Who Left Open the Cookie Jar?
A Comprehensive Evaluation of Third-Party Cookie Policies

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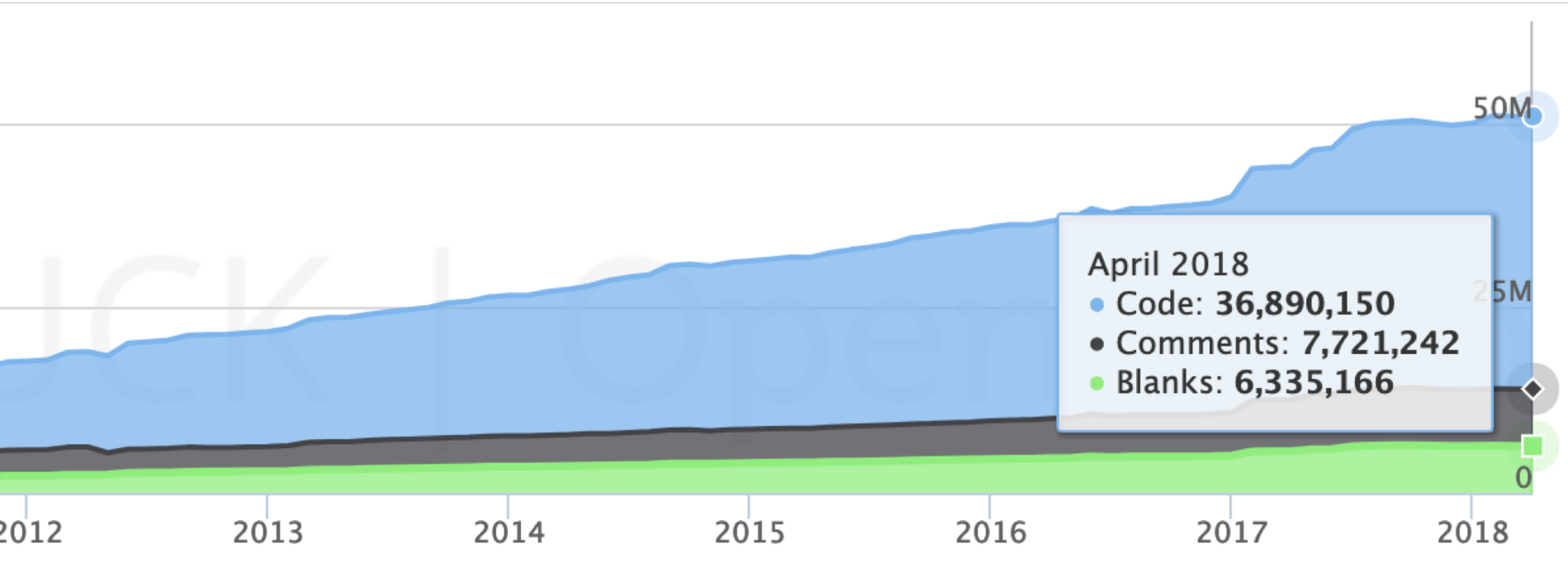
28 March 2019

KU LEUVEN DistriNet

When the web was designed, security was a high priority.

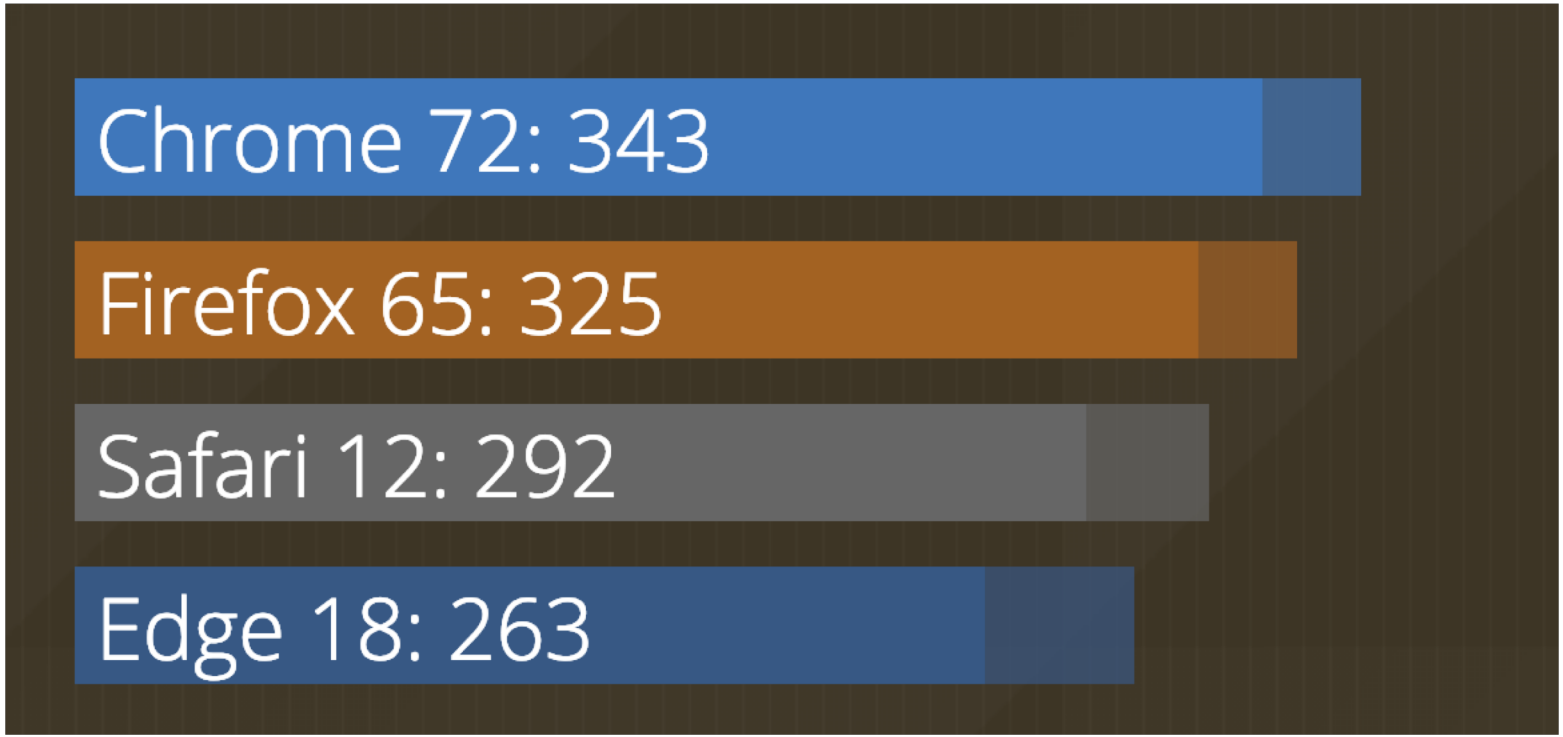
Do you trust your browser?

