Stony Brook University

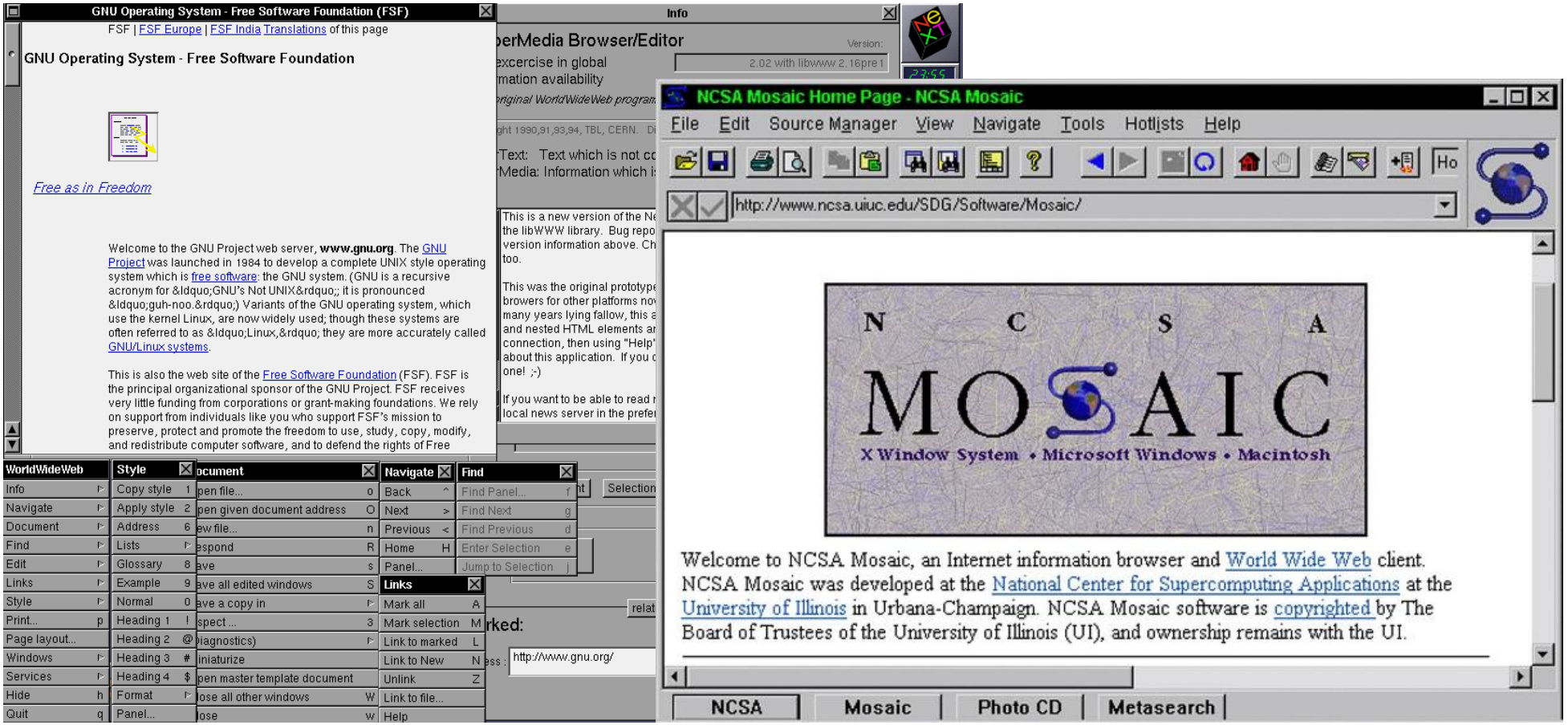
PragSec Lab

SECURITY AND PRIVACY ISSUES OF MODERN WEB BROWSERS

Nick Nikiforakis

April 2018

We've come a long way



Modern browsers are all-inclusive software platforms

- Modern browsers are constantly evolving
  - Streamlined extension frameworks
  - Push notifications
  - Custom web components
  - WebRTC
  - Payment Request API

- Rough size statistics (LOC = Lines of Code)
  - Google Chrome: 16 M. LOC
  - Mozilla Firefox: 18 M. LOC
  - Linux Kernel: 16.8 M. LOC

More features, greater attack surface

- As we keep on adding more and more features, we are expanding the attack surface of the browser
  - We are also increasing the chance of unpredicted interactions between software components

- Security 101: Where do flaws arise from?
  - Design flaws
    - Flaws that arise during the design phase of software
  - Implementation flaws
    - Buffer overflows, dangling pointers, XSS
  - Configuration flaws
    - Setting up software with guessable passwords

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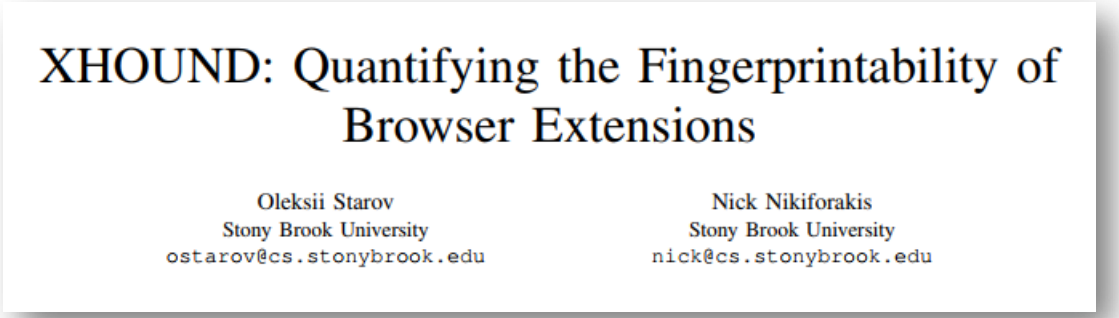

XHOUND: Quantifying the Fingerprintability of Browser Extensions

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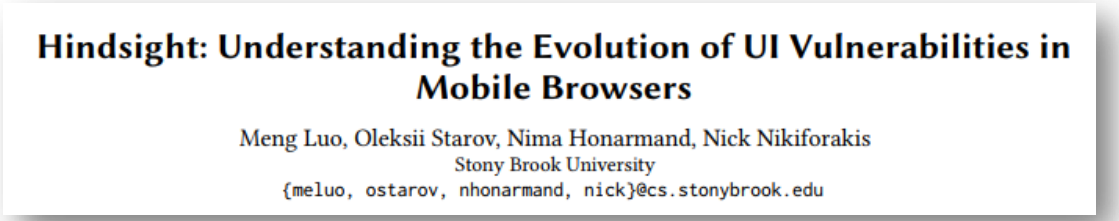
IEEE S&P 2017



