user217* / Does not own the account *user217*	Deanonymization

State-dependent URLs (SD-URLs)

URLs returning different responses depending on the requesting **browser's state**

SD-URL: *https://foo.hotcrp.com/api.php/review?p=278*

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Logged In · Reviewer · Reviews paper #278	

State-dependent URLs (SD-URLs)

URLs returning different responses depending on the requesting **browser's state**

SD-URL: *https://foo.hotcrp.com/api.php/review?p=278*	
State	**Response**
Logged In · Reviewer · Reviews paper #278	code = 200

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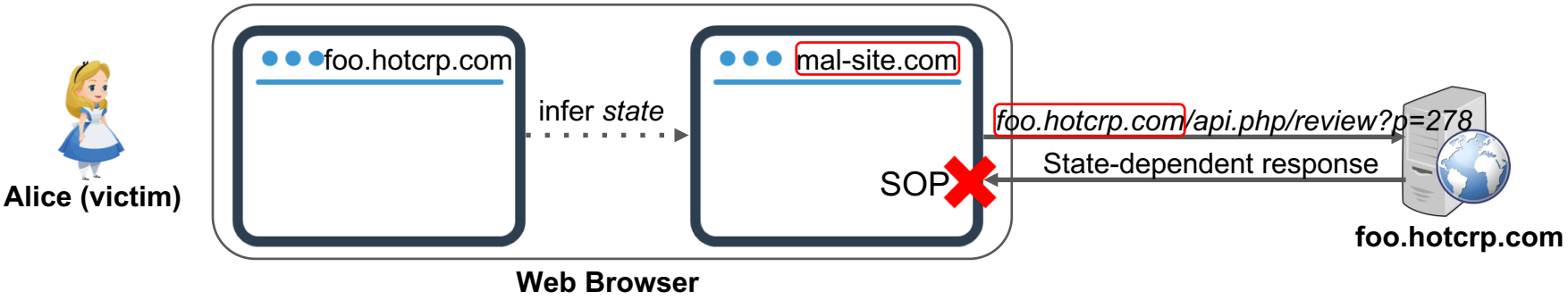
SD-URL: *https://foo.hotcrp.com/api.php/review?p=278*	
State	**Response**
Logged In · Reviewer · Reviews paper #278	code = 200
Logged In · Reviewer · Not review paper #278	code = 403

State-dependent URLs (SD-URLs)



SD-URL: *https://foo.hotcrp.com/api.php/review?p=278*

State	**Response**
Logged In, Reviewer, Reviews paper #278	code = 200
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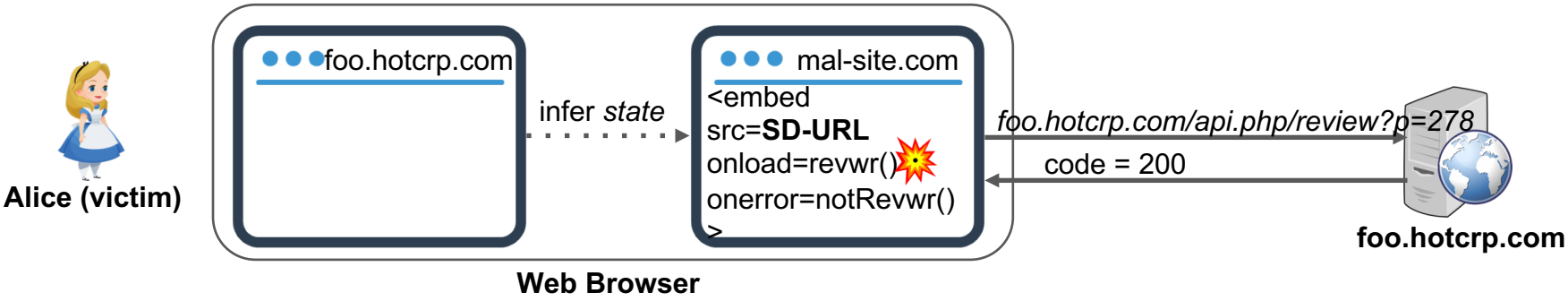
XS-Leaks

Browser side-channels for inferring the response of **cross-origin** requests

Leak Type	**References**
Events-Fired	[Grossman2006Blog, Goethem2015CCS, Cardwell2011Blog, ..]
Object-Properties	[Grossman2012Blog, Schwenk2017USENIX, Masas2018Blog..]
JS-Error	[Grossman2006Blog, Shiflett2006Blog]
CSS-Properties	[Evans2008Blog]
CSP-Violation	[Homakov2013Blog, Gulyas2018WPES]
Timing	[Bortz2007WWW, Evans2009Blog, Goethem2015CCS, ..]
AppCache	[Lee2015NDSS]