Lines of code for Firefox



Source: https://www.openhub.net/p/firefox/analyses/latest/languages_summary

How many different features do modern browsers support?



Source: https://caniuse.com

CSS

- ::first-letter CSS pseudo-element selector
- ::placeholder CSS pseudo-element
- ::selection CSS pseudo-element
- :dir() CSS pseudo-class
- :has() CSS relational pseudo-class
- :in-range and :out-of-range CSS pseudo-classes
- :matches() CSS pseudo-class
- :placeholder-shown CSS pseudo-class
- @font-face Web fonts
- Blending of HTML/SVG elements
- calc() as CSS unit value
- Case-insensitive CSS attribute selectors
- ch (character) unit
- 2.1 selectors
- ::marker pseudo-element
- :read-only and :read-write selectors

HTML5

- accept attribute for file input
- Attributes for form submission
- Audio element
- Audio Tracks
- Autofocus attribute
- Canvas (basic support)
- Canvas blend modes
- classList (DOMTokenList)
- Color input type
- contenteditable attribute (basic support)
- Custom Elements (V1)
- Custom protocol handling
- Datalist element
- dataset & data-* attributes
- Date and time input types
- Details & Summary elements

SVG

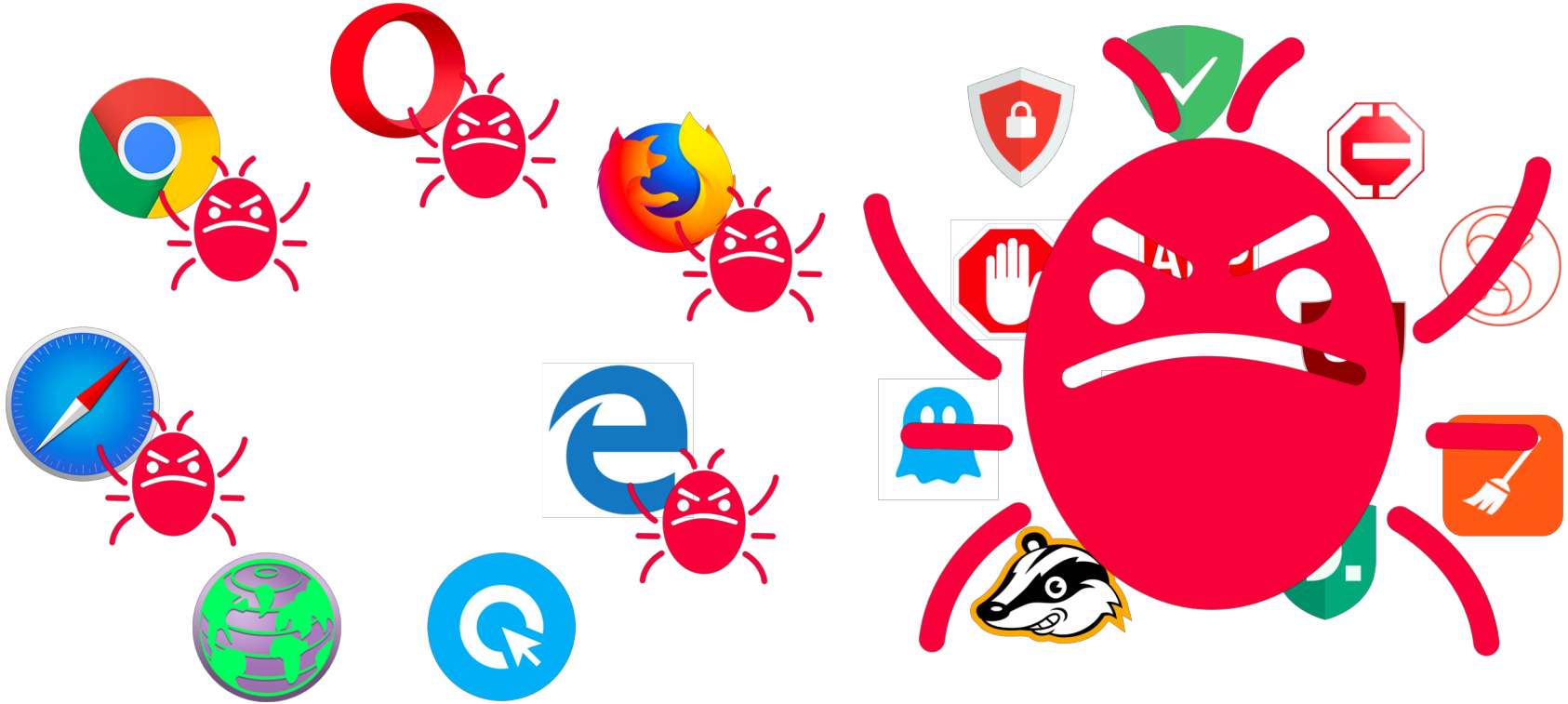
- Inline SVG in HTML5
- SVG (basic support)
- SVG effects for HTML
- SVG favicons
- SVG filters
- SVG fragment identifiers
- SVG in CSS backgrounds
- SVG in HTML img element
- SVG SMIL animation
- SVG fonts
- **All SVG features**