Hindsight: Understanding the Evolution of UI Vulnerabilities in Mobile Browsers

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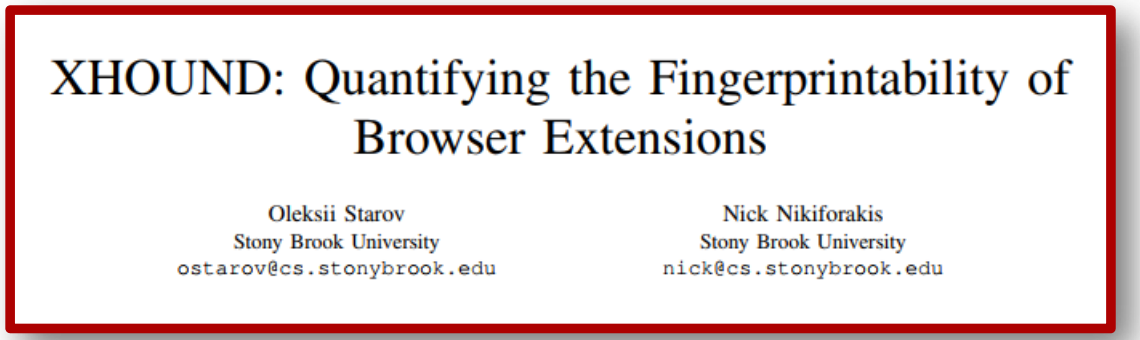

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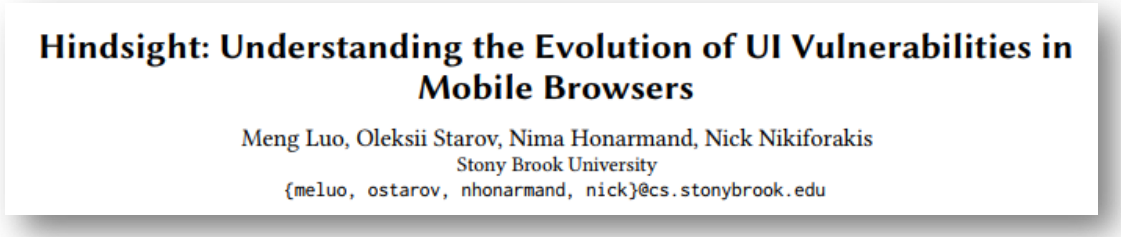

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CCS 2017

Browser extensions are popular!

> 10M users

> 10M users

> 5.7M users

> 2.6M users

> 4.3M users

> 2.8M users

> 10M users

> 1.4M users

> 10M users

> 1.3M users

> 1.6M users

> 0.6M users

+ Extensions are “more private”…

- Previous research showed that **plugins** were one of the most powerful features for browser fingerprinting:
  - https://panopticlick.eff.org
  - https://amiunique.org
- Plugins are fading away…
- **In comparison to plugins, there is no API for a web page to enumerate available browser extensions!**

Are extensions really undetectable?

No browser extensions

"Magic Actions for YouTube" extension

Extensions have visible side-effects!

> 10M users

> 10M users

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> 4.3M users

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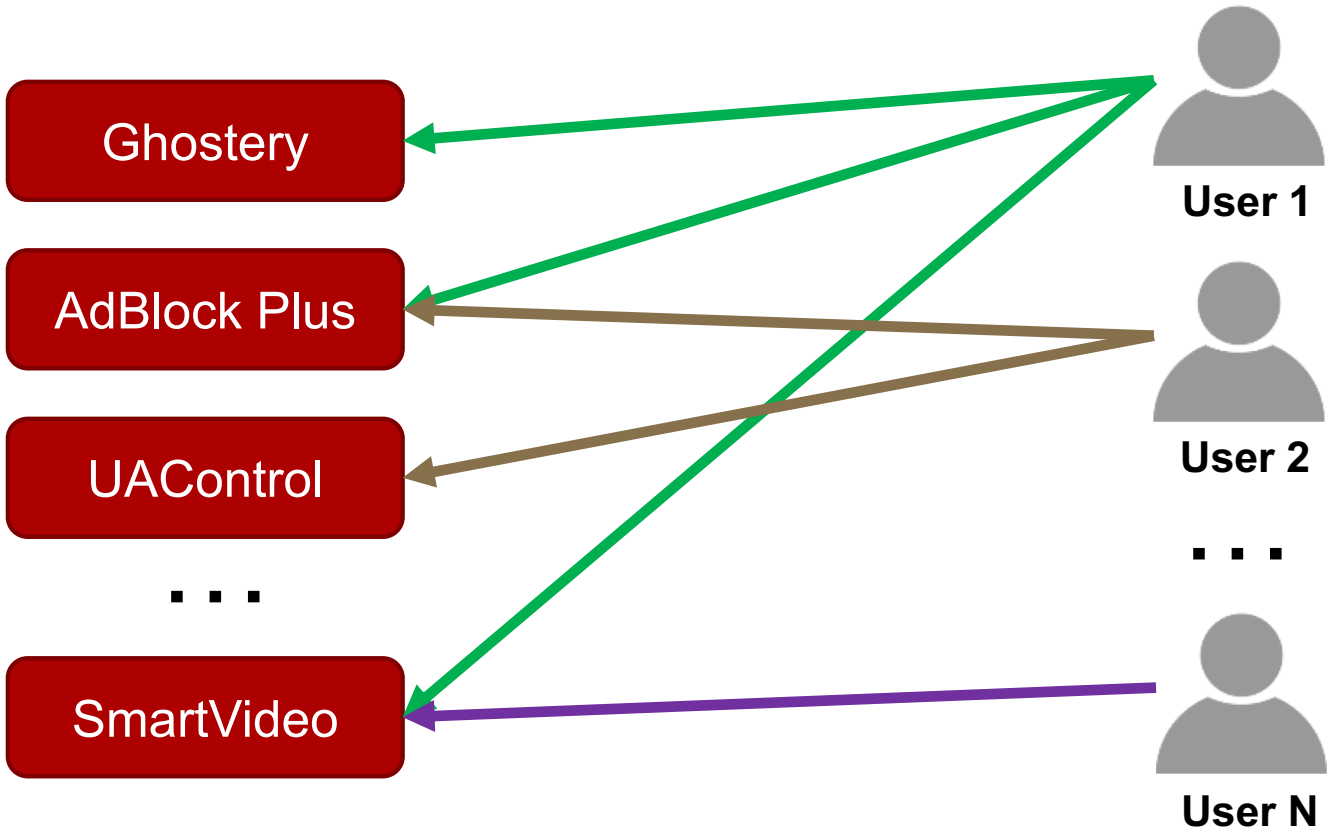
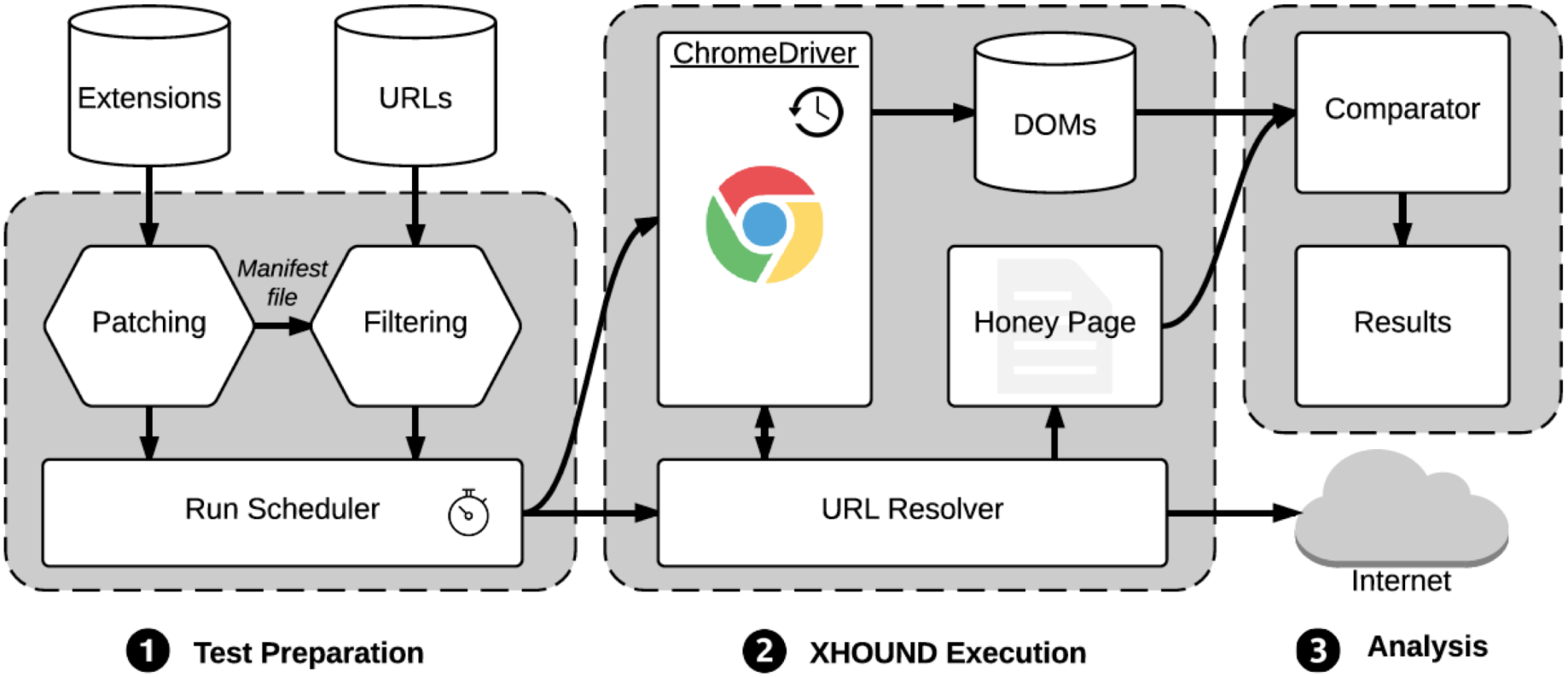
Privacy and Security implications

