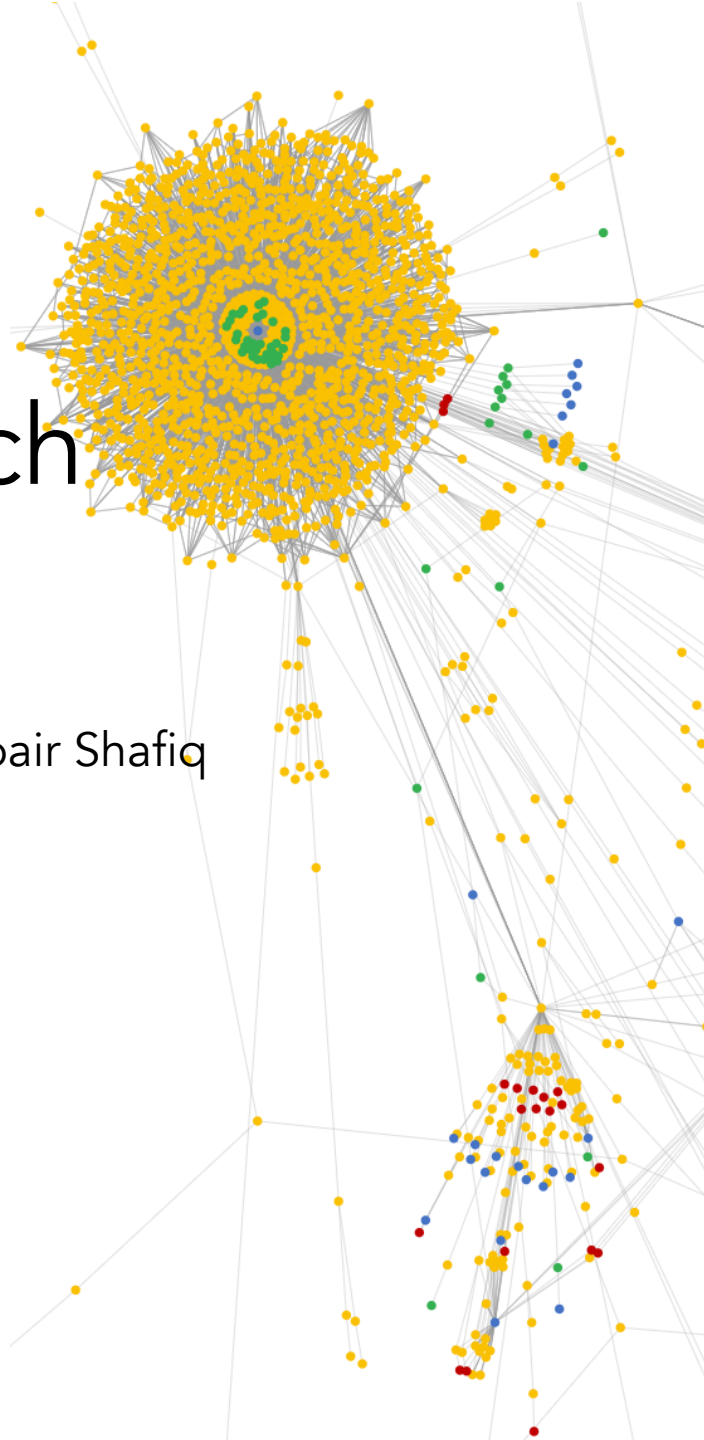
AdGraph: A Graph-Based Approach to Ad and Tracker Blocking

Umar Iqbal, Peter Snyder, Shitong Zhu, Benjamin Livshits, Zhiyun Qian, and Zubair Shafiq

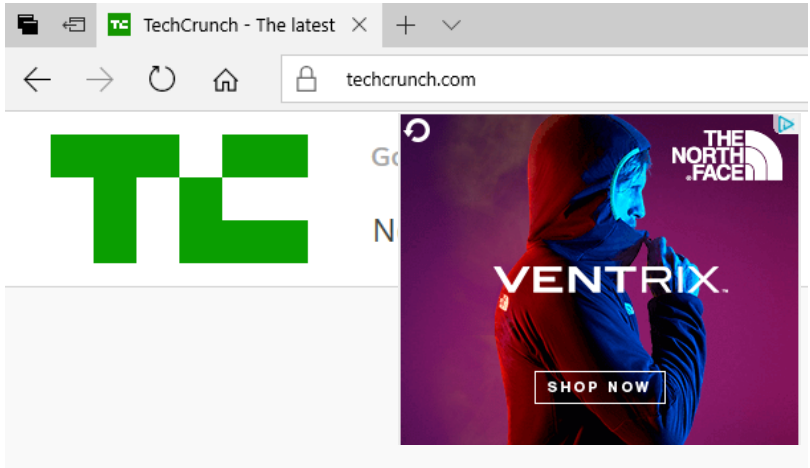
IEEE Symposium on Security and Privacy, 2020



Online Advertising

Advertising enables “free”content

- Publishers show content
- Earn revenue with ads



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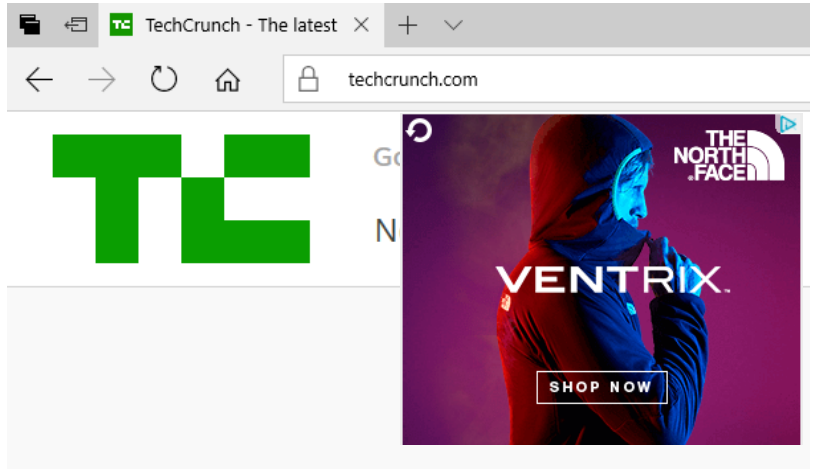

Digital revenues for full year 2018 surpassed $100 billion for the first time

Interactive Advertising Bureau (IAB) ‘19

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Problems with online advertising ecosystem

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Problems with online advertising ecosystem

- Privacy concerns – Behavioral targeting

“I see ads for things I dream about.”

“My phone is eavesdropping on me”

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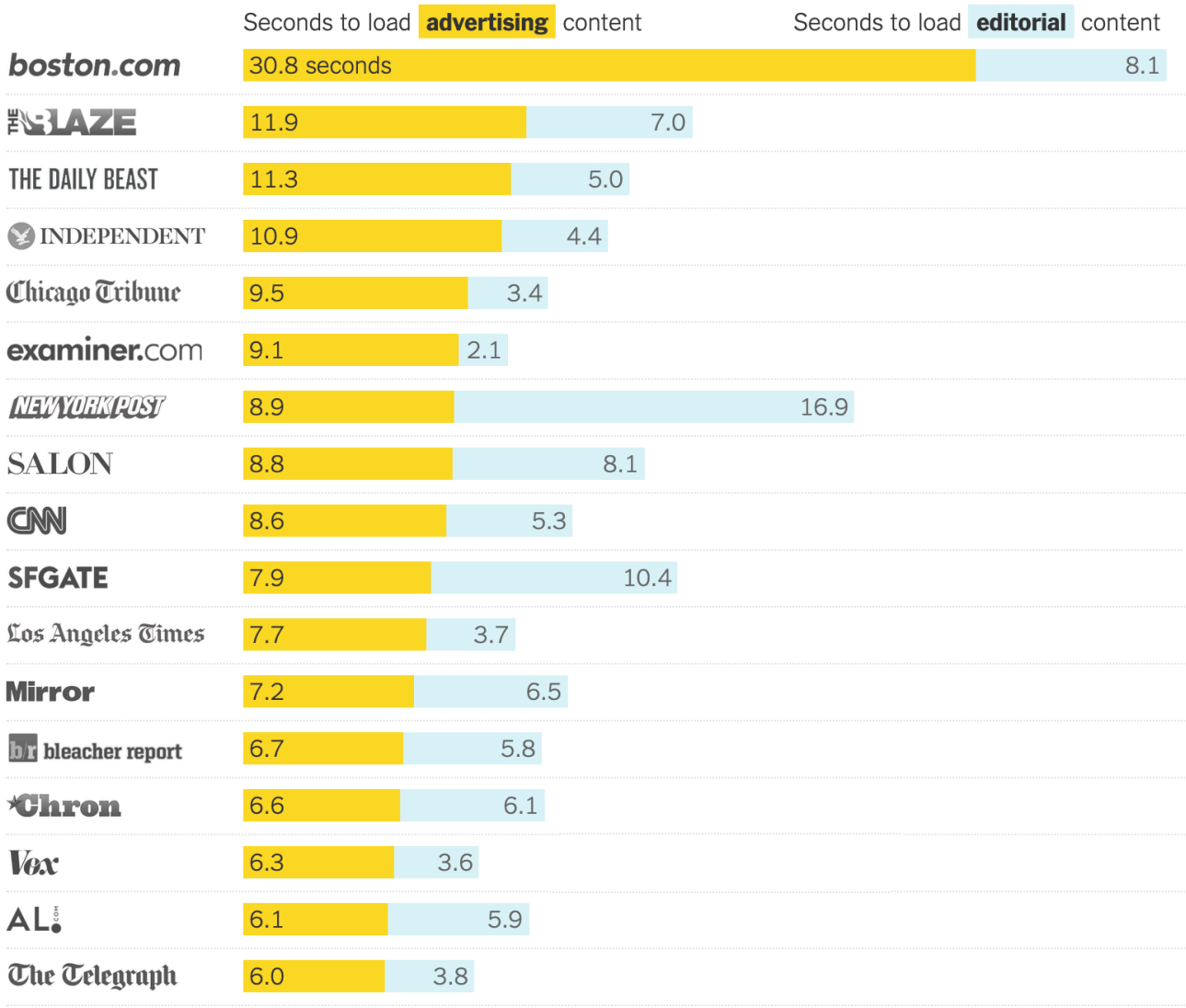

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Hackers have breached 60 ad servers to load their own malicious ads

Why buy legitimate ad slots to deliver malvertising when you can just hack the server instead.