JS API

- AbortController & AbortSignal
- Accelerometer

Source: https://caniuse.com

Do you trust your browser?



Overview

Cookies & SOP 101

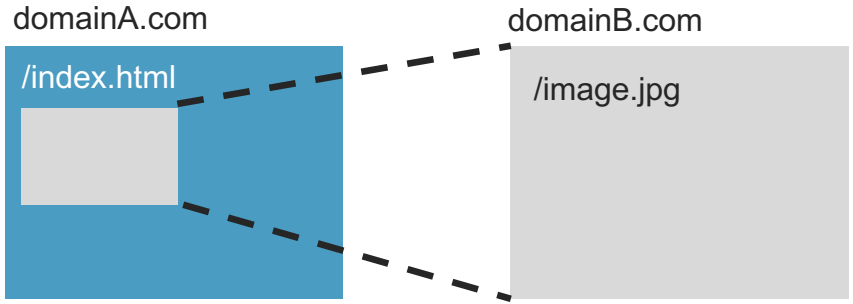
Cross-site attacks and tracking

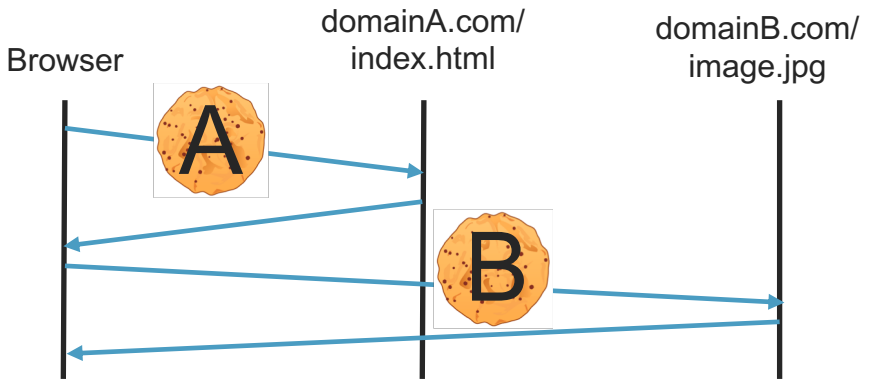
Third-party cookie policies

Comprehensive evaluation

Conclusion

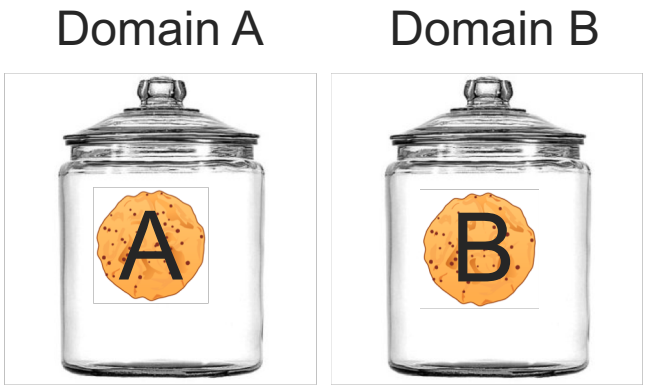
Cookie inclusion





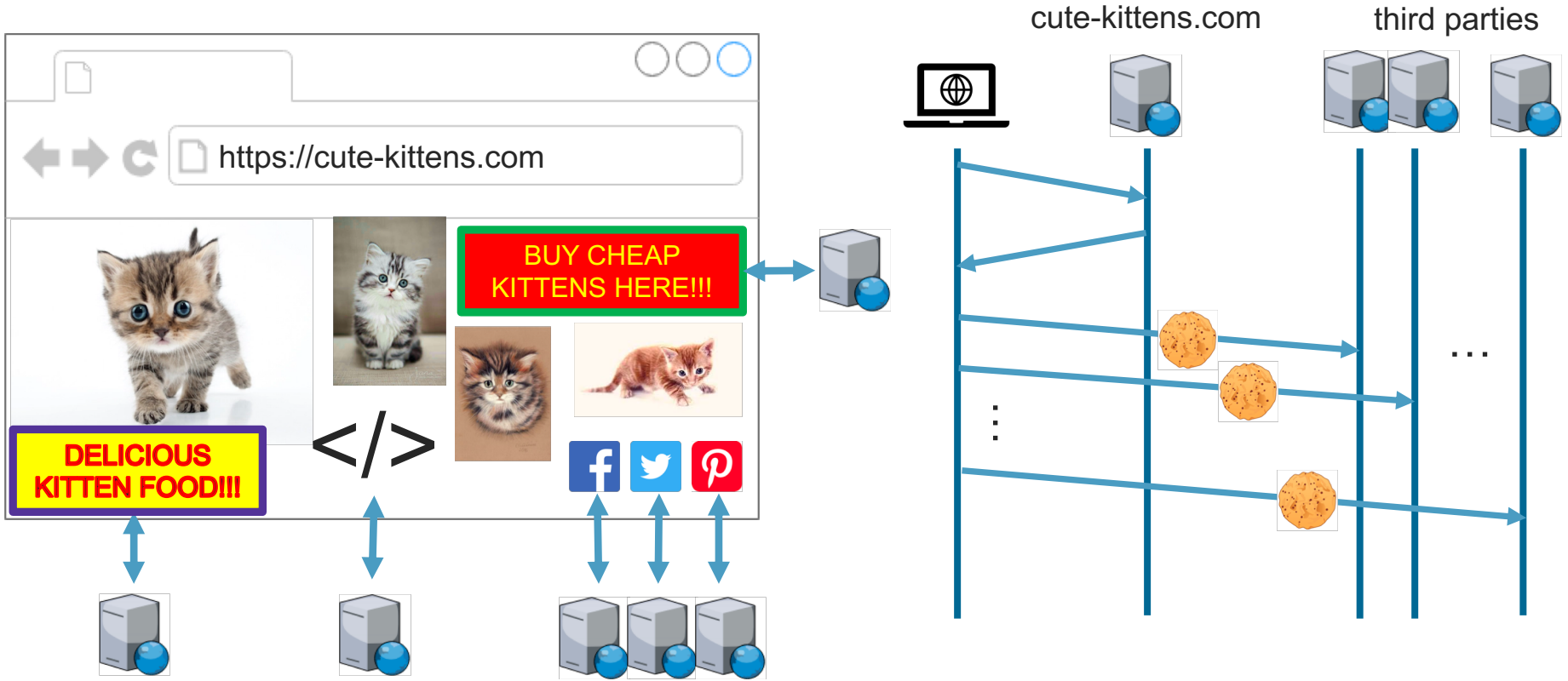
HTTP cookies [1]

- Implicit inclusion
- Authentication / identification
- Same-Origin Policy



[1] Barth, A., "HTTP State Management Mechanism", RFC 6265, DOI 10.17487/RFC6265, April 2011.

Third-party requests: implicit and ubiquitous

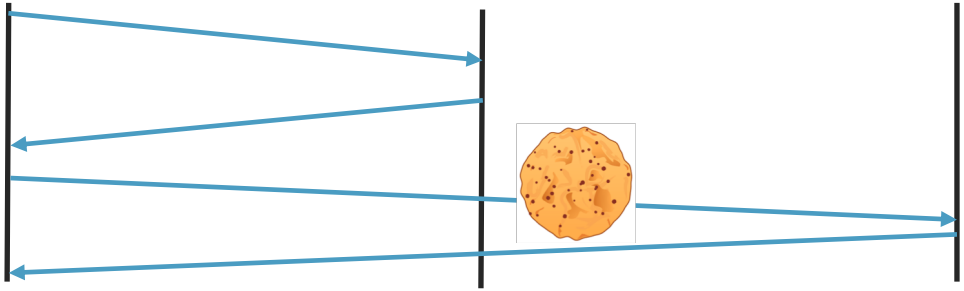


Cross-site attacks

Cross-site Request Forgery (CSRF)

victim cute-kittens.com doggo-bank.com

- Authenticated state-changing request



```
<img src="https://doggo-bank.com/transfer.php
    ?amount=999999&recipient=catboss">
```