- Discovering targets for known exploits in browser extensions
  - E.g. popular password managers (*LastPass*, *Blur*, etc.)
- Exposing sensitive extensions installed by browser users
  - E.g., *Mailvelope*, VPN extensions, discount alerts, political add-ons, etc.

Extensions as a fingerprinting feature?!

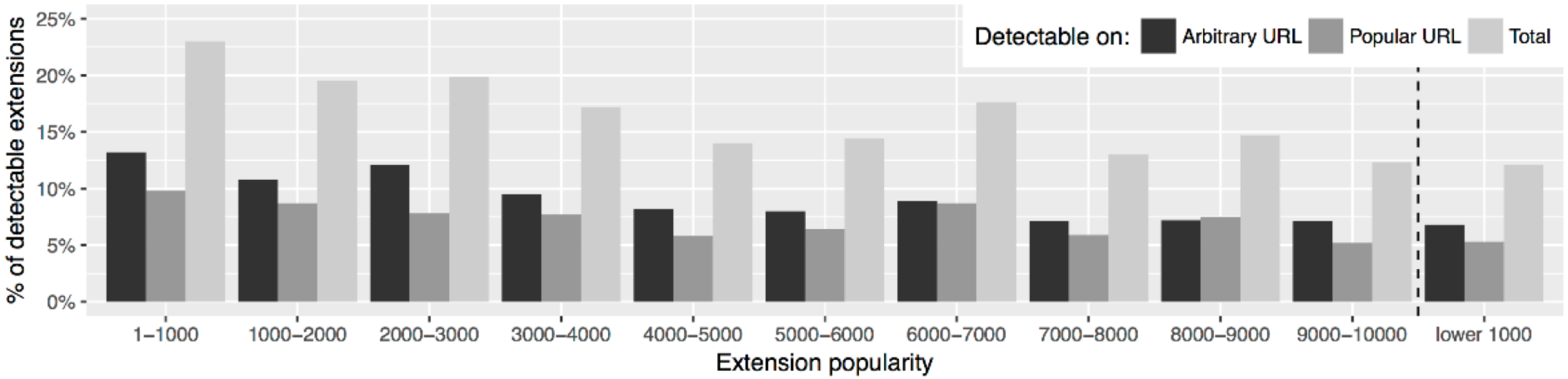


XHOUND's architecture



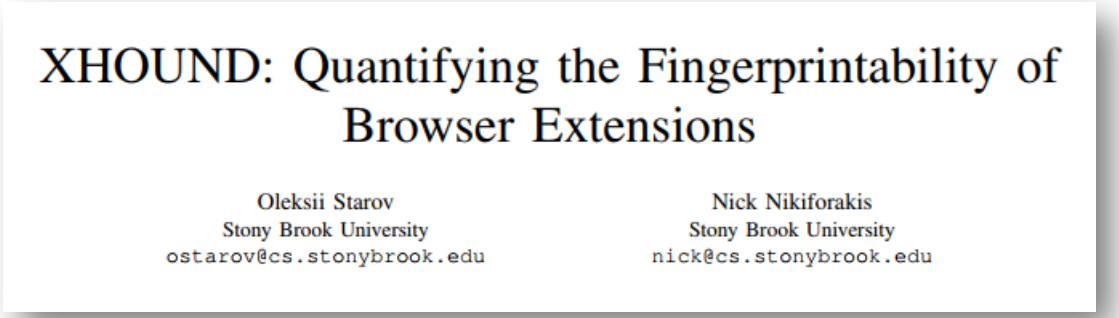
Results for top 10K Chrome extensions

- **9.2%** introduce detectable changes on any arbitrary URL *(any webpage can fingerprint)*
- **16.6%** introduce detectable changes on popular domains *(popular websites can fingerprint)*



Detectable extensions per category

Category	# Extensions	On Some URLs	On Any URL
Productivity	3,438	14.95%	10.01%
Social & Commun.	1,397	27.06%	9.81%
Fun	1,300	12.92%	6.31%
Accessibility	952	17.02%	11.87%
Developer Tools	936	9.29%	8.23%
Search Tools	595	13.28%	5.71%
Shopping	**444**	**34.68%**	**17.57%**
News & Weather	336	4.76%	3.87%
Photos	208	19.71%	11.54%
Blogging	144	14.58%	5.56%
Unknown	129	23.26%	4.65%
Sports	121	4.96%	4.13%