Events Fired XS-Leak



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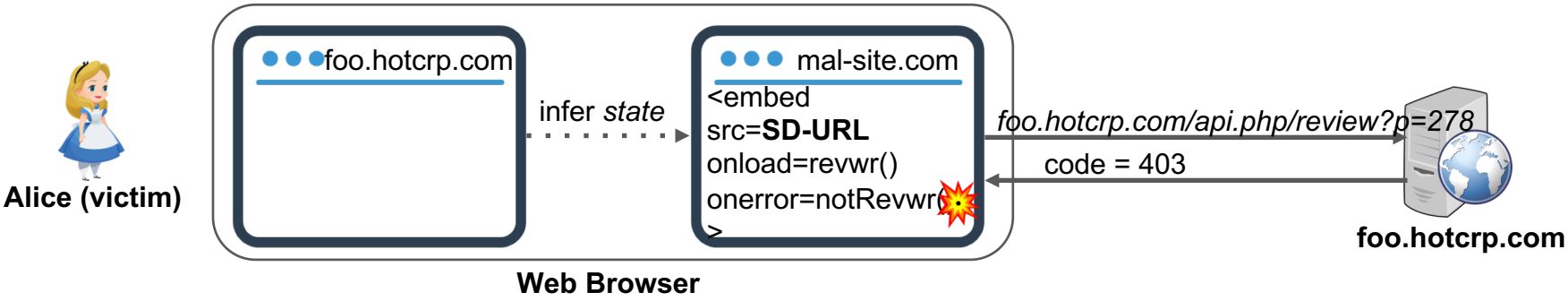

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Multiple States, Same Response

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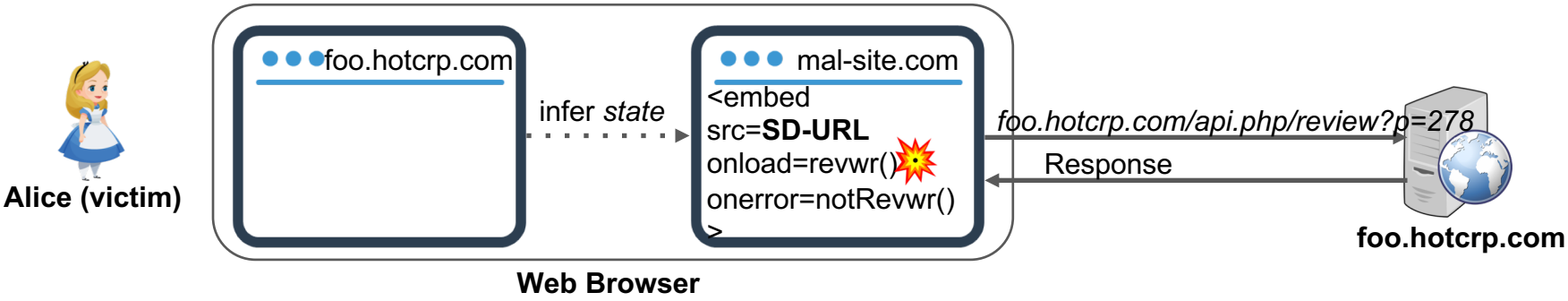