Cross-site Request Forgery

- OWASP Top 10

2010
5th place

2013
8th place

2017
dropped

- Why?
  - Framework-integrated server-side defenses
  - Awareness

ZDNet

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could have

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- UK citizens fear identity theft over other security concerns such as national security
- How science can fight insider threats
- The risk to OT networks is real, and it's dangerous for business leaders to ignore
- 66% UK SMBs believe they are being aggressively targeted by fraudsters
- Phishing attacks becoming more targeted, phishers

Zeljka Zorz, Managing Editor
October 3, 2018

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Popular TP-Link wireless home router open to remote hijacking

By concatenating a known improper authentication flaw with a newly discovered CSRF vulnerability, remote unauthenticated control over TP-Link TL-WR841N worldwide

How science can fight insider threats

How to make the CFO your best cybersecurity friend

Safeguarding hybrid-cloud infrastructures through identity privilege management

Why you should take an operational approach to risk management

Cross-site Request Forgery

- Why is this still a problem?
  - Defense (e.g. random token in request parameters) needs to be applied ubiquitously
  - Insecure by default
- How to move on from here?
  - SameSite cookies -> secure by default (if enforced correctly by the browser)

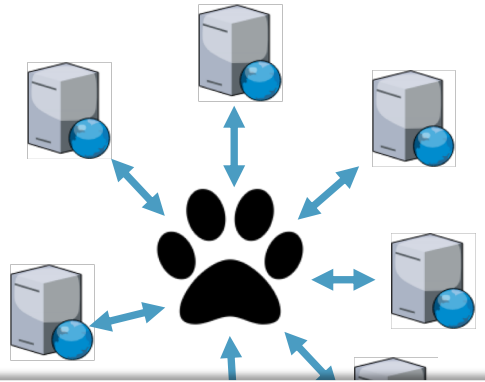

CROSS-SITE ATTACKS
LIGHTYEAR
CROSS-SITE ATTACKS EVERYWHERE

Cross-site attacks everywhere

- HEIST (HTTP Encrypted Information can be Stolen through TCP-windows)
- Cache API abuse
- Quota management API abuse
- Storage API abuse
- Cross-site size exposing
- Cross-site search
- Cross-site script inclusion / JSON hijacking
- Cross-site timing attacks

Third-party tracking

Third-party Tracking



victim

cat-news.com

paw-book.com

Tracking the Trackers

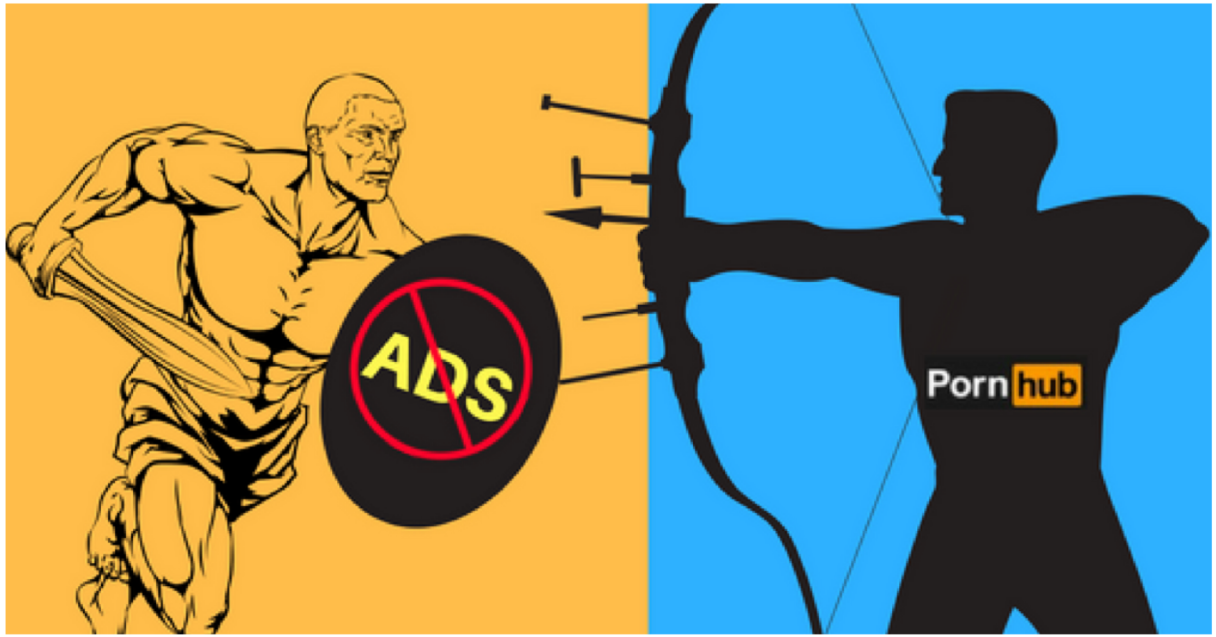
Zhonghao Yu Sam Macbeth Konark Modi

"95% of the pages visited contain 3rd party requests to potential trackers
78% attempt to transfer unsafe data"

Cliqz
Arabellastraße 23

Pornhub Bypasses Ad Blockers With WebSockets

BugReplay Follow
Nov 1, 2016 · 4 min read



Third-party cookie policies

Cookie policies for privacy

- Built-in browser options
  - Block third-party cookies
  - Firefox Tracking Protection
  - Opera Ad Blocker
  - Safari Intelligent Tracking Prevention
- Extensions
  - Ad blocking
  - Privacy protection