Major sites including New York Times and BBC hit by 'ransomware' malvertising

Adverts hijacked by malicious campaign that demands payment in bitcoin to unlock user computers

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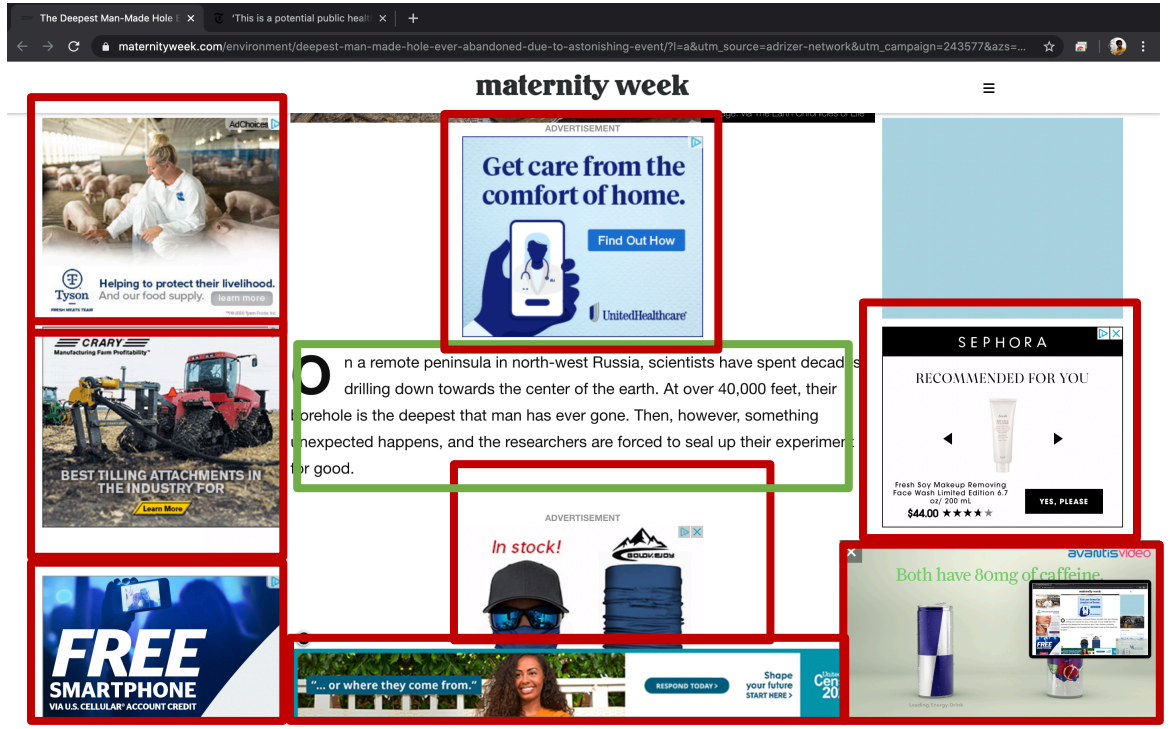

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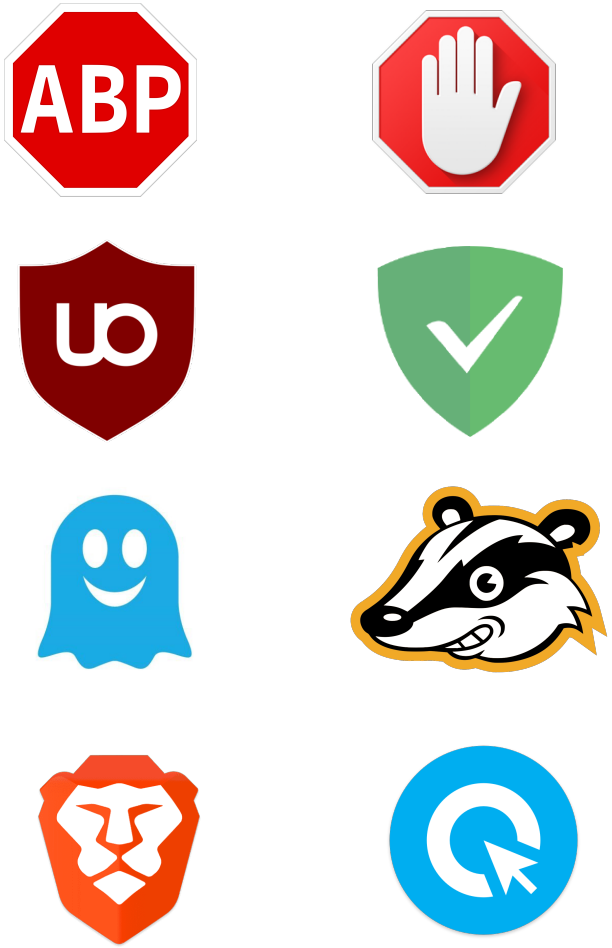
Solution
- Ad & tracker blockers



Outline

State of Ad/Tracker Blocking

- Ads & Trackers
- Filter list blocking
- Machine learning based blocking

AdGraph

- Graph-based representation
- Machine learning on graph representation
- Evaluation

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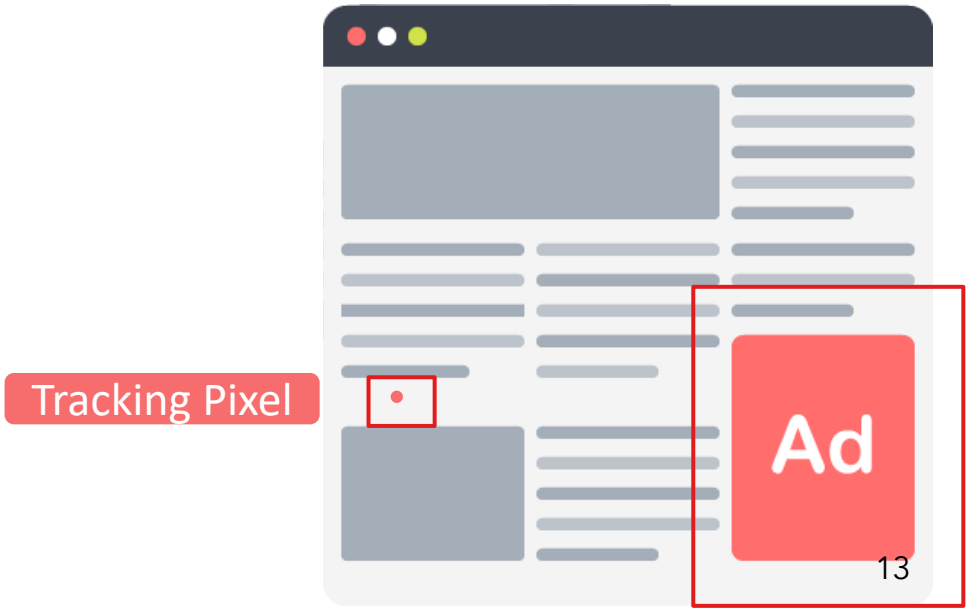

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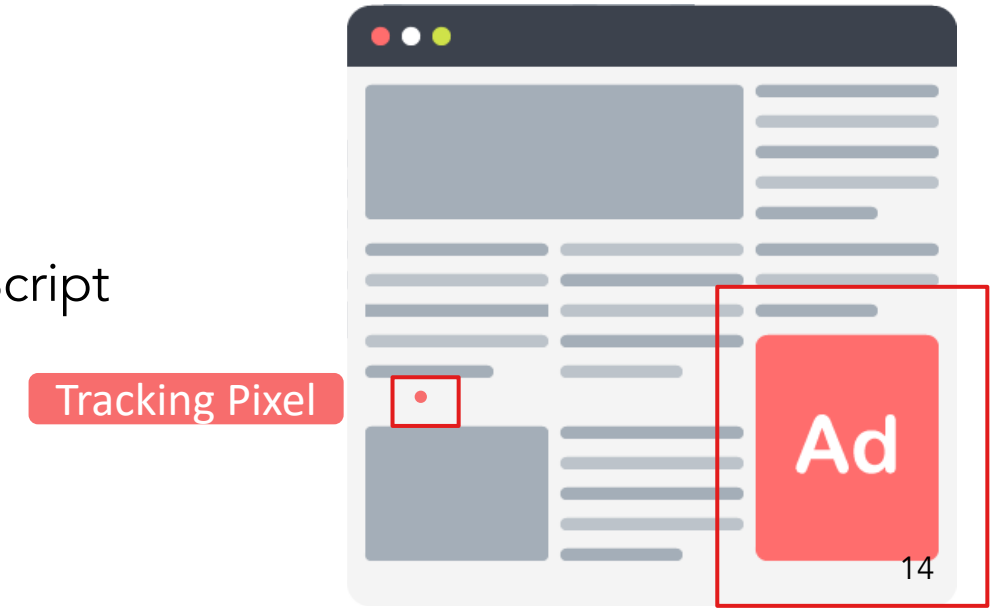
They are:

- Created with JavaScript
- Requested with HTTP
- Displayed with HTML

Ads and trackers involve HTML, Network, and JavaScript



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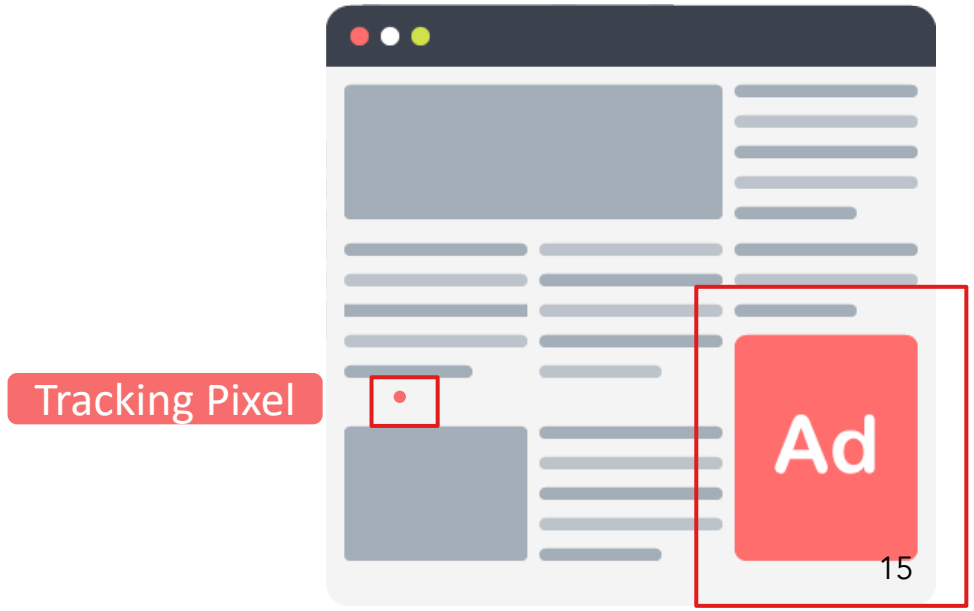

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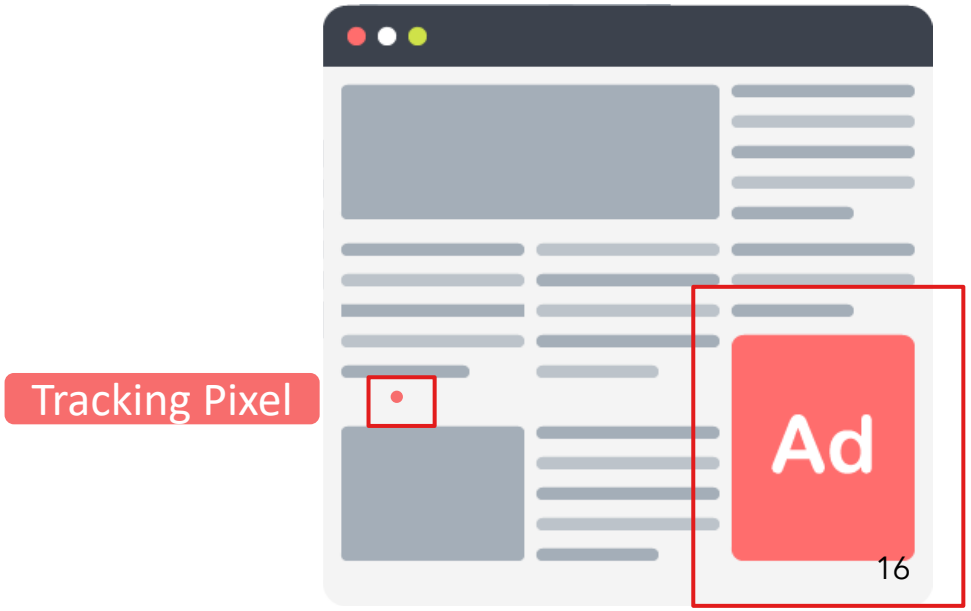

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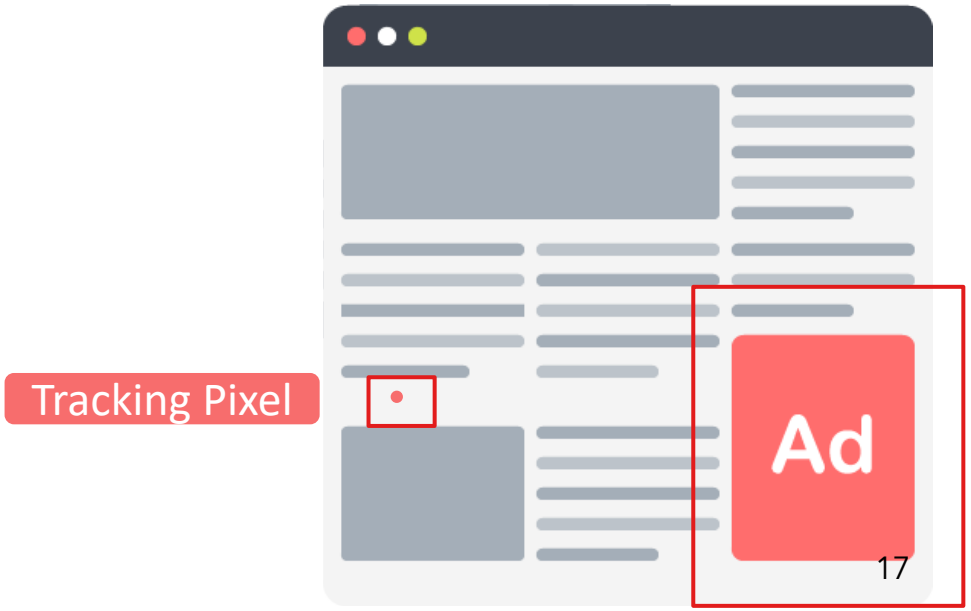

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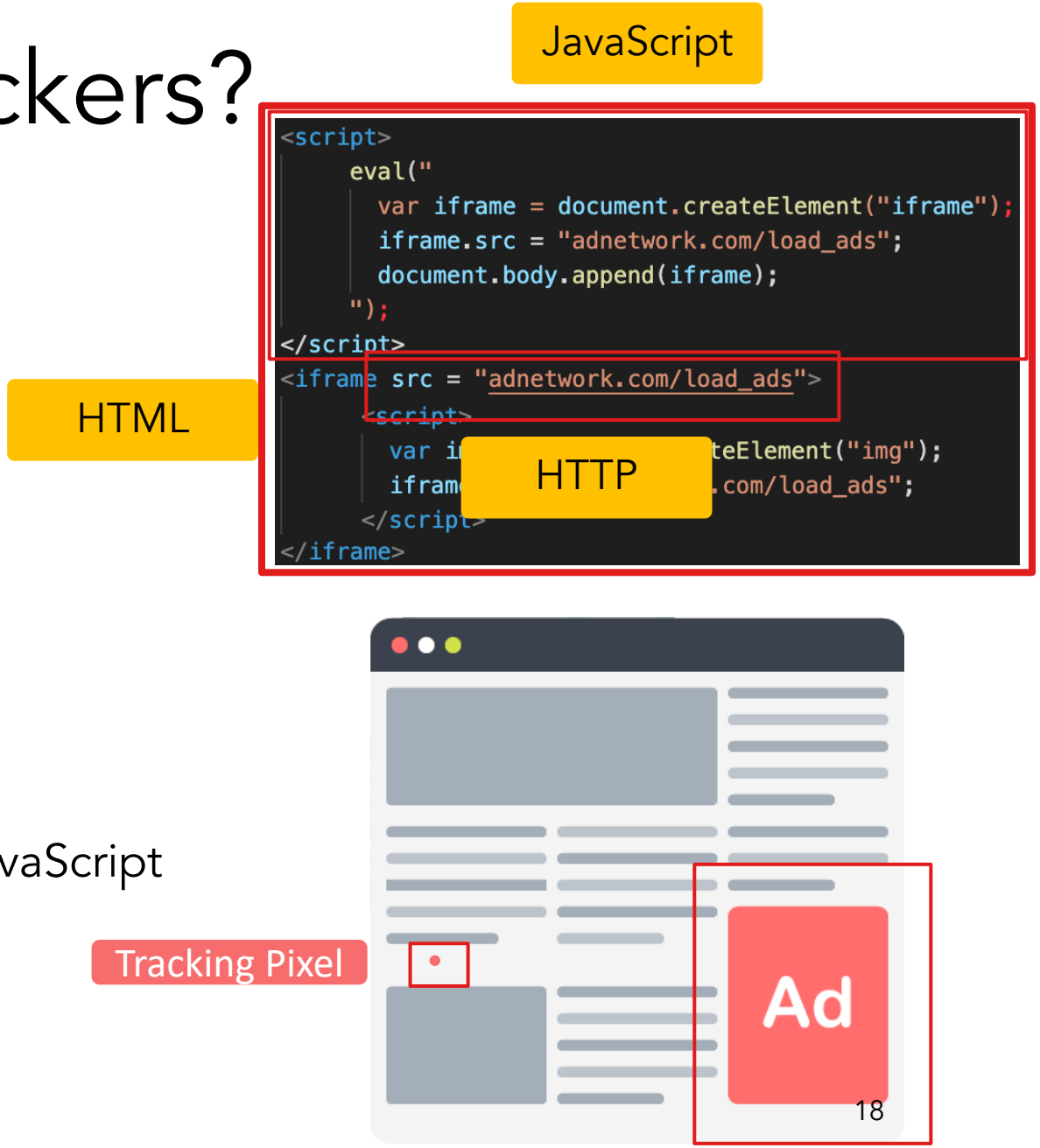