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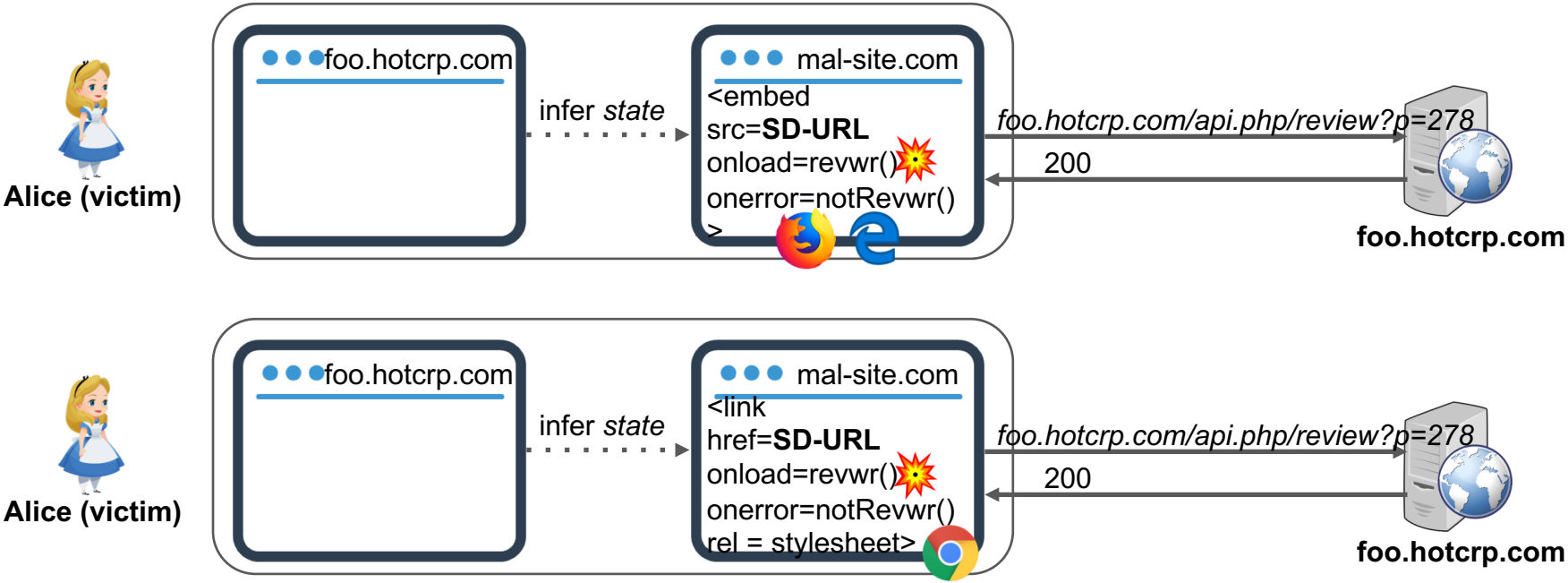
Same Attack Payload, Browser-specific Behavior

The same XS-Leak payload may work differently on **different browsers**



Attack Classes

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Name

:

Attack Classes

Name	SD-URL Responses	
	Response A	Response B

:

Attack Classes

Name	SD-URL Responses		XS-Leak	
	Response A	Response B	Inclusion	Manifest.

:

Attack Classes

Name	SD-URL Responses		XS-Leak		Browser Support		
	Response A	Response B	Inclusion	Manifest.	Chrome	Firefox	Edge

:

Attack Classes

Name	SD-URL Responses		XS-Leak		Browser Support		
	Response A	**Response B**	**Inclusion**	**Manifest.**	**Chrome**	**Firefox**	**Edge**
EF-StatusErrorScript	*code* = 200 *content-type* = text/javascript	*code* = 4xx || 5xx	<script>	onload / onerror	✓	✓	✓

:

Attack Classes

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Class	SD-URL Responses		Attack Page's Logic		Browsers		
	Response A	*Response B*	*Inclusion Methods*	*Leak Method*	*Firefox*	*Chrome*	*Edge*
EF-StatusErrorScript	sc = 200, ct = text/javascript	sc = (4xx OR 5xx)	`script src=URL`	[onload] / [onerror]	✓	✓	✓
EF-StatusErrorObject	sc = 200, ct ≠ (audio OR video)	sc ≠ (200 OR 3xx)	`object data=URL`	[onload] / [onerror]	✓	✗	✗
EF-StatusErrorEmbed	sc = 401, ct = (text/html)	sc ≠ 401, ct = (text/html)	`embed src=URL`	[] / [onload]	✗	✗	✓
EF-StatusErrorLink	sc = (200 OR 3xx), ct ≠ text/html	sc ≠ (200 OR 3xx)	`link href=URL rel=prefetch`	[onload] / [onerror]	✗	✓	✗
EF-StatusErrorLinkCss	sc = (200 OR 3xx), ct = text/css	sc ≠ (200 OR 3xx), ct ≠ text/css	`link href=URL rel=stylesheet`	[onload] / [onerror]	✓	✓	✗
EF-RedirStatLink	sc = 3xx	sc ≠ 3xx, cto = nosniff, ct ≠ (text/css OR text/html)	`link href=URL rel=stylesheet`	[onload] / [onerror]	✗	✓	✗
EF-StatusErrorIFrame	sc = (200 OR 3xx OR 4xx or 5xx), ct= (text/javascript OR text/css)	sc = (200 OR 3xx OR 4xx or 5xx), ct ≠ (text/javascript OR text/css)	`iframe src=URL`	[] / [onload]	✗	✗	✓