Client-side defense mechanisms

Same-site cookie [1]

In-depth defense against cross-site attacks

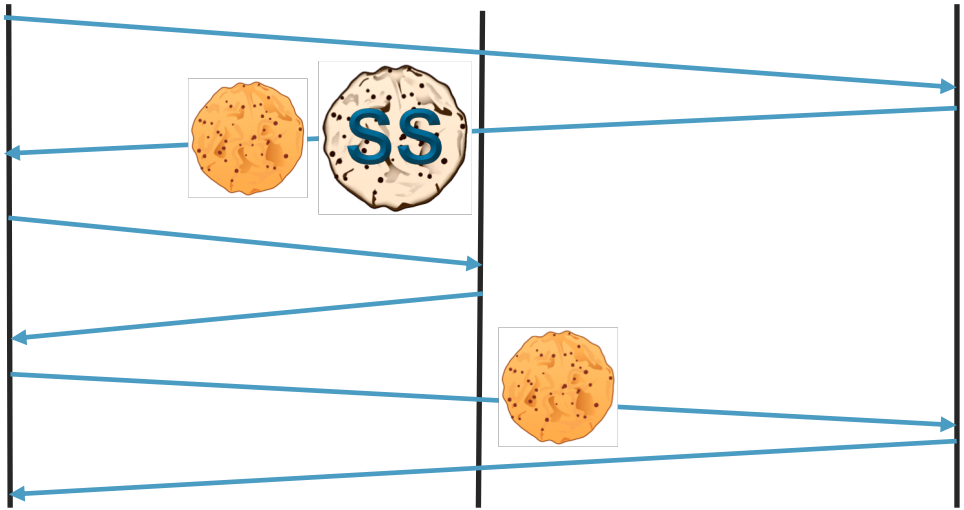
- Cookie with extra attribute ‘SameSite’
  - SameSite=strict → NO CROSS-SITE REQUESTS!
  - SameSite=lax → exceptions: top-level GET, prerender
- Adoption by websites is rather slow
  - Interesting blog: Dropbox’s use case [2]

[1] West, M., Goodwin, M. Same-site cookies. Internet- Draft draft-ietf-httpbis-cookie-same-site-00, IETF Secretariat, June 2016.
[2] https://blogs.dropbox.com/tech/2017/03/preventing-cross-site-attacks-using-same-site-cookies/

Use of same-site cookies

against cross-site attacks

doggo-bank.com victim cute-kittens.com doggo-bank.com



```
Set-Cookie: auth=ekSd2lksq090pQDs; SameSite=strict
```

Why evaluate third-party cookie policies?

- Browsers are known to exhibit inconsistent behavior
  - Interference from different standards
  - Unintended side-effects by code modification
- Saturated market of extensions
  - No clear quantification of quality