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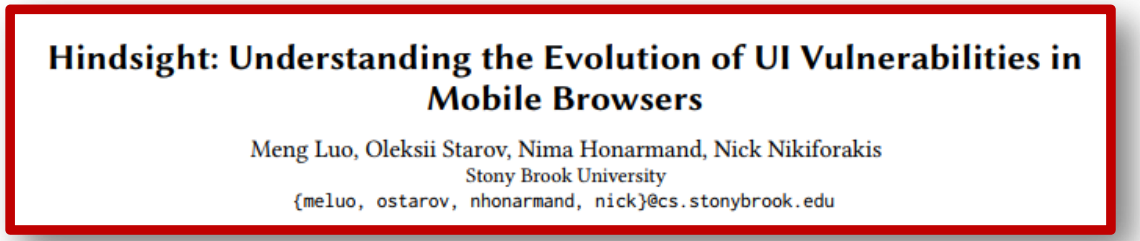

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CCS 2017

Smartphones are overtaking traditional computing platforms

- More and more users rely on mobile devices for part of their daily computing needs

- ComScore report from 2017 shows that, for some countries, users spend the majority of their “total digital minutes” on a mobile device:
  - 91% Indonesia
  - 71% China
  - 71% USA
  - 62% Canada
  - 61% UK

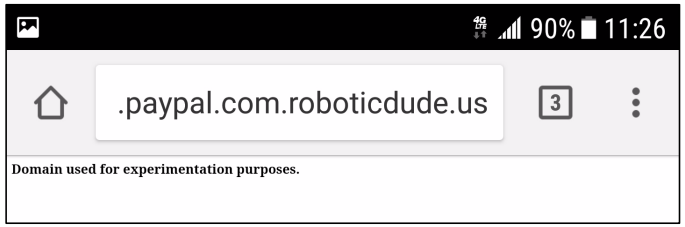
What is the security stance of mobile web browsers?

- Most research about security on mobile devices has revolved around
  - Malicious apps
  - Isolation of content and permissions from the different stakeholders present in a single app
- As mobile usage increases, it is almost guaranteed that attacks targeting specifically mobile browsers will increase
- Idiosyncrasies of the mobile platform allow novel attacks against mobile web browsers (in addition to all the standard ones)
  - Limited screen real-estate
  - The desire of mobile browser vendors to maximize the real-estate allotted to websites
  - Limited computing power and battery life

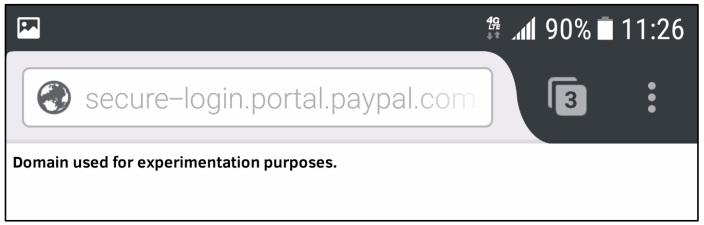
Limited real-estate example

- What happens when users clicks on a URL that is “longer” than the physical width of their device:
  - secure-login.portal.paypal.com.roboticdude.us

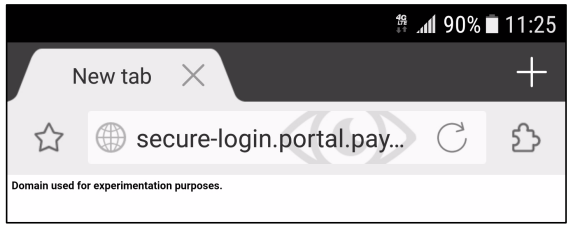
Chrome (1B – 5B)



Firefox (100M- 500M)



Dolphin (50M – 100M)



Limited real-estate example

- What happens when users clicks on a URL that is “longer” than the physical width of their device:
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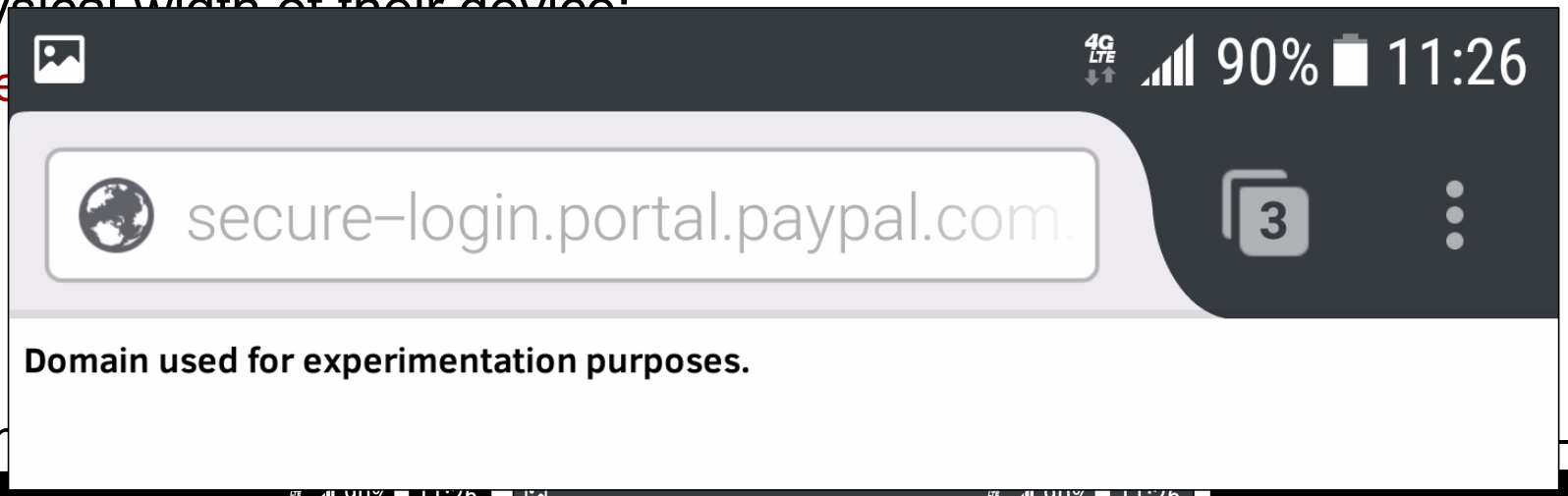
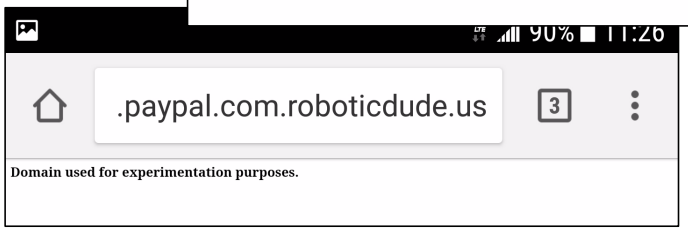
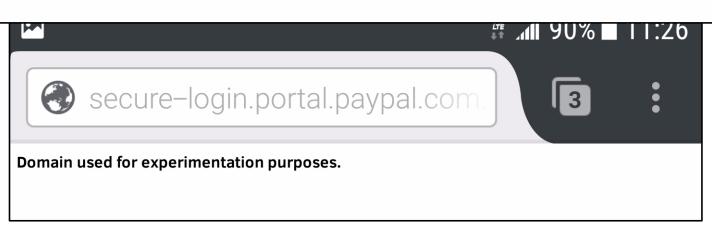
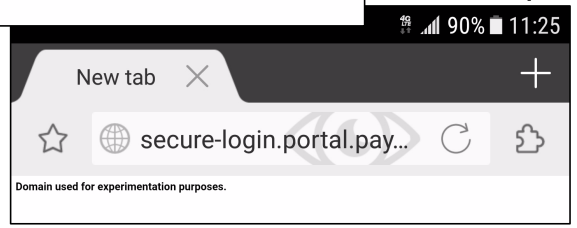


