# Malicious Browser Extensions at Scale

## Bridging the Observability Gap between Web Site and Browser

**Louis F. DeKoven**[1], Stefan Savage[1], Geoffery M. Voelker[1], Nektarios Leontiadis[2]

[1]UC San Diego, [2]Facebook

# Attacks on Social Media

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- Leverage the vantage point of a social network to
  - Detect devices infected with malware
  - Clean up malware from infected devices

# Objectives

- Detect and label malicious browser extensions quickly
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- Automatically cleanup infected devices
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**Malicious Browser Extensions (MBE)**: extensions that take actions on behalf of a user without their consent, or replace Facebook's key functionality or content.

# Browser Extensions

- Motivation
- Background
- Methodology
- Results
- Evaluating Alternatives
- Conclusion

# Browser Extensions 101

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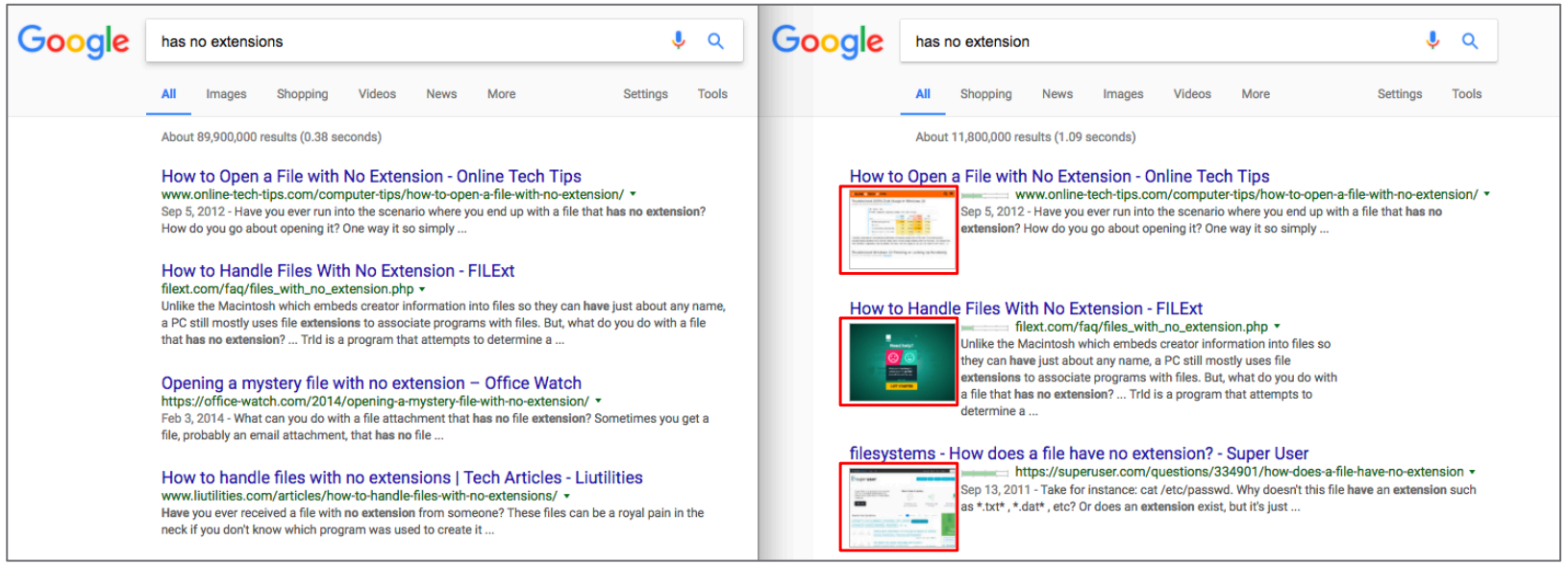