Automated evaluation of effectiveness

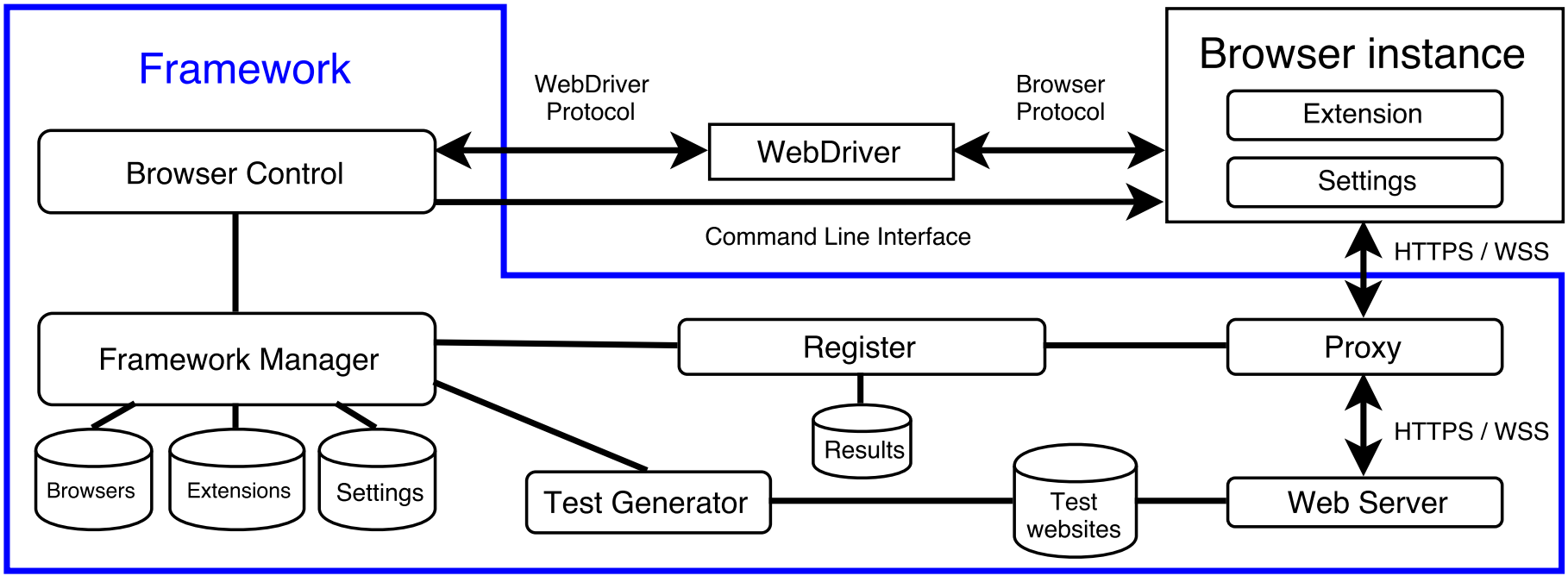
Comprehensive evaluation

Black box approach

- Browsers consist of millions of lines of code
  - Source code not always available
- Many extensions

Framework

Design



Initiating cross-site requests

- AppCache API
  - Caching cross-site pages
- HTML-tags
  - <script>, <img>, <link>, etc.
- Headers
  - Link, CSP headers
- Redirects
- JavaScript
  - Fetch, EventSource API, etc.
- PDF JS
  - sendForm()
- ServiceWorker API

Overview

- Browsers
  - Chrome SameSite
  - Opera SameSite
  - Firefox SameSite
  - Safari SameSite
  - Edge SameSite
  - Tor Browser
  - Cliqz
- Extensions
  - Ad blocking (31)

...

  - Tracking protection (15)

...

	AppCache	HTML	Headers	Redirects	PDF JS	JavaScript	SW
Chrome 63	●	●	●	●	●	●	●
- Block third-party cookies	◐	◐	◐	●	●	◐	◐
Opera 51	●	●	●	●	●	●	●
- Block third-party cookies*	◐	◐	◐	●	●	◐	◐
- Ad Blocker	●	●	○	●	○	●	●
Firefox 57	●	●	●	●	○	●	●
- Block third-party cookies	◐	◐	◐	●	○	◐	◐
- Tracking Protection	●	●	●	●	○	●	●
Safari 11	○†	◐	○	●	○	◐	N/A
- No Intelligent Tracking Prevention	●†	●	○	●	○	●	N/A
- Block third-party cookies‡	●†	●	◐	●	○	●	N/A
Edge 40	●	●	◐	●	○	●	N/A
- Block third-party cookies	●	●	◐	●	○	●	N/A
Cliqz 1.17*	◐	●	◐	●	○	◐	◐
- Block third-party cookies	◐	◐	◐	●	○	◐	◐