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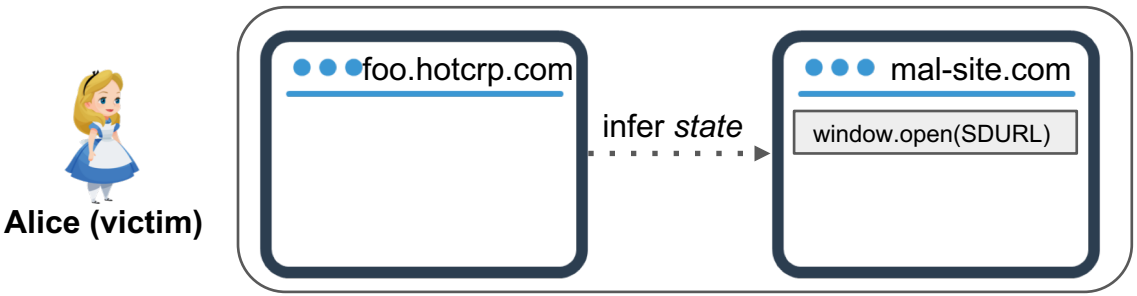
- **40** attack classes
- **21** new attack classes
- **1** completely novel XS-Leak (based on **postMessage** API)

New XS-Leak: postMessage broadcasts

- SD-URL property

State	Response
A	Broadcasts message “x”
B	Broadcasts message “y”



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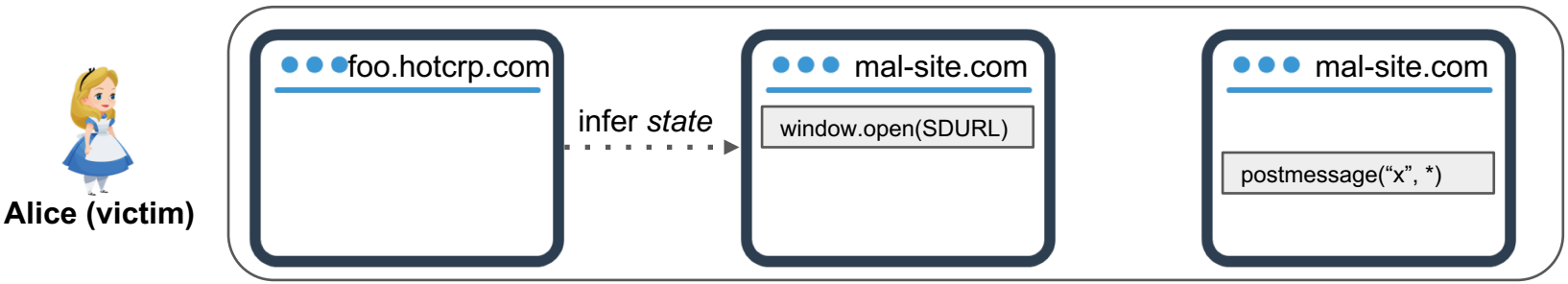

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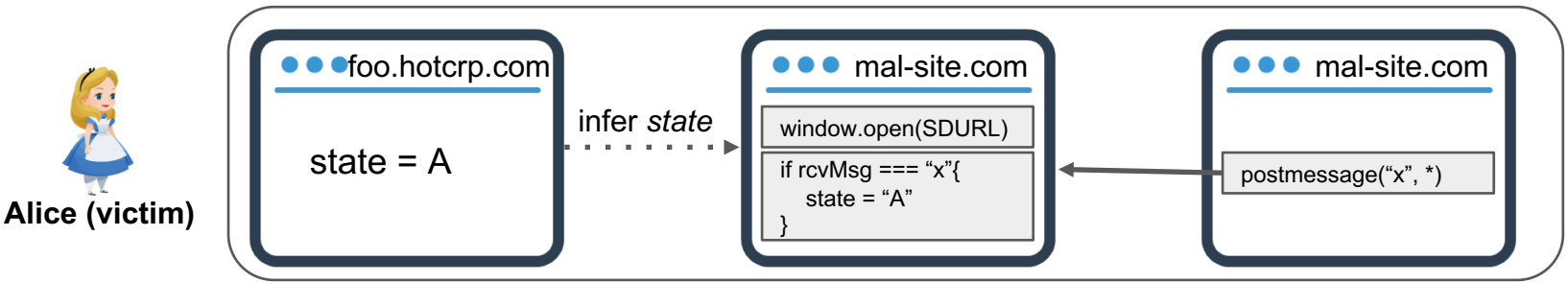

Related Work

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Timing	[Bortz2007WWW, Evans2009Blog, Goethem2015CCS, ..]
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:	:

- Given **different names** login detection, login oracle, URL status identification, etc.
- Not much discussion on
  - need to handle multiple states
  - support for multiple browsers
  - automatic detection of COSI attacks and automatic creation of attack pages

Contributions

Present COSI attacks as a **comprehensive category**

Introduce the concept of **attack classes**

Identify a new XS-Leak (based on postMessage API)

Present **Basta-COSI**, a tool to automatically identify COSI attacks and build complex attack pages

Test **4** stand-alone web apps and **58** top web sites, discovering COSI attacks on all of them