Filter List Based Blocking

Manually curated with crowdsourcing

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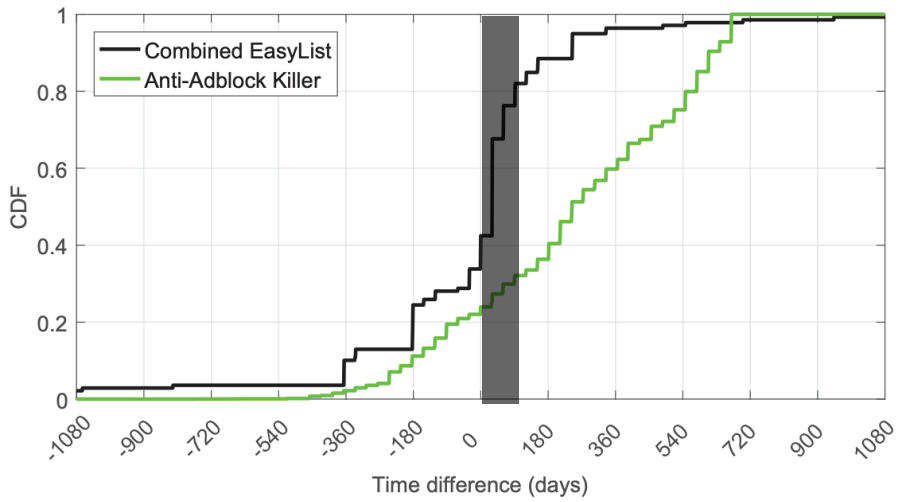
Leads to scalability issues



3 months to add new rules [Iqbal et al. ‘17]

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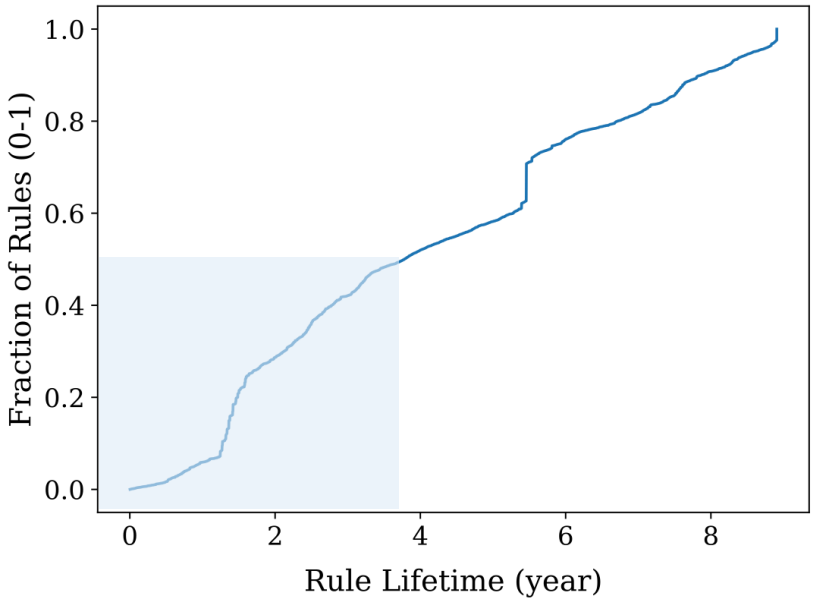

3.8 year to remove rules [Snyder et al. ‘20]

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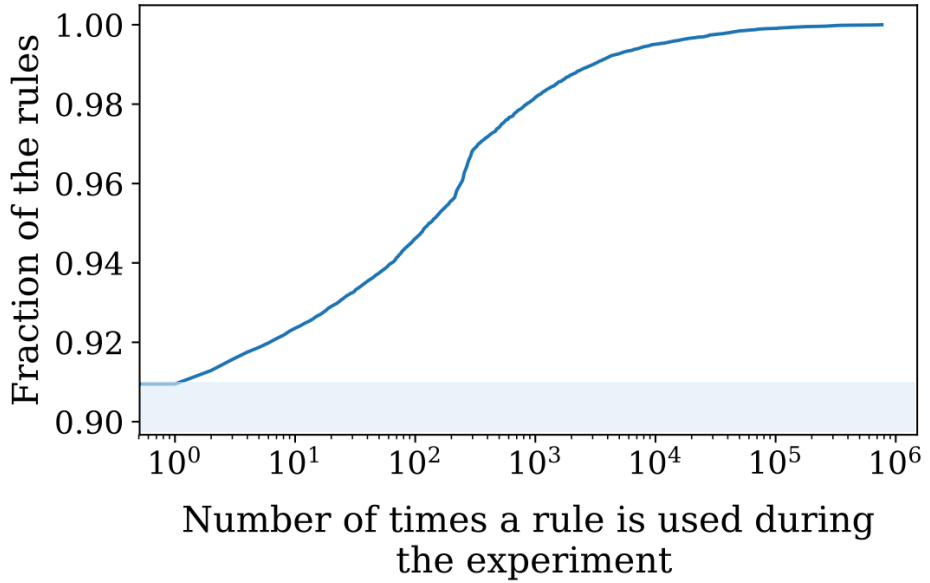

90% rules are useless [Snyder et al. ‘20]

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Operate at HTML/Network/JS layer in isolation

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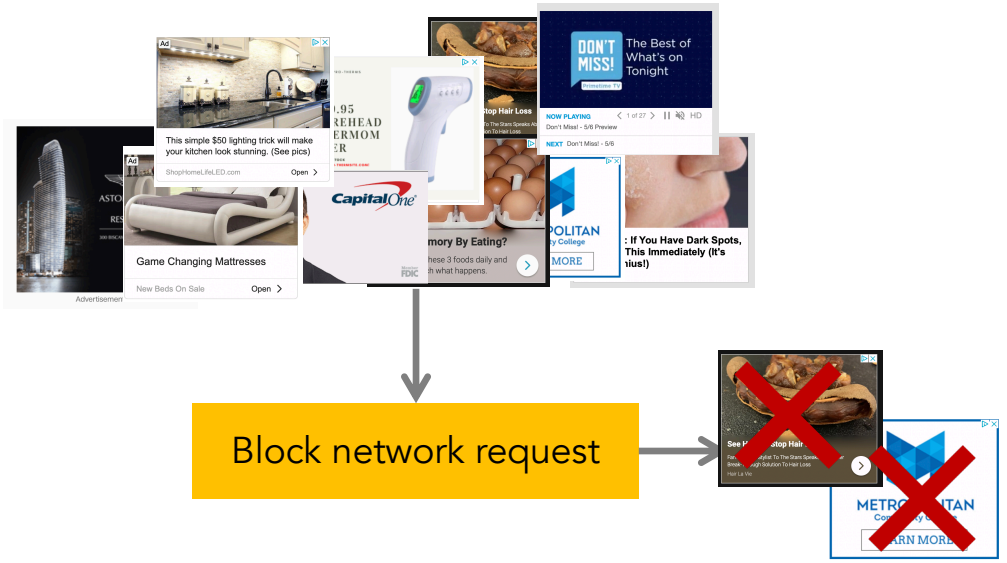