No extension Extension

# Browser Extensions 101

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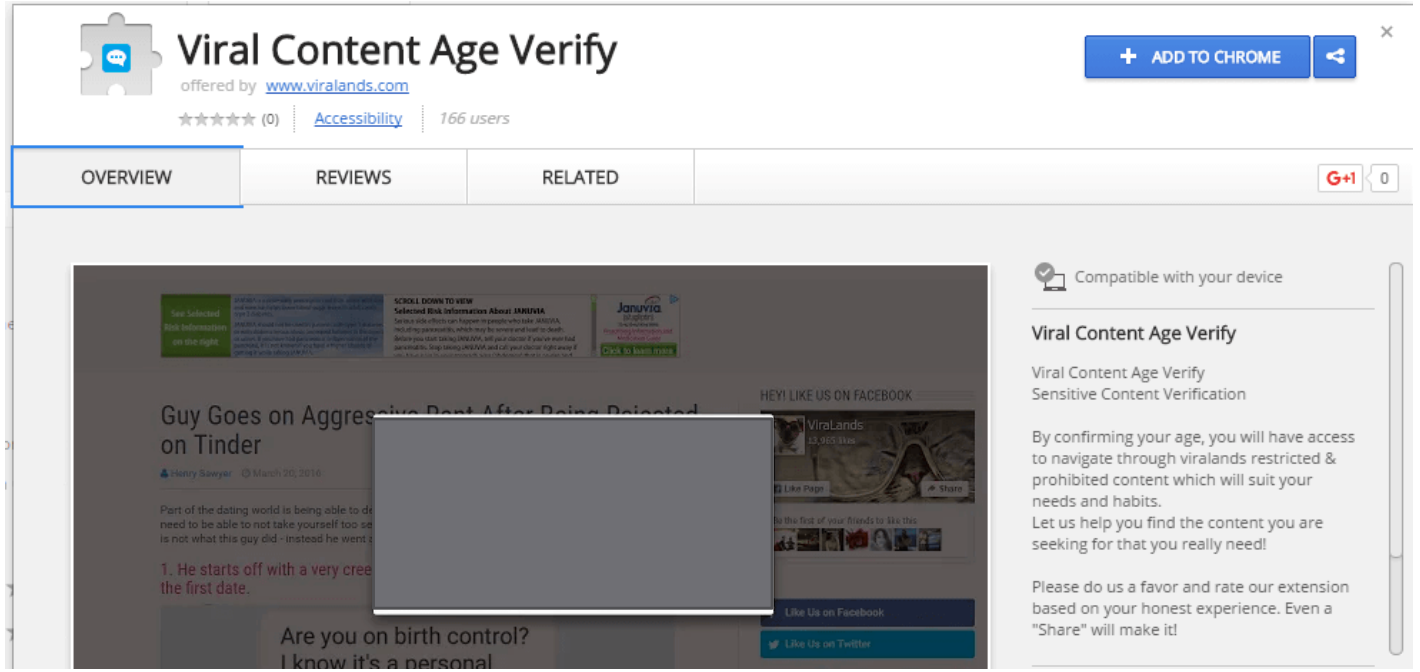
- Can change how the browser interacts with Web pages
- How?
  - Have elevated set of privileges

# Browser Extensions 101

- Enhance user experience beyond a Web page
- Can change visual appearance of Web pages
- Can change how the browser interacts with Web pages
- How?
  - Have elevated set of privileges
    - Modify HTTP headers
    - Change Content Security Policy
    - Rewrite any Web site content

# Browser Extensions 101

- Example MBE targeting Facebook
  - Steals user's Facebook access token
  - Generates likes
  - Subscribes to YouTube channels
  - And more…




https://kjaer.io/extension-malware/

# Defending Against MBE

- Harden the browser [1,2,3]
- Detecting extensions vulnerable to Web page JavaScript[4]
- Vetting code within extension marketplaces [5]
- Dynamic analysis and sandboxing [6,7]