Outline

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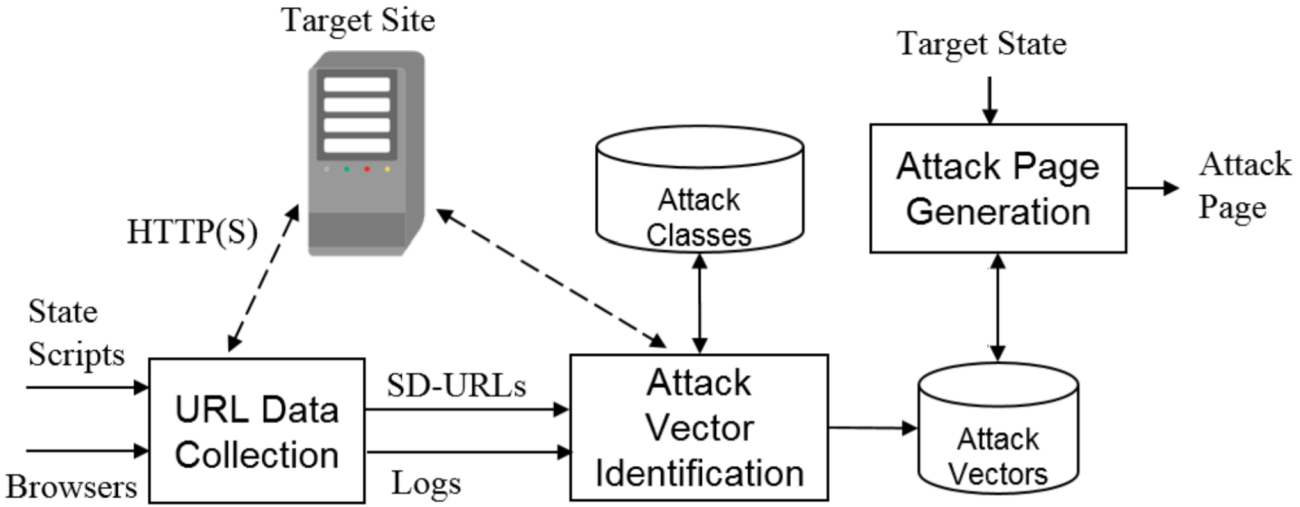
➔ **Approach**

Evaluation

Conclusion

Basta-COSI: Architecture

Tool to automatically identify COSI attacks on web apps



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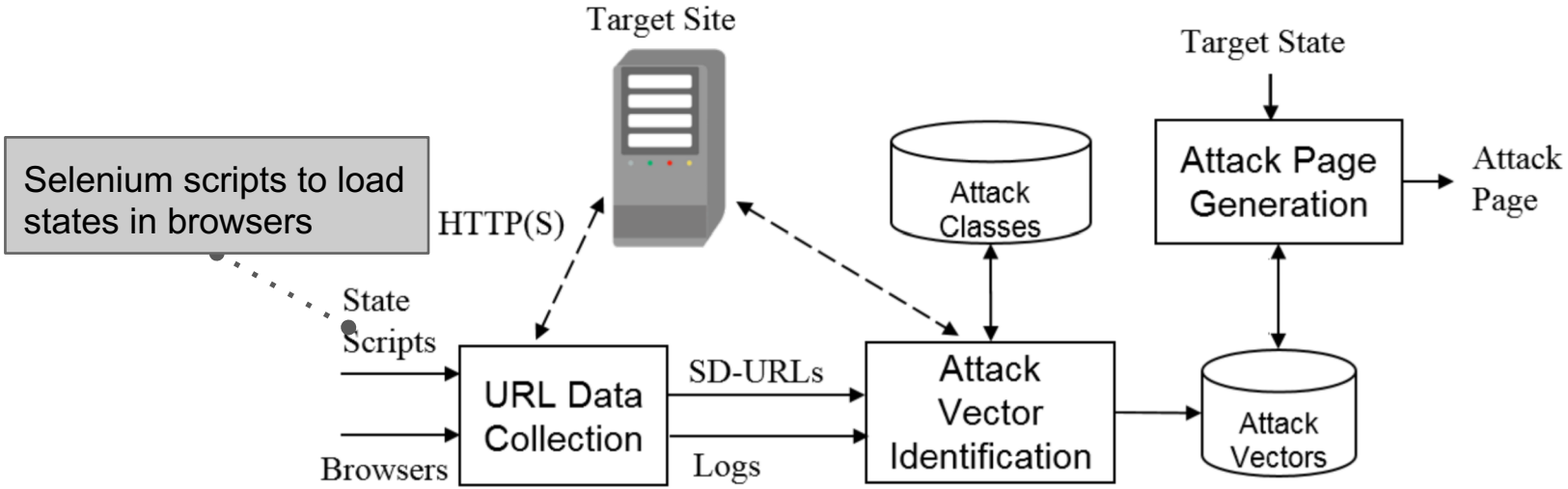