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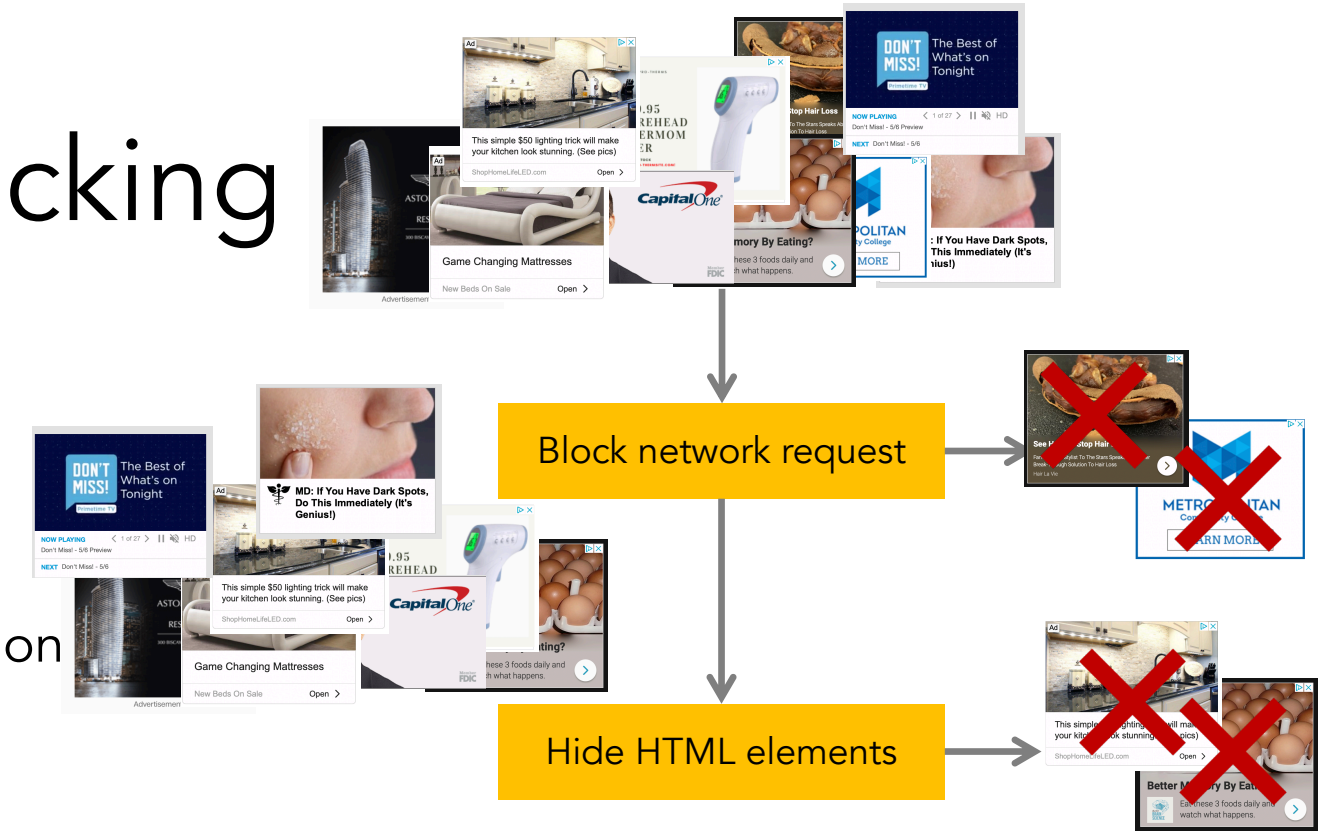

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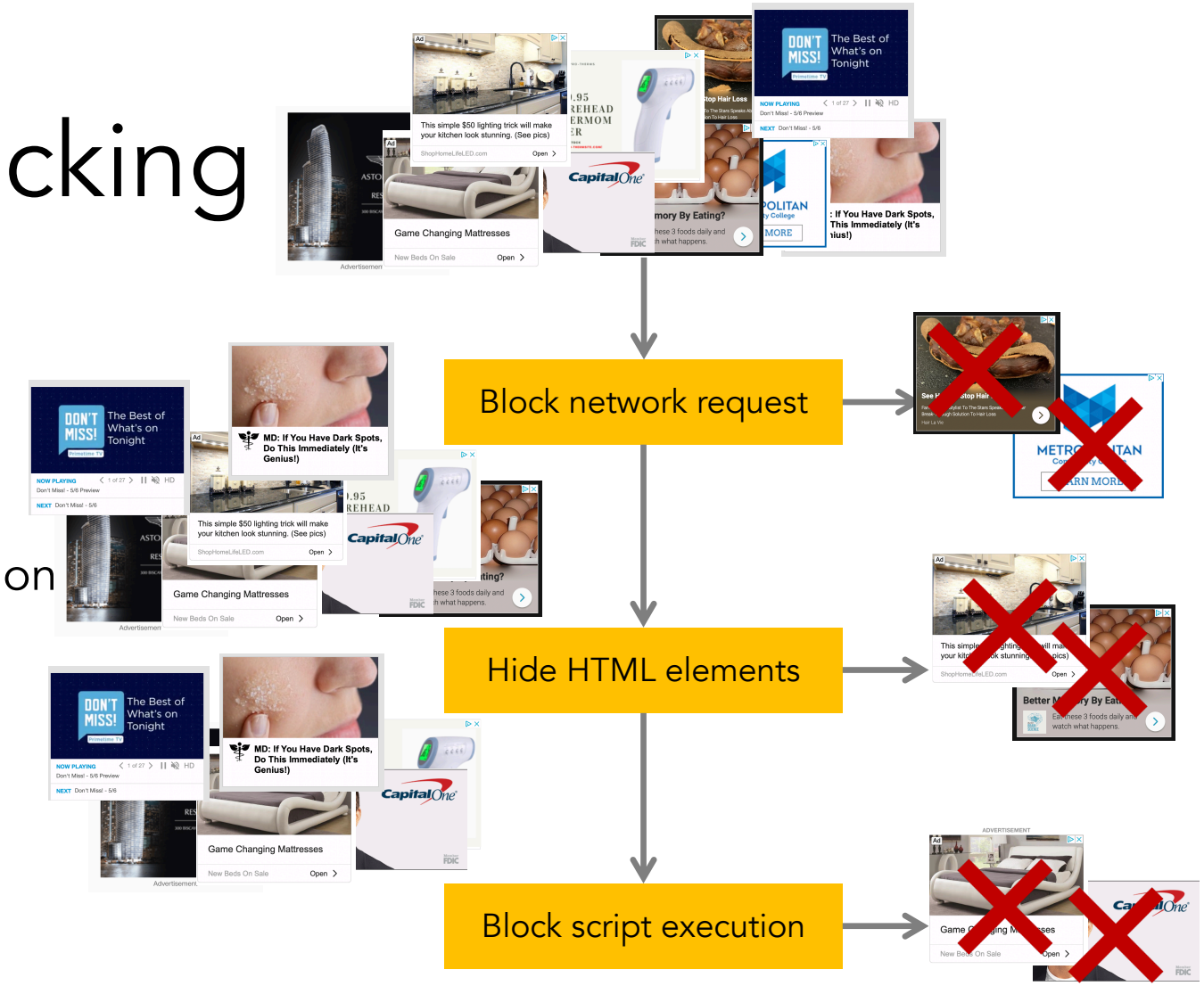

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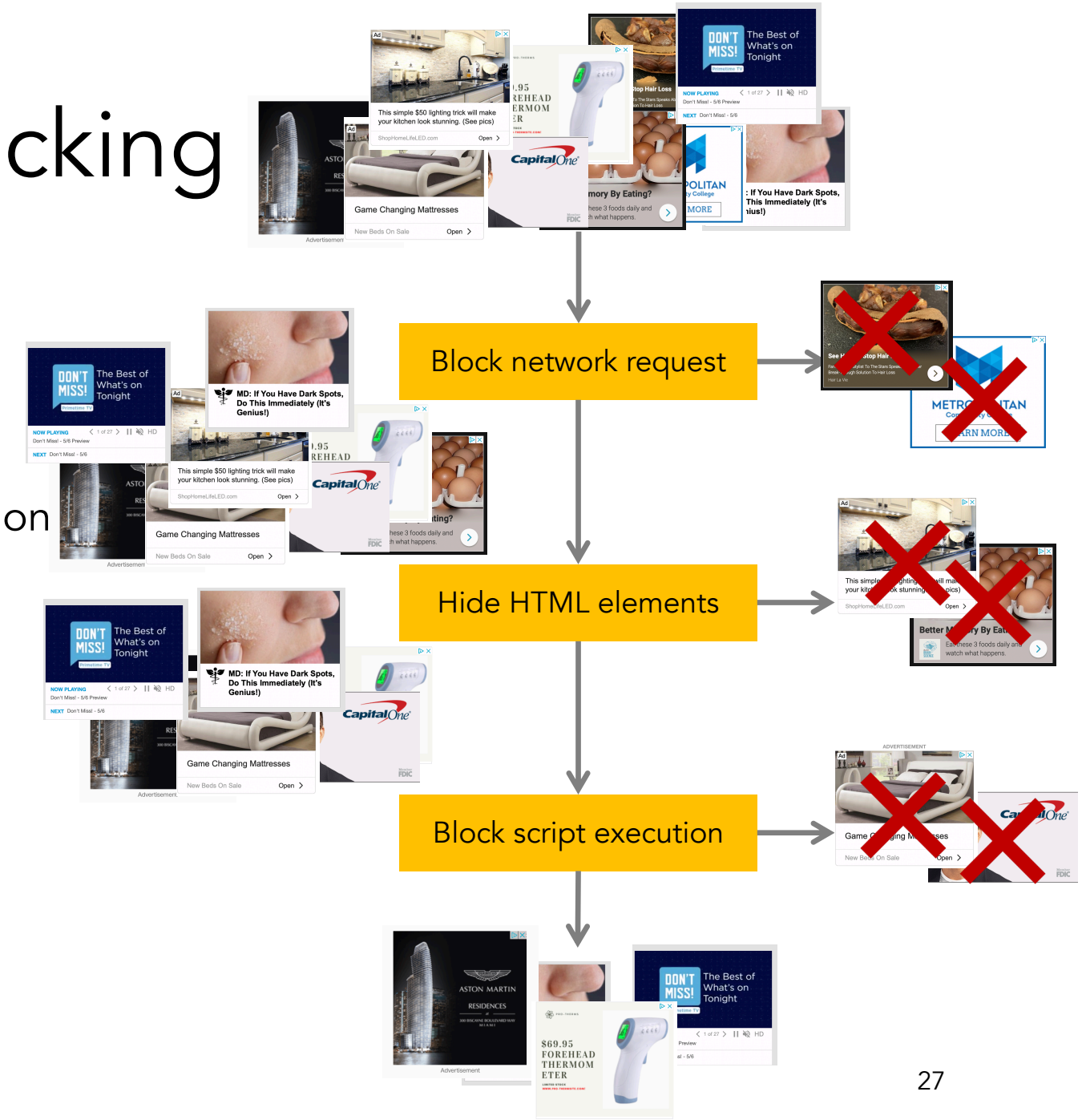