Ch - 100M)







Limited real-estate example

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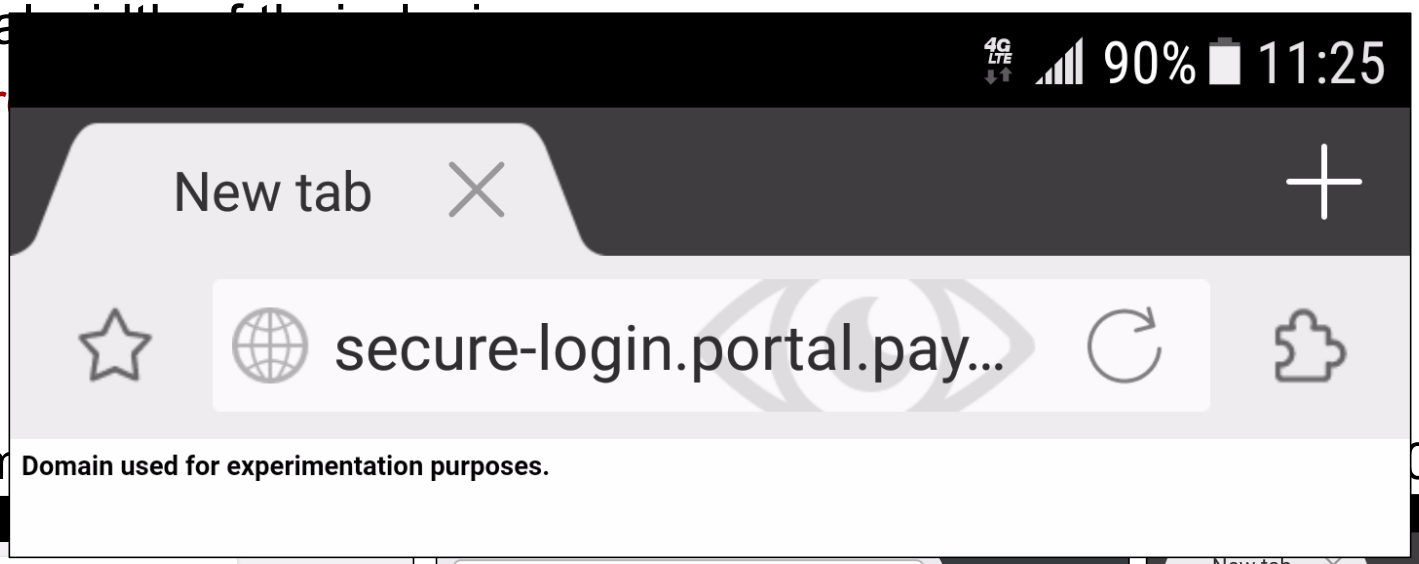
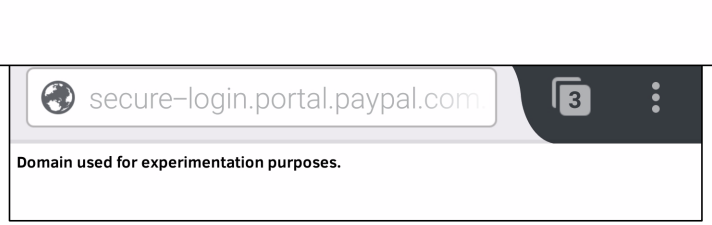
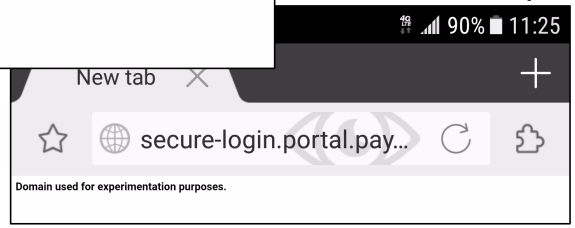


Chrom 0M – 100M)

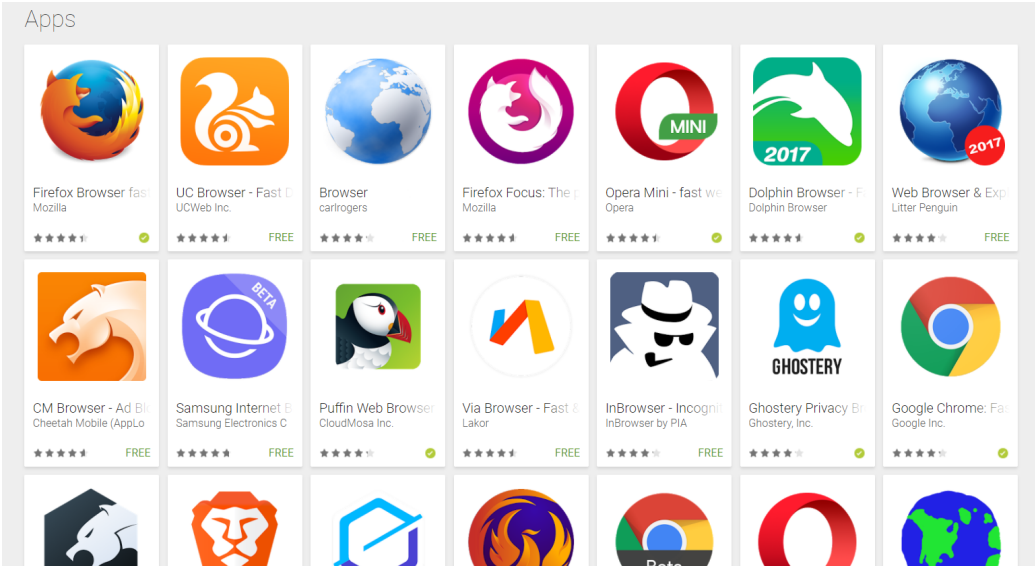




Manual analysis does not scale

- Number of browsers in the market
  - More than a hundred browser families
- Speed of new releases and updates
  - Tens of updates every year
- Number of attacks

- Most secure browser?
- Least secure browser?
- Which browser has stopped fixing bugs?