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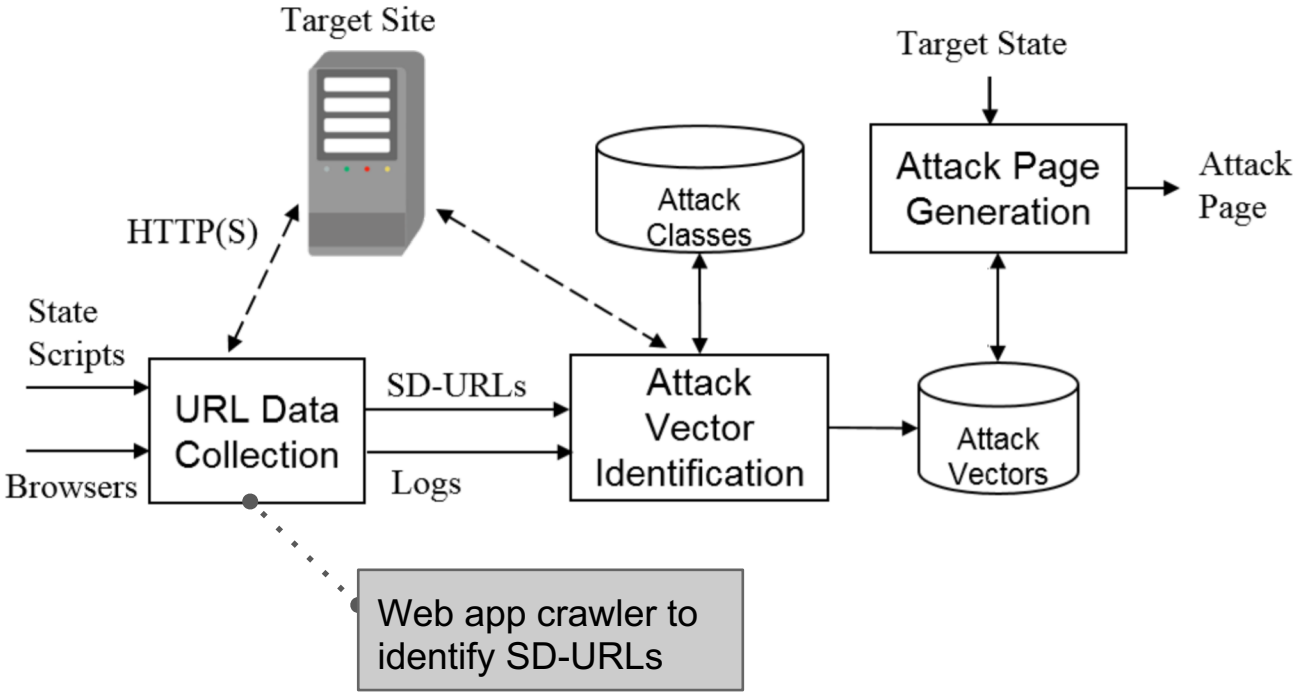

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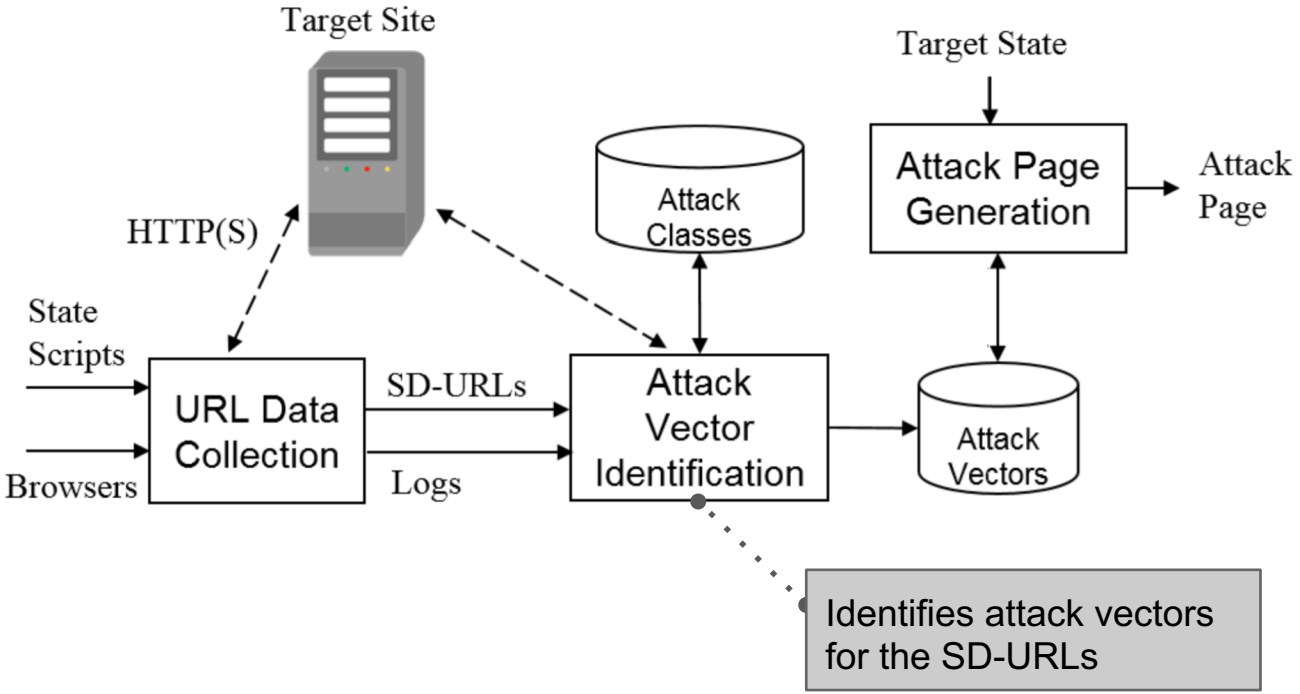