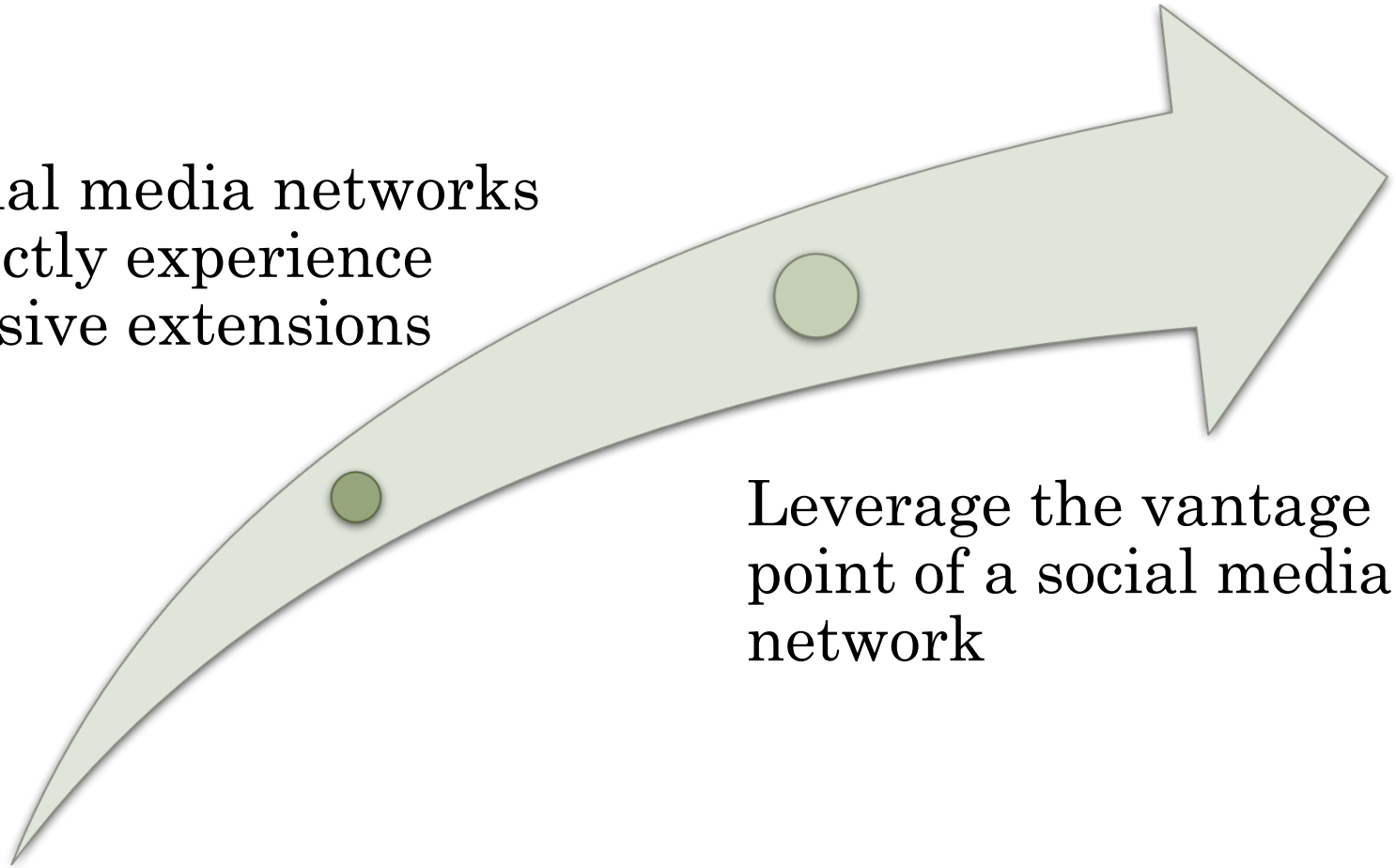

[1] V. Djeric and A. Goel. Securing Script-Based Extensibility in Web Browsers. In *Proc. of USENIX Security*, 2010.
[2] A. Guha, M. Fredrikson, B. Livshits, and N. Swamy. Verified Security for Browser Extensions. In *Proc. of IEEE S&P*, 2011.
[3] L. Liu, X. Zhang, G. Yan, and S. Chen. Chrome Extensions: Threat Analysis and Countermeasures. In *Proc. of NDSS*, 2012.
[4] M. T. Louw, J. S. Lim, and V. N. Venkatakrishnan. Enhancing web browser security against malware extensions. *Journal in Computer Virology*, 2008.
[5] H. Shahriar, K. Weldemariam, T. Lutellier, and M. Zulkernine. A Model-Based Detection of Vulnerable and Malicious Browser Extensions. In *Proc. of SERE*, 2013.
[5] S. Bandhakavi, S. T. King, M. Parthasarathy, and M. Winslett. Vetting Browser Extensions for Security Vulnerabilities with VEX. In *Proc. of USENIX Security*, 2010.
[6] A. Kapravelos, C. Grier, N. Chachra, C. Kruegel, G. Vigna, and V. Paxson. Hulk: Eliciting Malicious Behavior in Browser Extensions. In *Proc. of USENIX Security*, 2014.
[7] N. Jagpal, E. Dingle, J. Gravel, P. Mavrommatis, N. Provos, M. A. Rajab, and K. Thomas. Trends and Lessons from Three Years Fighting Malicious Extensions. In *Proc. of USENIX Security*, 2015.

# It's Hard to Detect MBE

- Anti-malware products
  - May run static analysis on extension JavaScript
  - Struggle with dynamic resources
- Extension marketplaces/Browser vendors
  - May track how extensions use the browser
  - Struggle with temporal badness
- Researchers
  - May run sandboxed analysis
  - Struggle with scale and temporal badness

# A Different Perspective

Social media networks directly experience abusive extensions



Leverage the vantage point of a social media network

# Detecting MBE

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- Insight: We can link extension content to abusive content

# System Methodology

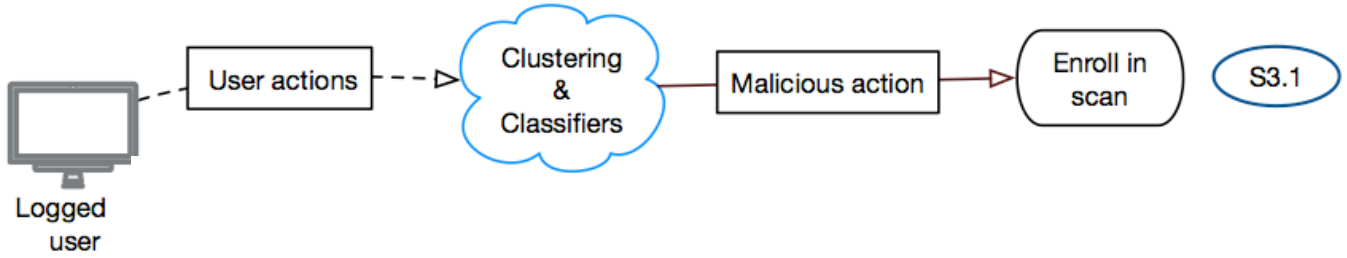
Using signals from malware within Facebook enables the detection and remove MBE at a large scale