Automation is your friend

- Design and develop the first browser-agnostic, vulnerability testing framework for mobile browsers (Hindsight)

- High-level idea:
  - Collect as many mobile-browser-specific attacks as possible
    - Experiment with them to arrive at novel variations
  - Collect as many mobile browser versions from as many browser families as possible
  - Install each browser on a test device
  - Expose it to your collect attacks
  - Analyze collected data

Attack Building Blocks

Class	Test#	Explanation	Prior Work	Potential Attacks
Event Routing	1–6	Do cross-origin, overlapping elements receive events when they are not the topmost ones? (Different tests for combinations of overlapped images and buttons, links, forms, and other images)	[3, 6]	Clickjacking, CSRF
URL	7–9	When presented with a long URL (long subdomain, long filepath, or a combination of both), does a browser render that URL in a way that could be abused for spoofing attacks?	[30, 38]	Phishing, malware/scam delivery
	10	When presented with an Internationalized Domain Name (IDN), will a browser display the IDN format?	[16]	Phishing, malware/scam delivery
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	23	Is a webpage with self-signed certificate rendered without warnings?	[4, 5, 14, 37]	MITM attack, Phishing
Content	24	Can an iframe expand its size past the one defined by its parent frame?	[3, 6]	Phishing
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	27	Is JavaScript code included in a self-signed website executed before the warning is accepted?	Novel	Phishing, MITM attack

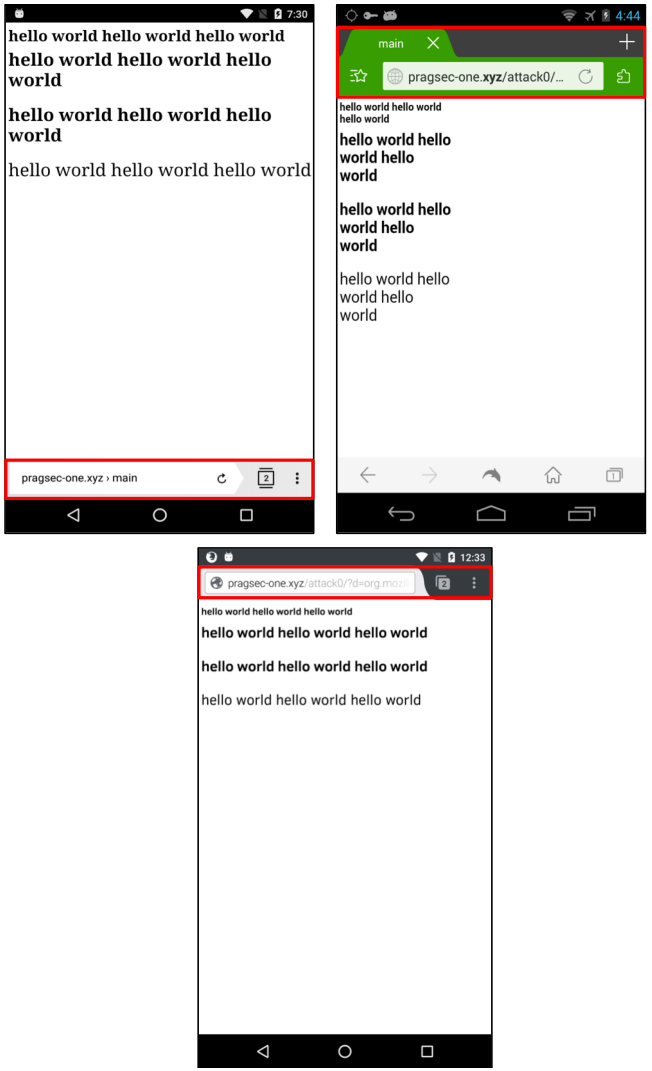
Attack Building Blocks

Class	Test#	Explanation	Prior Work	Potential Attacks
Event Routing	1–6	Do cross-origin, overlapping elements receive events when they are not the topmost ones? (Different tests for combinations of overlapped images and buttons, links, forms, and other images)	[3, 6]	Clickjacking, CSRF
URL	7–9	When presented with a long URL (long subdomain, long filepath, or a combination of both), does a browser render that URL in a way that could be abused for spoofing attacks?	[30, 38]	Phishing, malware/scam delivery
	10	When presented with an Internationalized Domain Name (IDN), will a browser display the IDN format?	[16]	Phishing, malware/scam delivery
Address Bar	11	Is the address bar hidden if the top-level frame is navigated by a child frame?	[3, 6]	Phishing, malware/scam delivery
	12	Does a browser show a page's title instead of its URL?	[8]	Phishing, malware/scam delivery
	13	Is the address bar hidden if the visited website has a lot of content?	Novel	Phishing, malware/scam delivery
	14	Is the address bar hidden when switching the device to "landscape" mode?	Novel	Phishing, malware/scam delivery
	15–16	Is the address bar hidden upon manual/automatic page scrolling?	[30, 32]	Phishing, malware/scam delivery
	17–18	Is the address bar hidden when typing in a textbox and tapping on a button?	[15, 38]	Phishing, malware/scam delivery
	19	Is the address bar hidden when typing to a fake (e.g., canvas-created) textbox?	Novel	Phishing, malware/scam delivery
Security Indicators	20	Is the favicon placed next to padlock icon?	[4, 5, 14, 37]	MITM attack, Phishing
	21–22	When rendering an HTTPS page, is the address bar displayed the same in the presence of mixed content (image and JavaScript) as in its absence?	[9]	MITM attack
	23	Is a webpage with self-signed certificate rendered without warnings?	[4, 5, 14, 37]	MITM attack, Phishing
Content	24	Can an iframe expand its size past the one defined by its parent frame?	[3, 6]	Phishing
	25	Is a mixed-content image resource loaded?	[9]	MITM attack
	26	Is a mixed-content JavaScript script executed?	[9]	MITM attack
	27	Is JavaScript code included in a self-signed website executed before the warning is accepted?	Novel	Phishing, MITM attack

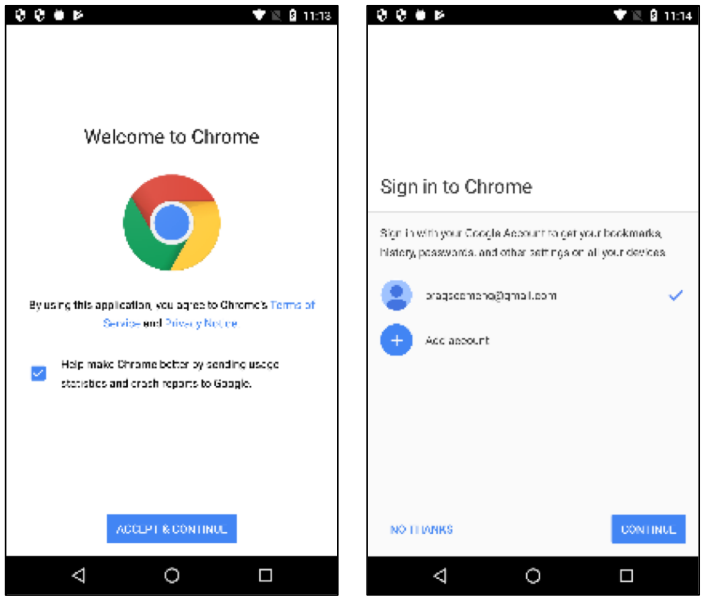
Combination of multiple ABBs in a single attack