Tor Browser 7	○	◐	◐	●	○	◐	N/A

●: request with cookies ◐: request without cookies ○: no request

* Secure cookies were omitted in all requests.

† Safari does not permit cross-domain caching over https (only over http).

‡ Safari 10.1.2

	AppCache	HTML	Headers	Redirects	PDF JS	JavaScript	SW
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Opera 51	●	●	●	●	●	●	●
- Block third-party cookies*	◐	◐	◐	●	●	◐	◐
- Ad Blocker	●	●	○	●	○	●	●
Firefox 57	●	●	●	●	○	●	●
- Block third-party cookies	◐	◐	◐	●	○	◐	◐
- Tracking Protection	●	●	●	●	○	●	●
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Opera 51	●	●	●	●	●	●	●
- Block third-party cookies*	◐	◐	◐	●	●	◐	◐
- Ad Blocker	●	●	○	●	○	●	●
Firefox 57	●	●	●	●	○	●	●
- Block third-party cookies	◐	◐	◐	●	○	◐	◐
- Tracking Protection	●	●	●	●	○	●	●
Safari 10	○†	◐	○	●	○	◐	N/A
- No Intelligent Tracking Prevention	●†	●	○	●	○	●	N/A
- Block third-party cookies‡	●†	●	◐	●	○	●	N/A
Edge 40	●	●	◐	●	○	●	N/A
- Block third-party cookies	●	●	◐	●	○	●	N/A
Cliqz 1.17*	◐	●	◐	●	○	◐	◐
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Opera 51	●	●	●	●	●	●	●
- Block third-party cookies*	◐	◐	◐	●	●	◐	◐
- Ad Blocker	●	●	○	●	○	●	●
Firefox 57	●	●	●	●	○	●	●
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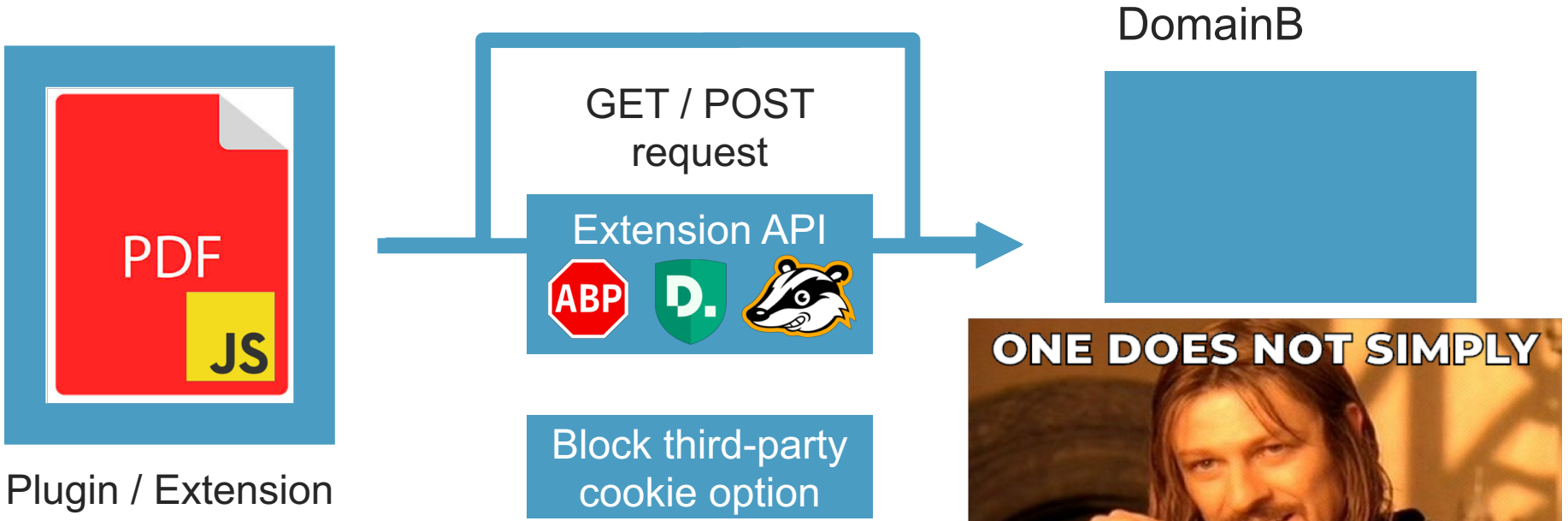
Extensions