**We do this by:**

- Identifying compromised Facebook accounts
- With user consent, we fetch the installed extensions from devices exhibiting malicious behavior
- Determine if the extension is malicious or benign by comparing it to abusive content (while fetching extensions)
- If the extension is malicious remove it from the user's device

# System Design

- Detecting compromised user accounts



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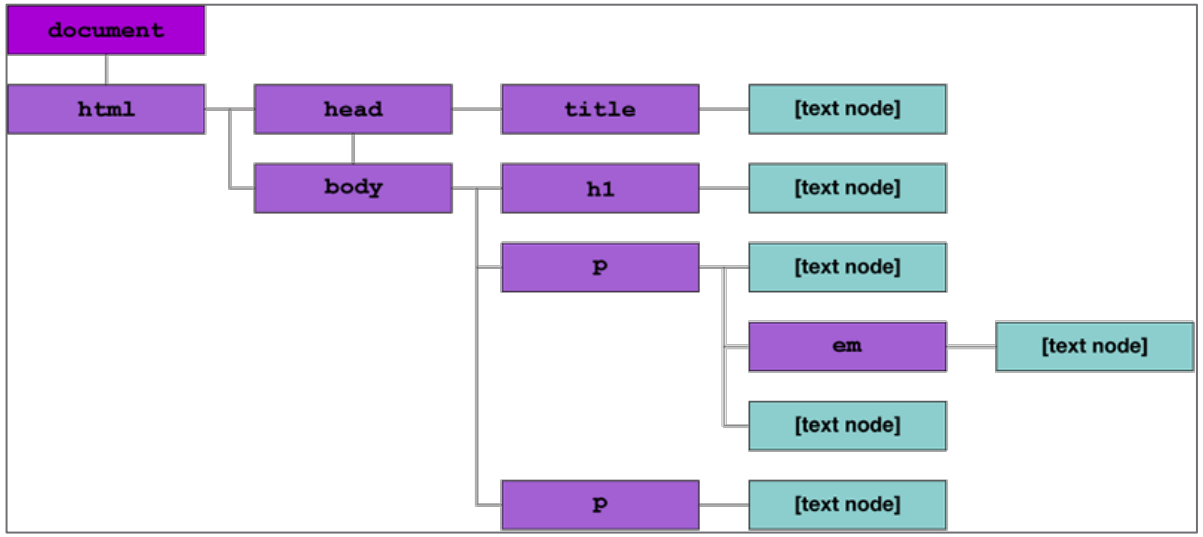
  - Periodically scan Facebook's DOM for third-party elements