Filter List Based Blocking

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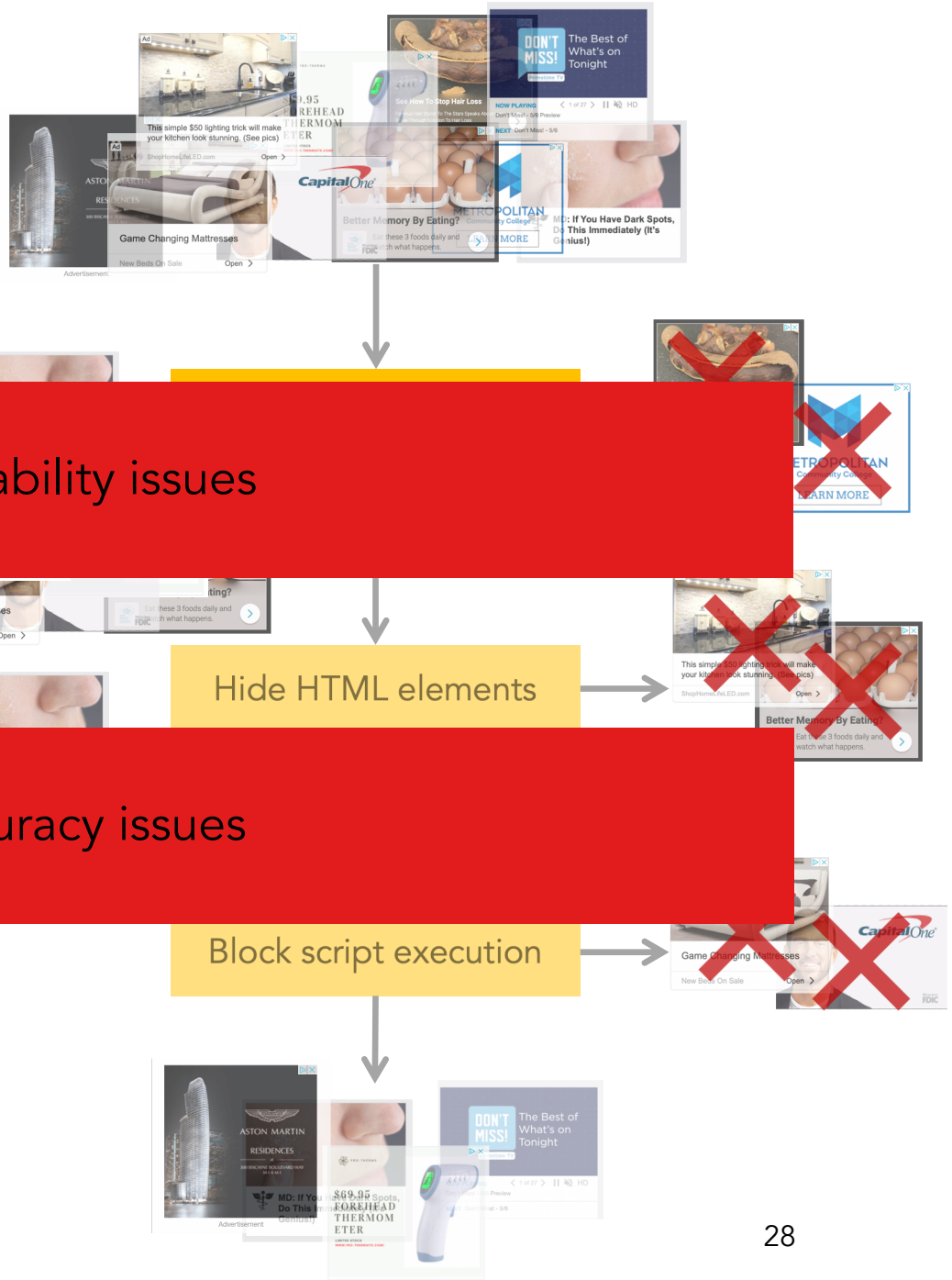
to

Suffer from scalability issues

Operate at HTML/Network/JS layer in isolation

Leads to accuracy issues

Suffer from accuracy issues



Machine Learning Based Blocking

Network layer [Bhagavatula et al. 14, Gugelmann et al. ’15]

- HTTP header properties as features
  - presence of words like “ad”
  - cookies set by response

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- HTTP header properties as features
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JavaScript layer [Wu et al. ‘16, Ikram et al. ‘17]

- JS API names as features
  - document.cookie
  - element.clientWidth

Machine Learning Based Blocking

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Solve scalability issues

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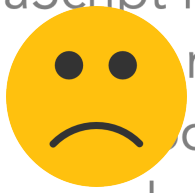

Do not solve accuracy issues

element.clientWidth

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- Graph-based representation
- Machine learning on graph representation
- Evaluation

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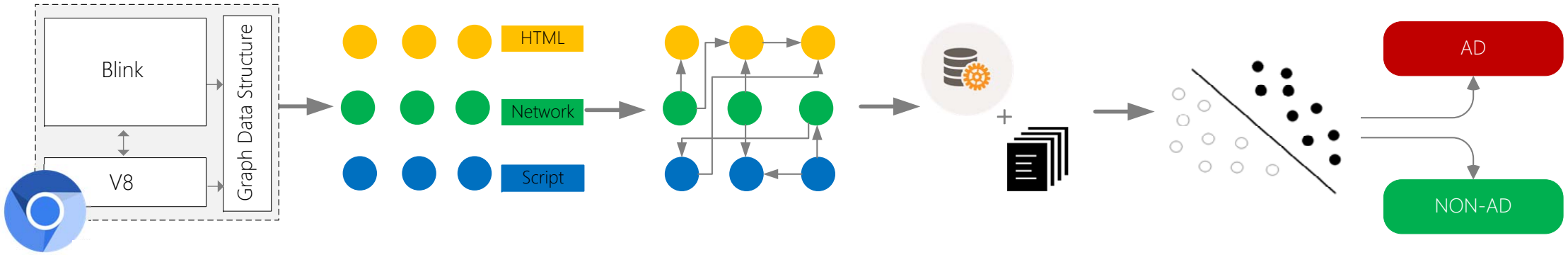
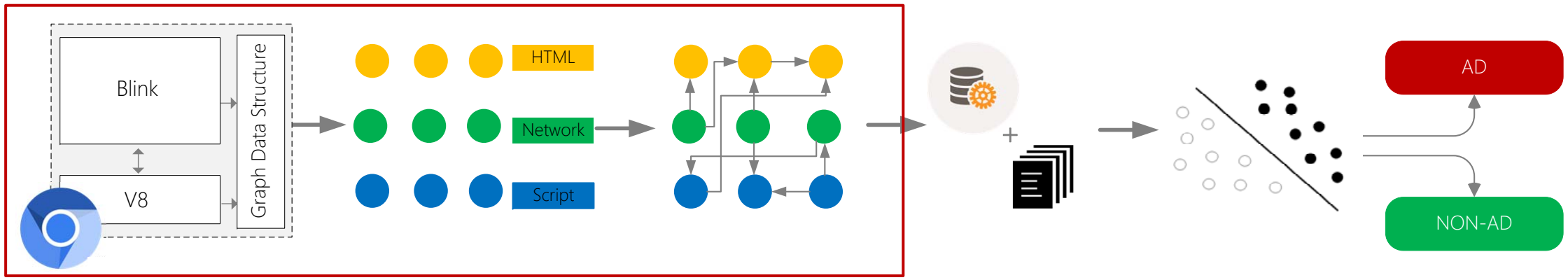


AdGraph

Graph-based cross-layer representation of ad/tracker behavior



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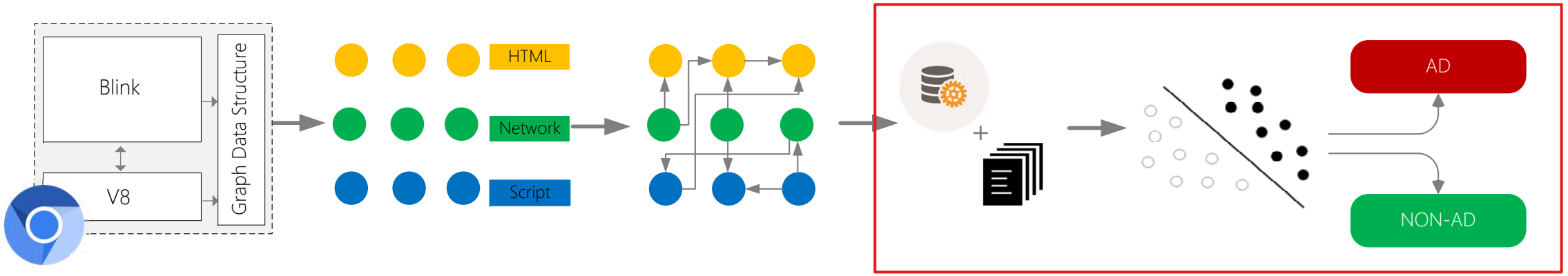
ML to automatically learn ad/tracker behavior