Tested in Chrome, Firefox, Opera and Edge

- No extension managed to block all third-party cookies to blacklisted domains
- Insufficient API
  - PDF JS for Chromium, but also Firefox favicon (HTML tags)
- Unclear API
  - No clear distinction for browser background requests
- Common mistakes
  - Insufficient permissions to intercept certain requests

PDFium design flaw

Chrome and Opera



Unclear WebExtension API

AppCache API

```
<html manifest='/manifest.appcache'>
```

```
CACHE MANIFEST
# ...

CACHE:
https://tracker.com/report/?leak=appcache-cache
```

-1	chrome.tabs.TAB_ID_NONE	Since Chrome 46. An ID that represents the absence of a browser tab.

tabs.TAB_ID_NONE

A special ID value given to tabs that are not browser tabs (for example, tabs in devtools windows).

Affected browsers:

Unclear WebExtension API

ServiceWorker API

- Firefox
  - Assign tab id of tab that initiated ServiceWorker
  - Blocked by <u>all</u> extensions

Affected browsers:

Common mistakes by extension developers

- Requesting insufficient permissions
- Catch: WebSockets use ws:// and wss://
- Solution: use “<all_urls>”

Extension manifest

```
{
    "name": "My extension",
    ...
    "permissions": [
        "webRequest",
        “http://*/*”,
        “https://*/*
    ],
    ...
}
```

Same-site cookie policy

- Chrome and Opera: prerender functionality
  - Both lax and strict included in cross-site request
- Edge
  - Lax bypasses: WebSocket API, <embed>, <object>
  - Strict bypasses: WebSocket API, redirects
- Firefox and Safari: no bugs detected

Evaluation of the framework

Completeness and novelty

- Distributed crawler setup
  - Interception of headless Chrome network traffic (using linux network namespaces)
  - Analysis of intercepted HTTP requests
- Alexa Top 10,000 websites
  - Up to 20 pages on each website
  - 160,059 pages visited

Conclusion

Conclusion

Initial findings

- Built-in browser policies can be bypassed
  - Same-site cookie, third-party cookie policies
  - Advanced options (e.g. Opera AdBlocker, Firefox Tracking Protection)
- All adblocking and privacy extensions can be bypassed
  - Due to extension API provided by browsers
  - Due to common mistakes by extension developers

Future work

What about other policies?

- Expansion of framework
  - Policy-wise → private browsing mode, security (e.g. CSP)
  - Platform-wise → mobile browsers

- Goal: tool for comprehensive, automated analysis of security and privacy policy implementations

Illustration of importance

The prerender bug (same-site cookie policy bypass)

- Originally reported for Chrome 57
- Present in: 58 59 60 61
- Fixed in: 62 63 64 65
- Reintroduced in: 66 67 68 69 70 71

- Shows importance of a comprehensive evaluation of implemented policies

Key takeaways

- Virtually every built-in third-party cookie policy, and every adblocking and privacy extension can be bypassed

- The current state of browser policy testing is inadequate

- Browser evaluation results available at WhoLeftOpenTheCookieJar.com

Thank you!

WhoLeftOpenTheCookieJar.com

@tomvangoethem @gjfr_ @wlotcj