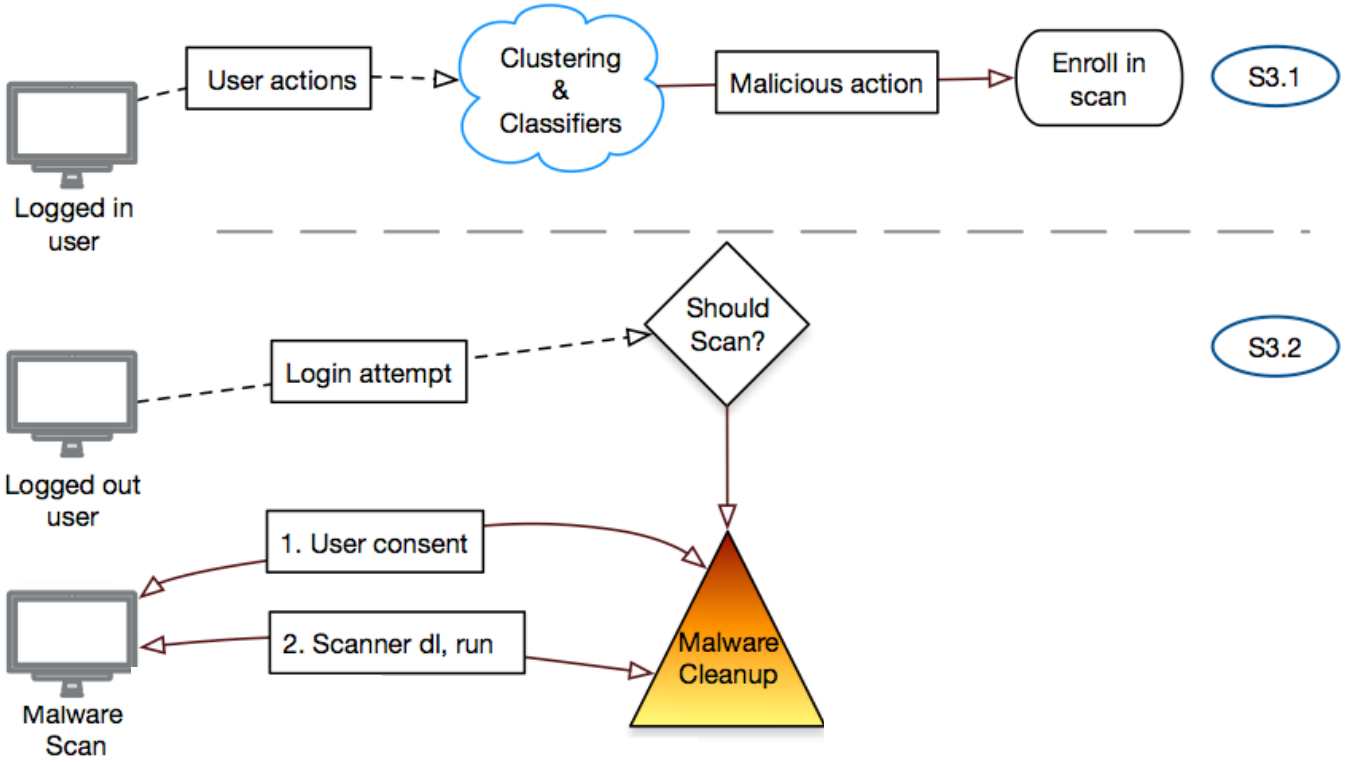

Example DOM

# Detecting Compromised User Accounts

- Spiking content
  - Monitor time series of user activity
- Document Object Model (DOM) based detection
  - Periodically scan Facebook's DOM for third-party elements
- Negative feedback
  - Feedback on posted content