Browser-Agnostic UI Analysis

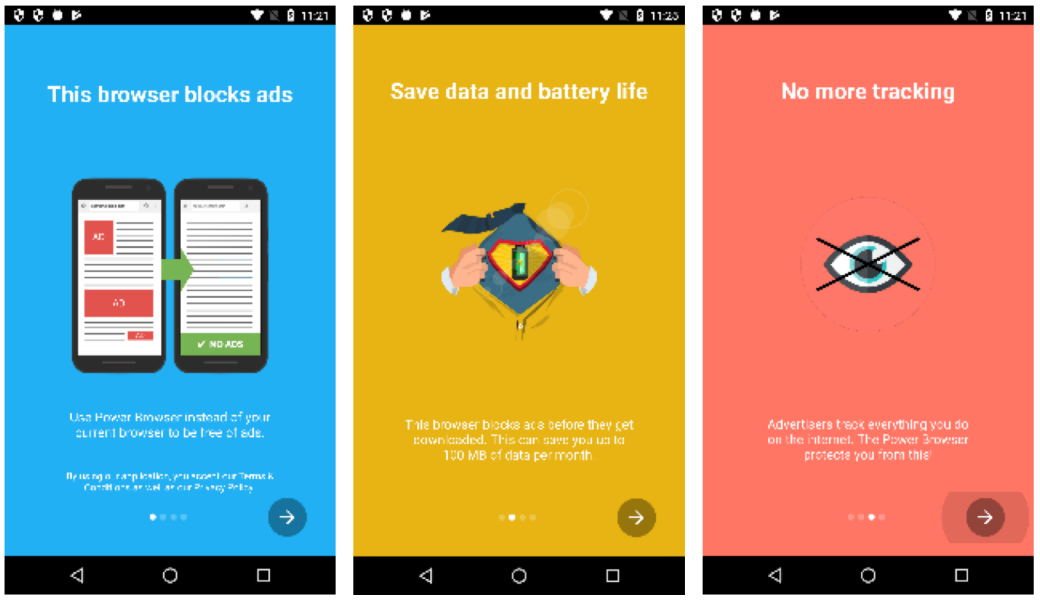
- Application-level UI
  - i.e., address bar, favicon, padlock
- Web page content
  - E.g., user interactions to HTML elements
  - Lacks in pixel-level mapping for web page and device
- Techniques: UIAutomator, OCR and image comparison algorithms