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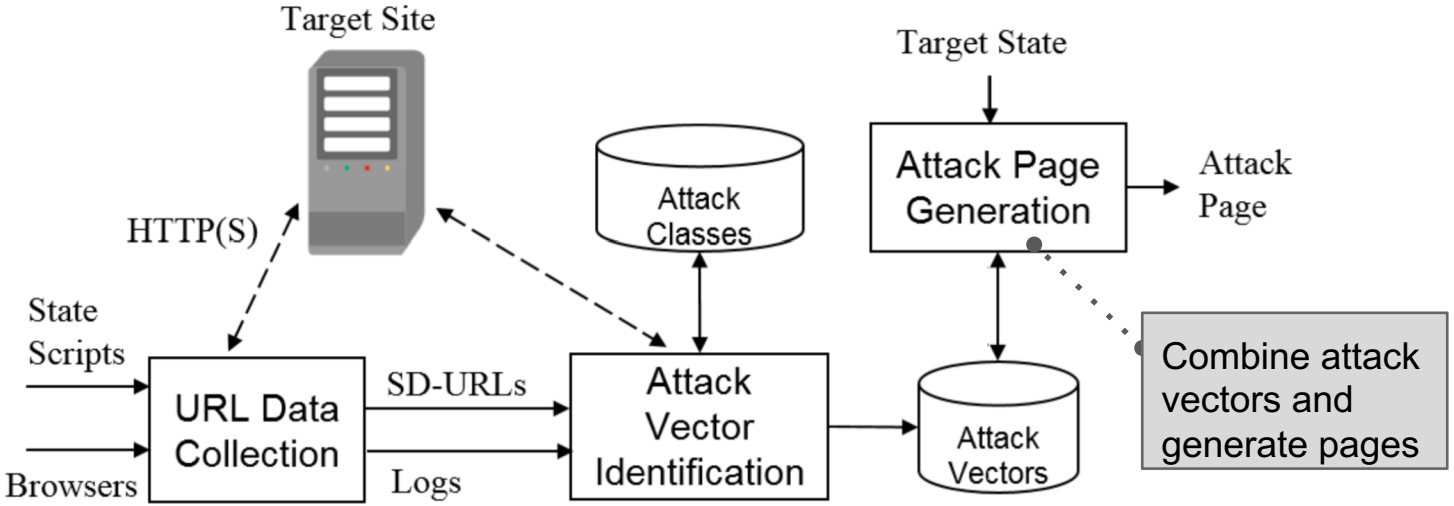

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Experiments

Tested:

- **4** stand-alone web applications (HotCRP, GitLab, GitHub Enterprise, OpenCart)
- **58** web sites from the Alexa Top 150 (having account creation)

Results:

- Found at least one attack on **all sites**
- Responsibly disclosed, vulnerabilities confirmed, some already fixed, some bug bounties paid

Results (Excerpt)

Web Site Vendor	Top Vulnerabilities
HotCRP.com	Deanonymize reviewer

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imgur	
LinkedIn	
GitHub GitLab	Deanonymize users and role

Ethics: All tests were performed on the accounts we controlled

Defenses

Web site-based:

- SameSite Cookies (control automatic sending of cookies in **3rd party context**)
- Cross-Origin Resource Policy
- Fetch Metadata
- Cross-Origin Opener Policy..