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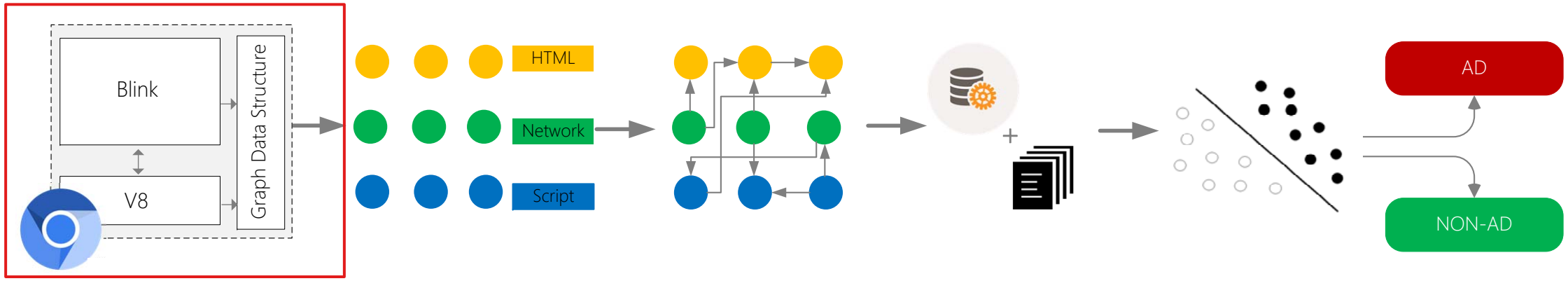

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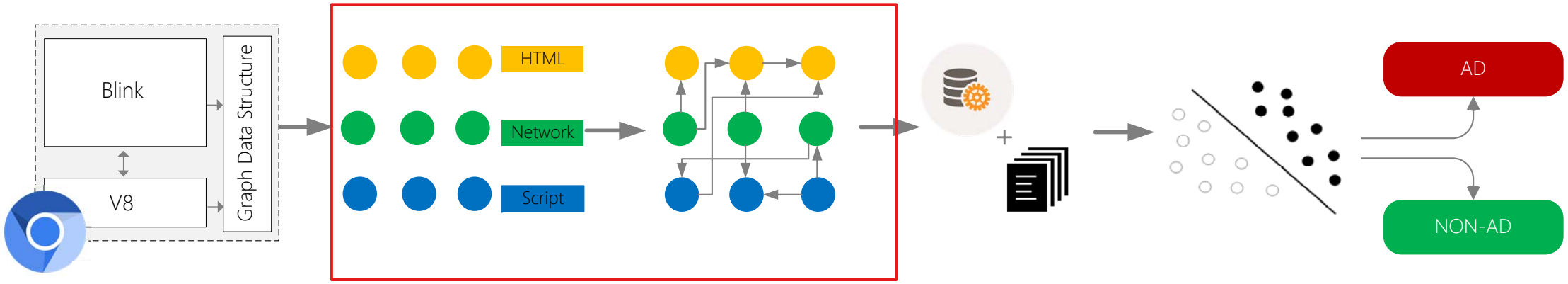

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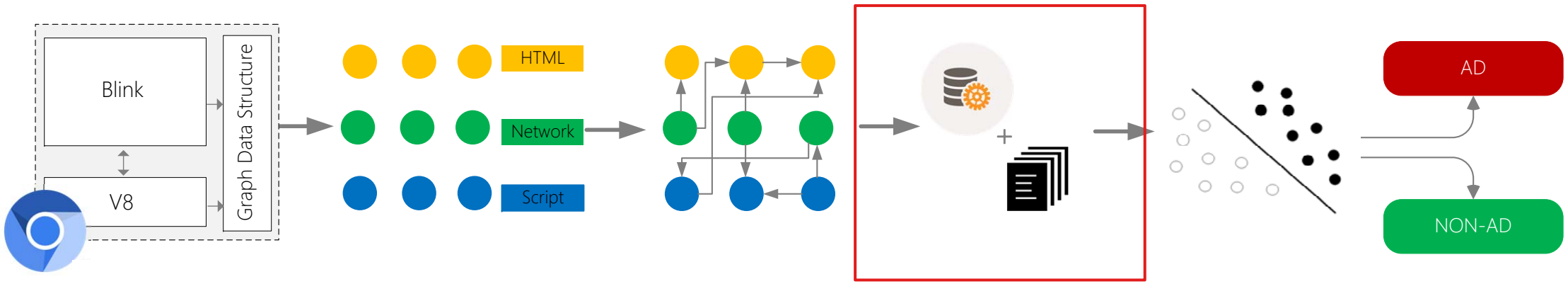

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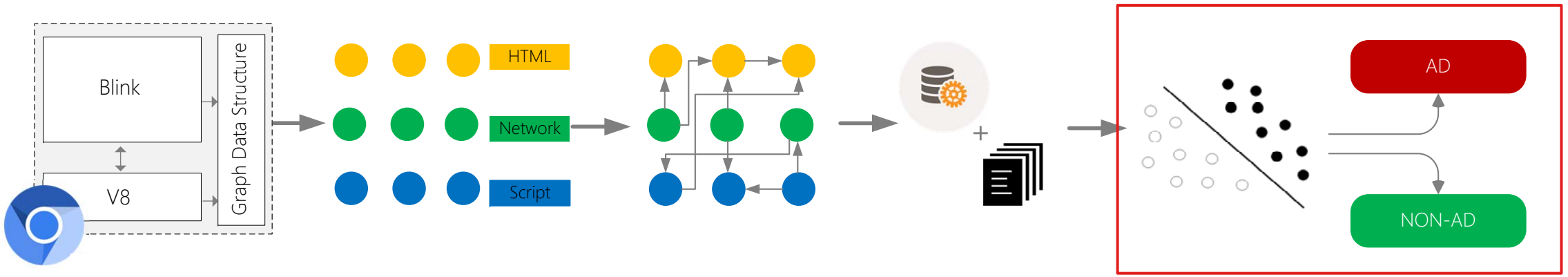

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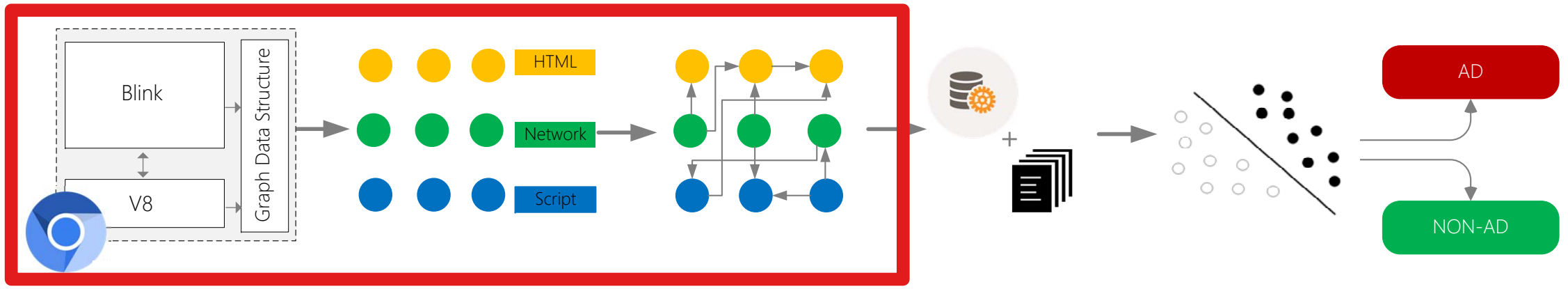

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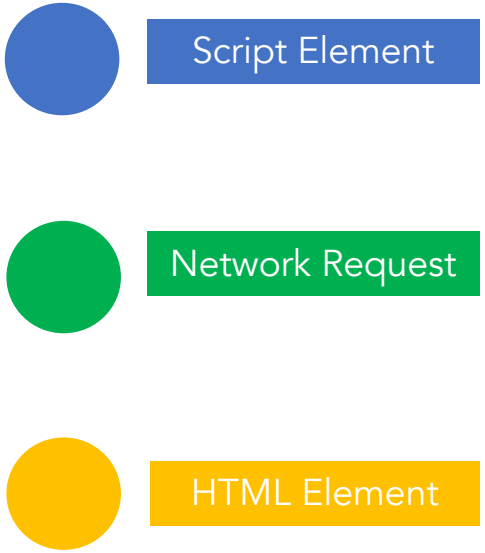

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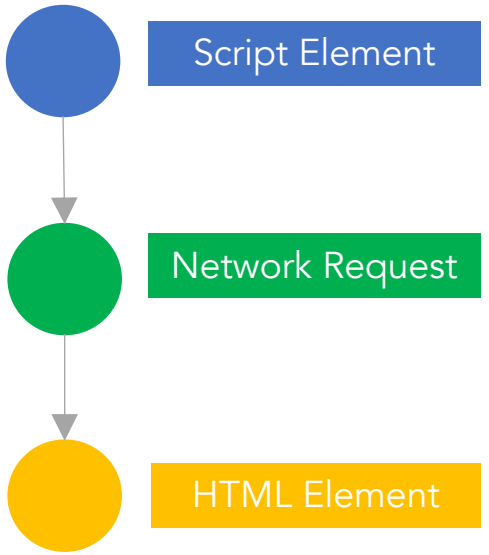

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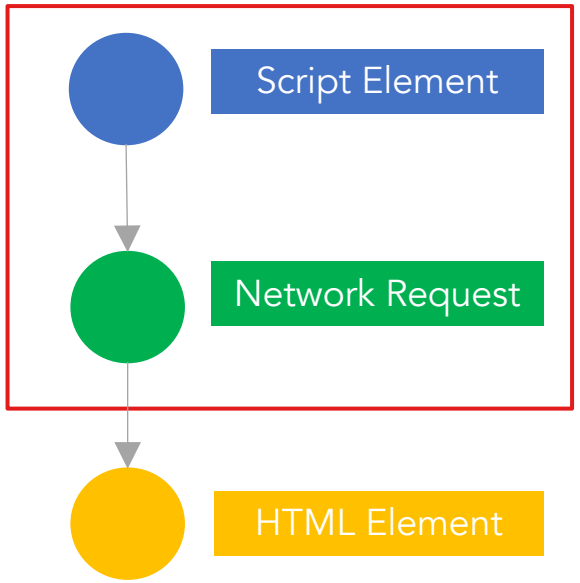