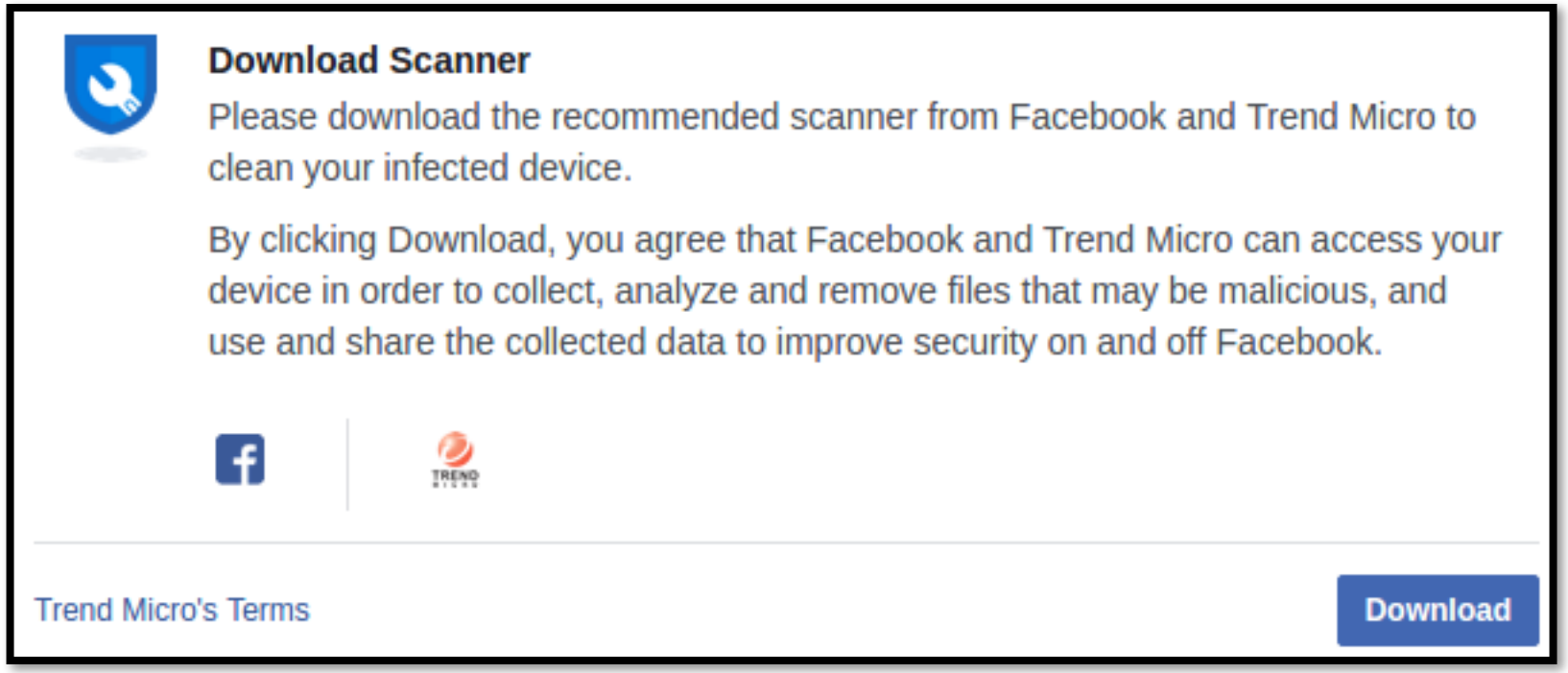
# System Design

- Detecting compromised user accounts
- Anti-malware scanner



# Anti-Malware Scanner

- Facebook's custom scanner is executed on the compromised device following user consent



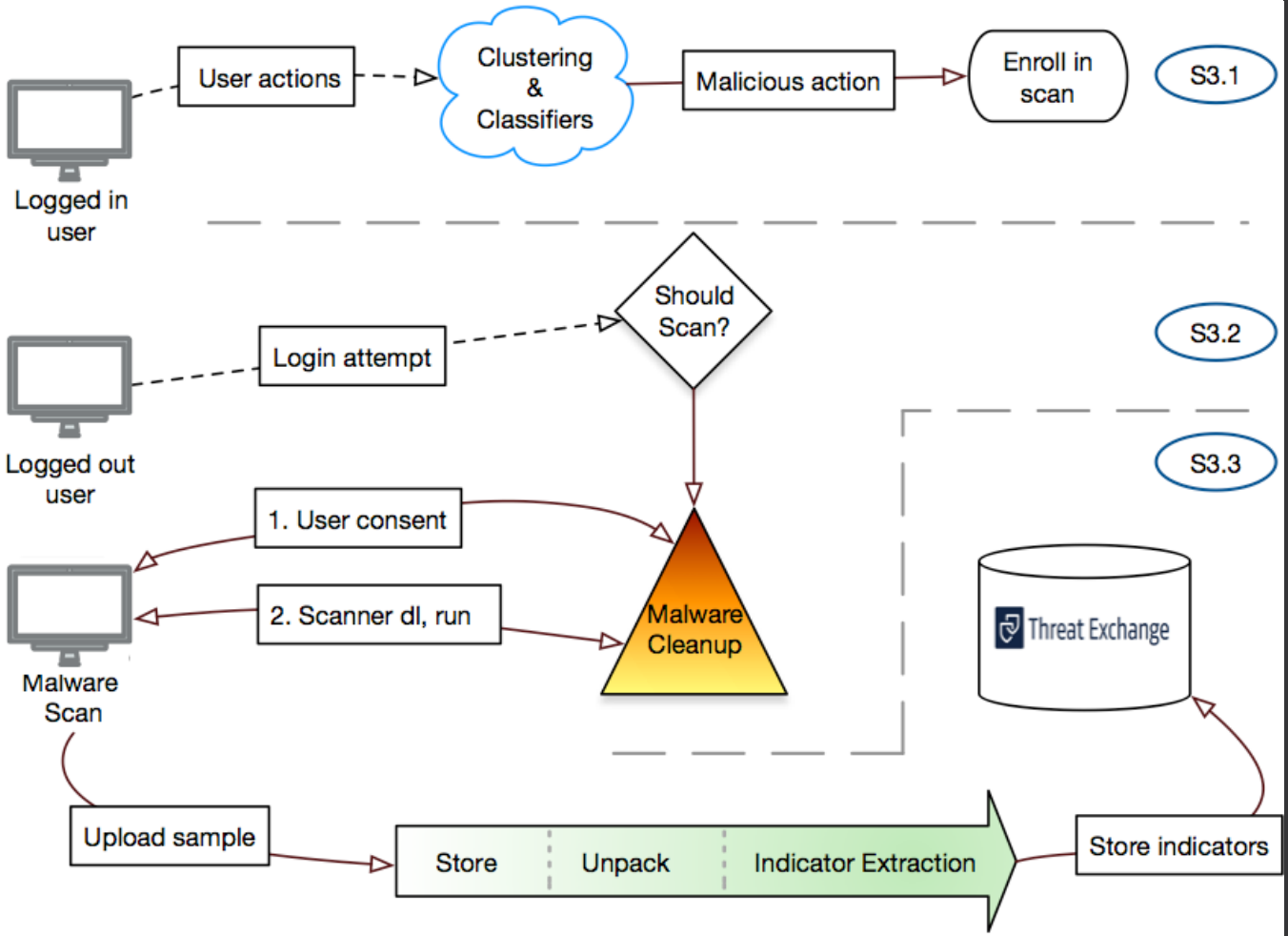
# Anti-Malware Scanner

- Facebook's custom scanner is executed on the compromised device following user consent