Browser-based:

- Enforce default SameSite policy
- Tor browser behavior SameSite=Lax (not send cookies in 3rd party context)
  - does not prevent window based attacks (postMessage, frame count)
  - reported and Tor is planning to fix this

Conclusions

Present COSI attacks as a **comprehensive category**

Introduce the concept of **COSI attack classes**

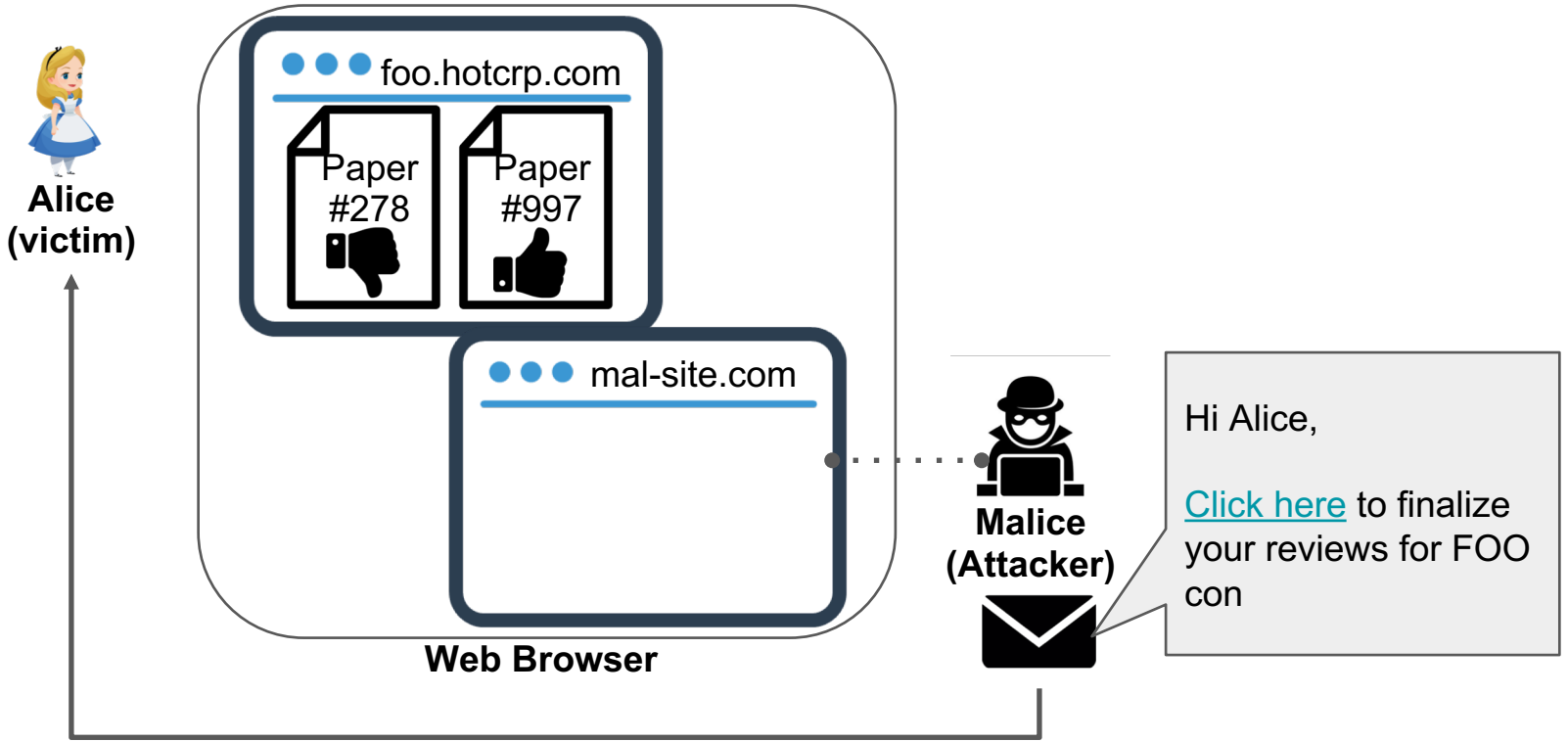
Identify a **new XS-Leak** (based on postMessage API)

Present Basta-COSI, a tool to **automatically** identify COSI attacks and build **complex** attack pages

Test **4** stand-alone web apps and **58** top web sites, finding COSI attacks on each of them

Thank You

Questions?


Alice
(victim)
foo.hotcrp.com
Paper
#278
Paper
#997
mal-site.com
Web Browser
Malice
(Attacker)
Hi Alice,
Click here to finalize your reviews for FOO con