Splash screens of mobile browsers

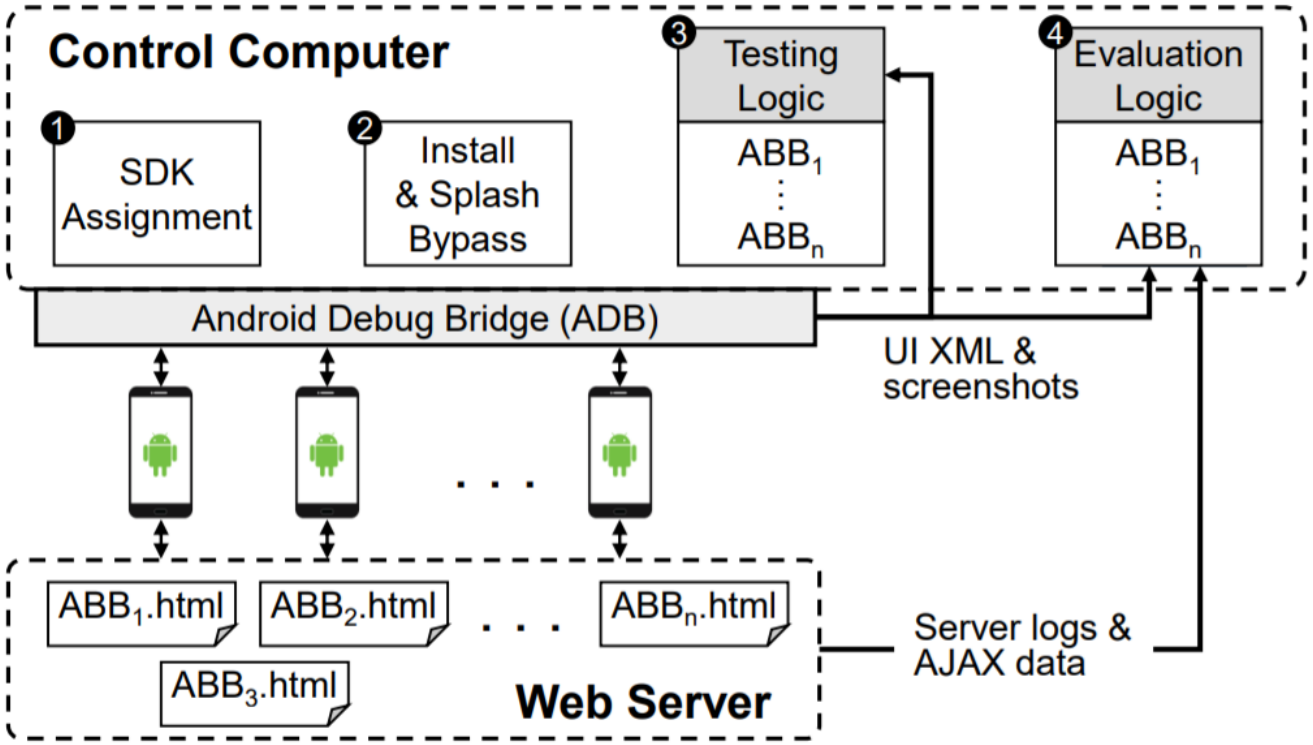


Google Chrome



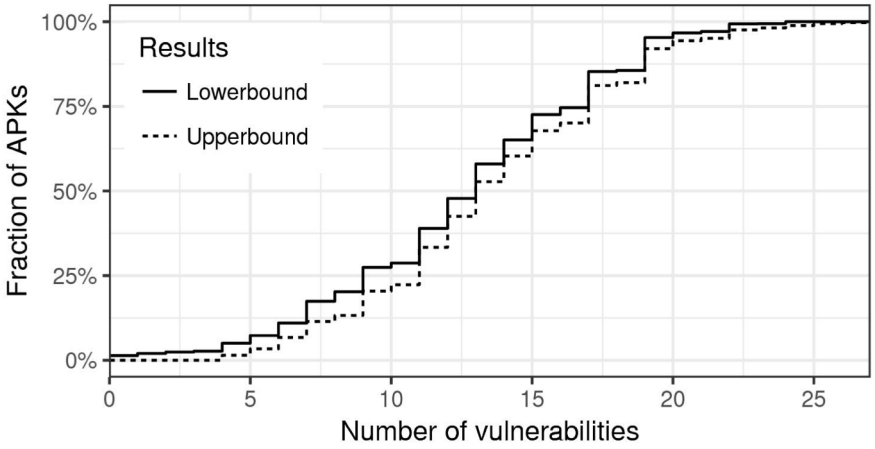
Power Browser

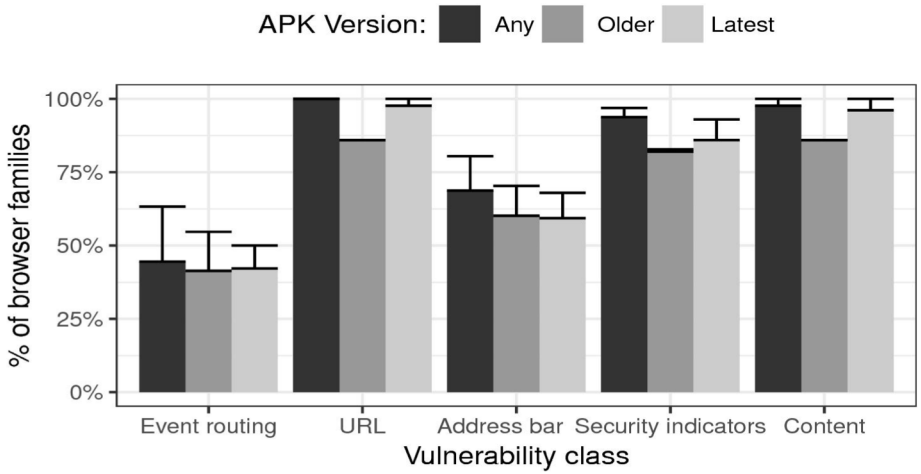
Architecture of Hindsight framework



Hindsight in action

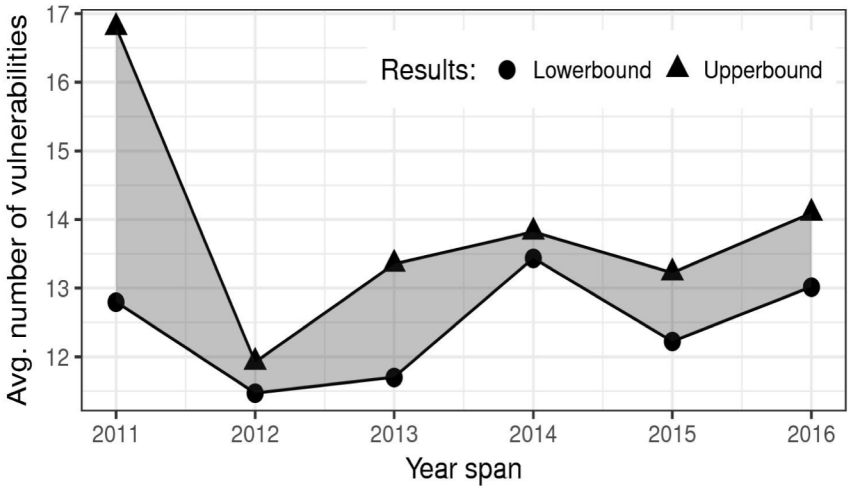
Hindsight: Results from 2,324 browser APKs

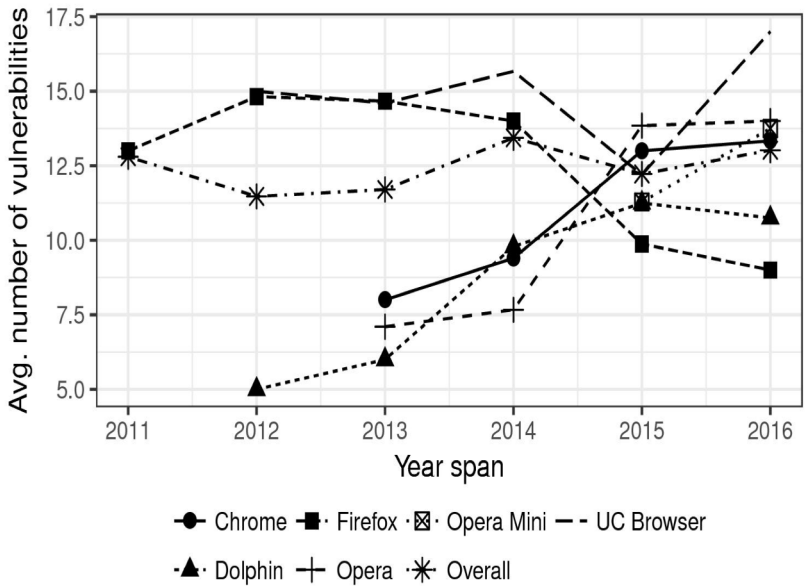




- 98.6% of the evaluated browser APKs are vulnerable to at least one ABB.
- 50% of APKs are vulnerable to more than 12 ABBs.
- URL ABBs more potent than the rest

Hindsight: Longitudinal analysis of vulnerabilities





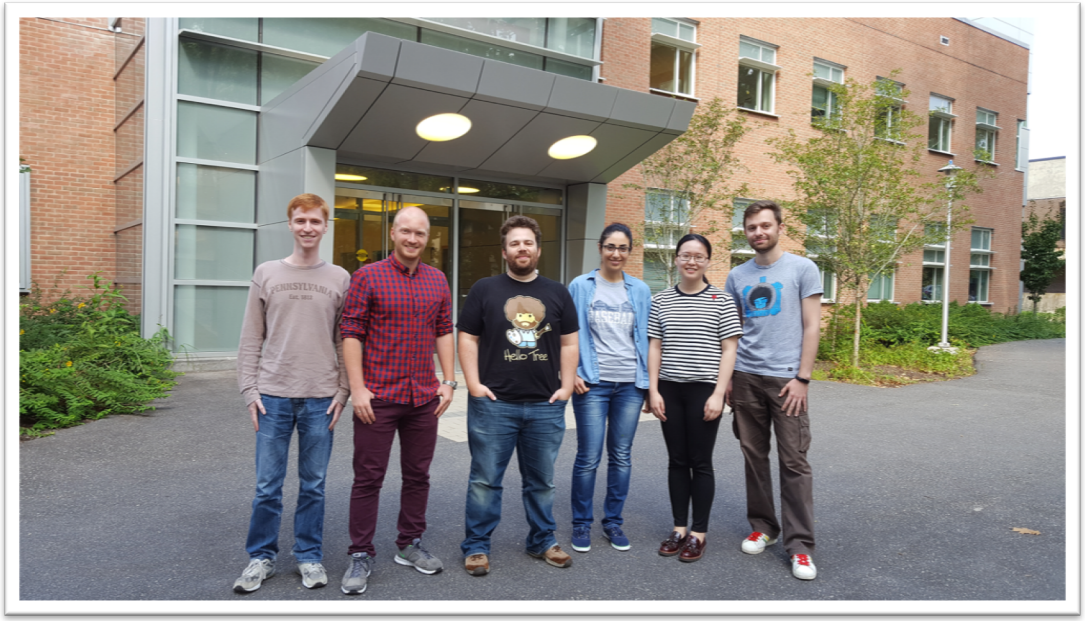
Other things we do…

- Identify ways that malware can bypass modern sandboxes
  - Joint work with Professor Michalis Polychronakis
- Construct more realistic honeypots
  - Get attacks to spend more time on them
  - Understand how they are evaded
- Study abuse of the Domain Name System
  - Domain squatting
  - Domain name hijacking
  - Malicious domain registrations
- Track cybercrime campaigns
  - Technical support scams
  - Affiliate abuse

Conclusion

- As the functionality of browsers expand, so does their attack surface

- Whenever a new feature is added, we must try to reason about the interaction of that feature with existing security policies and mechanisms
  - Automation is key



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