- Uploads digital fingerprint of extensions to Facebook
  - MD5 hash
- New extensions are uploaded to Facebook
- When MBE are detected they are removed
- Third-party anti-virus scanner executed

# System Design

- Detecting compromised user accounts
- Anti-malware scanner
- Static analysis pipeline



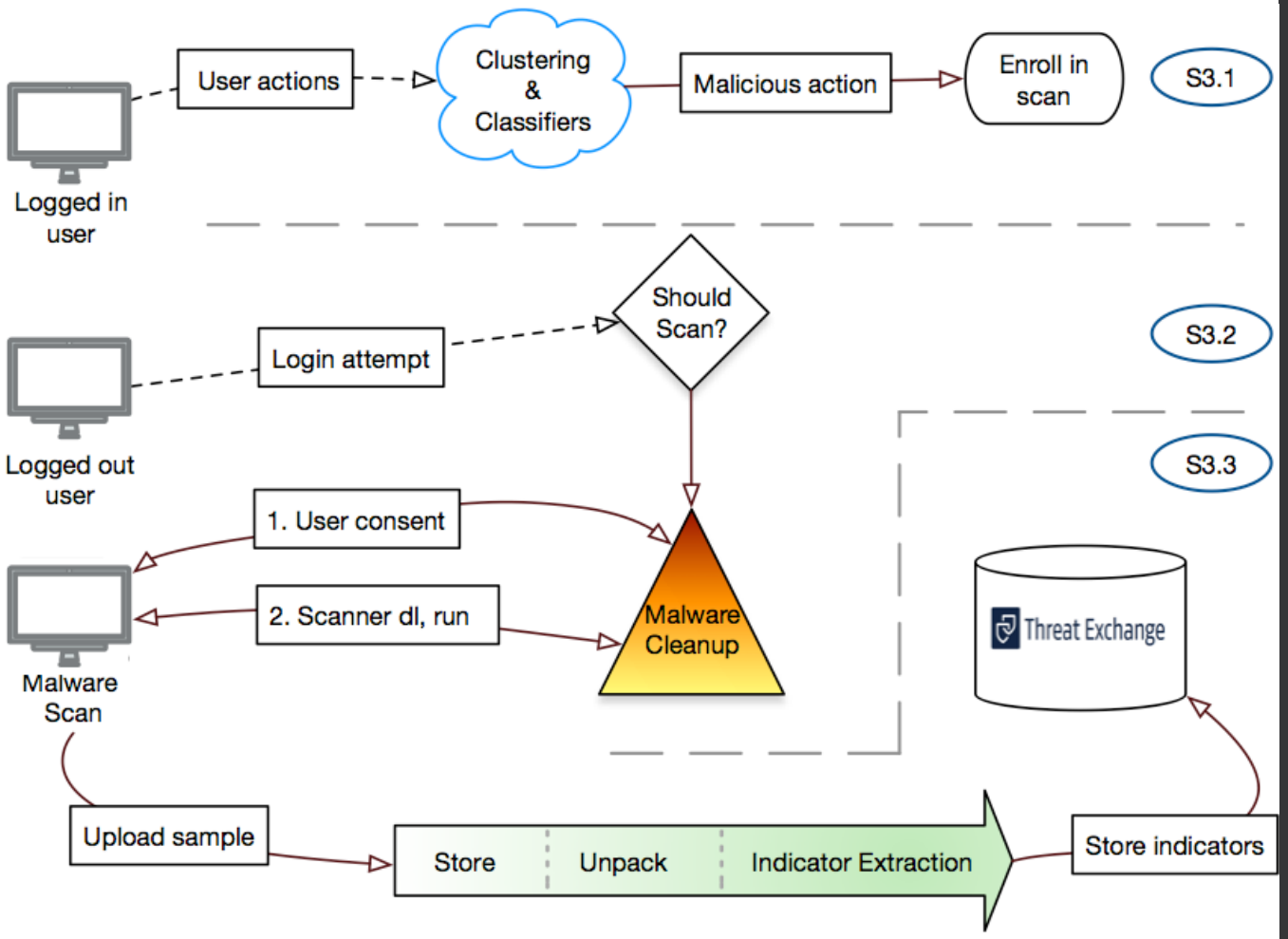
# Static Analysis Pipeline

- **Unpacking**
  - Recursively unpack the extension and files
- **Indicator extraction**
  - Deobfuscate, decode, and repair broken URLs
  - Regular expressions extract indicators e.g. URLs, API keys
    - Treating each file as text

- Insight: Extensions collected by Facebook's malware scanner exhibited malicious behavior at the time of collection

# System Design

- Detecting compromised user accounts
- Anti-malware scanner
- Static analysis pipeline
- Extension labeling



# Indicator Labeling

- `MALICIOUS`
  - Malicious with high-confidence
- `UNKNOWN`
  - Default label for all samples
- `NON_MALICIOUS`
  - Benign samples, or samples from trusted sources

- Labels produced by system that detects compromised accounts

# Propagating Indicator Labels

- Apply vetted threat labels to indicators from static analysis
- How do we label extensions?
  - JavaScript contains a `MALICIOUS` URL
  - `MALICIOUS` label propagates to the file
  - `MALICIOUS` label propagates the extension
- Erroneously marked indicators
  - Propagate automatically
  - Rules in place to prevent single indicators from mass-labeling
  - Manual labels overrides automated labeling

# System Results

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# Malicious Indicators

| | Extension Contents | | Extracted Indicators | | Scan Sessions | |
|---|---|---|---|---|---|---|
| | JS | HTML | Total # | Malicious (#%) | # | % |
| Chrome Ext. | 67 380 | 720 | 66 134 | 1 559 (2.4%) | 718 497 | 96.9 |
| Firefox Ext. | 17 979 | 16 | 19 004 | 609 (3.2%) | 257 164 | 34.7 |
| Total Unique | 84 905 | 733 | 73 281 | 1 516 (2.1%) | 741 276 | 100.0 |

- 6-week measurement period
- Only a small number of all indicators are labeled `MALICIOUS`

# Malicious Extensions

| | All Extensions | | Malicious Extensions | |
|---|---|---|---|---|
| | # | % | # | % of total |
| Chrome Ext. | 23 376 | 67.6 | 1 697 | 7.3 |
| Firefox Ext. | 11 183 | 32.4 | 88 | 0.8 |
| Total Unique | 34 559 | 100.0 | 1 785 | 5.2 |

- A high proportion (5.2%) of malicious extensions is expected as our system targets devices exhibiting malicious behavior
- 422 of 1,697 Chrome MBE were once online Google's Web Store
  - Suggests a high number of MBEs to be side loaded

# MBE Detection Rates

- Average 39.5 Chrome MBE/day
- Average 2 Firefox MBE/day

- 92% of new MBE are labeled by a median time of **21 seconds**
- 8% of new MBE are labeled more than one day after collection
  - Detected on 9% of user devices cleaned during the experiment

This result is expected from an indicator-based labeling system as labels can change over time

# *Known* False Positives

- 124 extensions are incorrectly labeled `MALICIOUS`
- 0.8% of all scan sessions removed one or more of these extensions
- Median detection time: 18 days

- This result is expected from an indicator-based labeling system as labels can change over time
- We find the low number of incorrectly labeled MBEs to be an acceptable tradeoff

# Comparing Systems

- Motivation
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# Evaluating Alternatives

- Was it necessary to create a new system that detects MBE?
- Focus on Chrome extensions
  - Majority of extensions are for Chrome browser
  - Each Chrome extension's Web store presence is checked
  - 2,200/23,376 Chrome extensions *once* on the Chrome Web store

- Facebook labels 422 (19.2%) `MALICIOUS`
- Facebook labels 1,778 (80.8%) `UNKNOWN`

# VirusTotal

- Provided with 9,172 unique CRX from authors of Hulk[1]
  - VT was aware of *only* 73 extensions
  - Moreover 5 are labeled `MALICIOUS` by at least 1 anti-virus engine

Facebook cannot use general malware databases to detect MBEs

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Facebook cannot use general malware databases to detect MBEs

- Of the 422 MBE identified by Facebook
  - 96 (22.7%) are labeled `MALICIOUS` by one or more anti-virus engine

Facebook cannot rely on anti-malware engines to identify MBEs

[1] A. Kapravelos, C. Grier, N. Chachra, C. Kruegel, G. Vigna, and V. Paxson. Hulk: Eliciting Malicious Behavior in Browser Extensions. In *Proc. of USENIX Security*, 2014.

# Google Chrome Web Store

- By the six-week period Google removed 367 of the 2,200
  - 70 MALICIOUS
  - 297 UNKNOWN

Facebook cannot rely on Google to remove all MBE targeting FB

- Does Facebook identify MBEs faster?
  - These 70 MBE have over 1 million installs according the the Web Store
  - Facebook identifies the 70 MBE with a median time of **2.8 days** (67.3 hours) before they are removed from the Web store

Our system successfully reduces the median monetization time of MBE

# Take Away

MBE are challenging to address from any single vantage point

- Browser vendors
  - Can restrict extension distribution
  - Have limited insight into abusive extensions in the wild
- Abused sites
  - Directly experience malicious behavior
  - But are not in a position to identify which extensions are implicated

# Conclusion

- This system is currently running to protect users of Facebook
- As a result Facebook is able to very quickly detect and remove new MBE at scale

422 Chrome MBE MD5 hashes: https://pastebin.com/nzVGPLnr

- Samples available in VirusTotal and Facebook ThreatExchange