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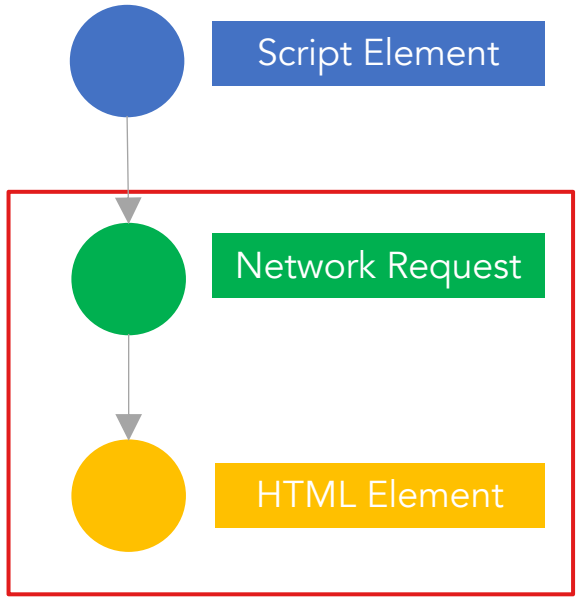

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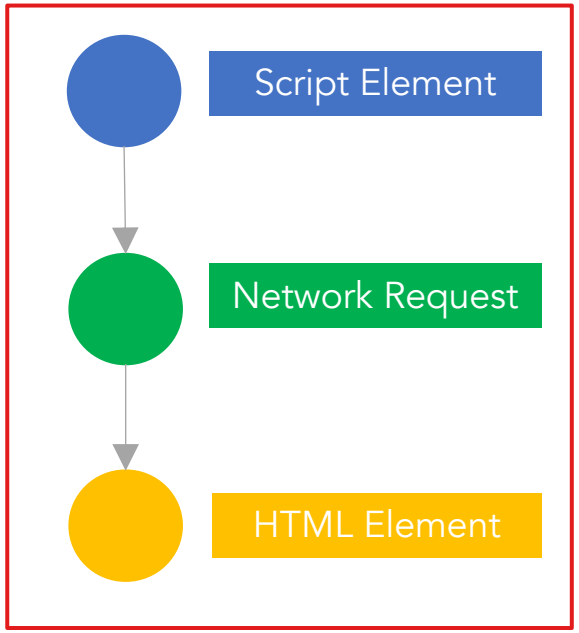

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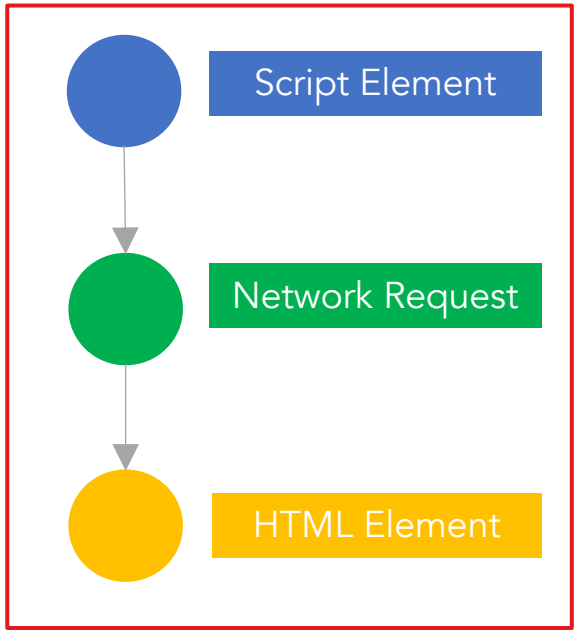

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Building cross-layer context

- Easy to link Network with HTML
- JavaScript activity attribution is tricky

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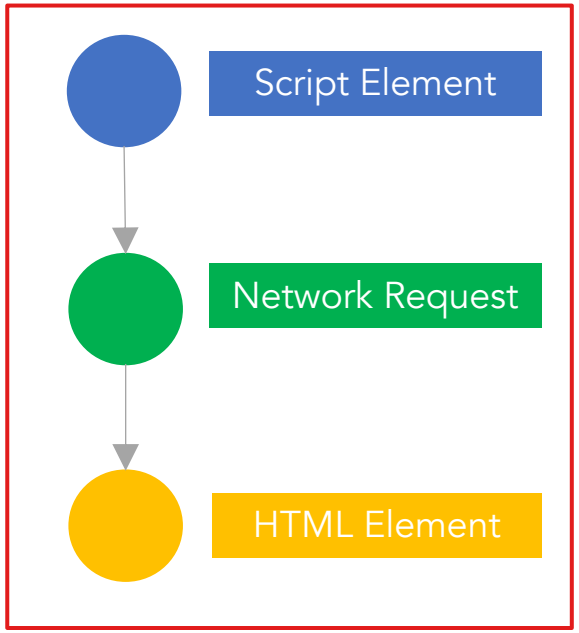

JavaScript Attribution

No API to attribute JavaScript to HTML and Network requests

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Stack Walking [Privacy Badger, OpenWPM]

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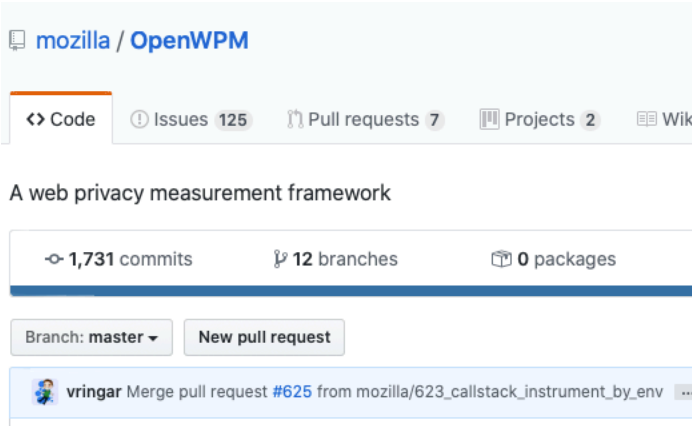

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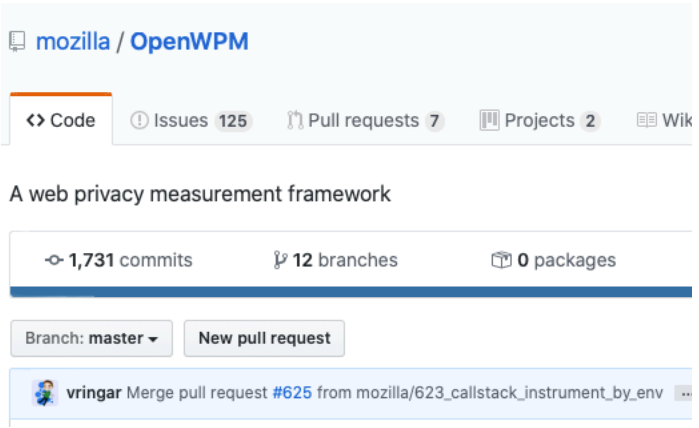
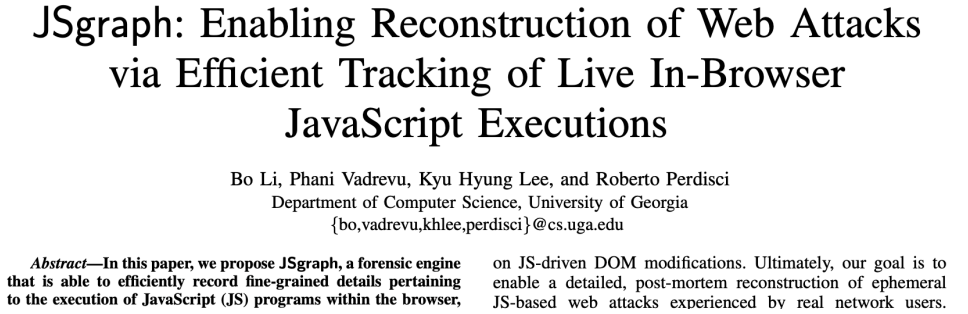


Browser Instrumentation [JSGraph '18]

- Capture events as scripts execute
- Detailed cross-layer interaction



JSgraph: Enabling Reconstruction of Web Attacks via Efficient Tracking of Live In-Browser JavaScript Executions

Bo Li, Phani Vadrevu, Kyu Hyung Lee, and Roberto Perdisci
Department of Computer Science, University of Georgia
{bo,vadrevu,khlee,perdisci}@cs.uga.edu

***Abstract*—In this paper, we propose JSgraph, a forensic engine that is able to efficiently record fine-grained details pertaining to the execution of JavaScript (JS) programs within the browser,** on JS-driven DOM modifications. Ultimately, our goal is to enable a detailed, post-mortem reconstruction of ephemeral JS-based web attacks experienced by real network users.

Chromium Instrumentation

Instrument rendering (Blink) and JavaScript (V8) engines

- Build cross-layer context as a graph
- HTML modifications, Network requests, JS attributions

Chromium Instrumentation

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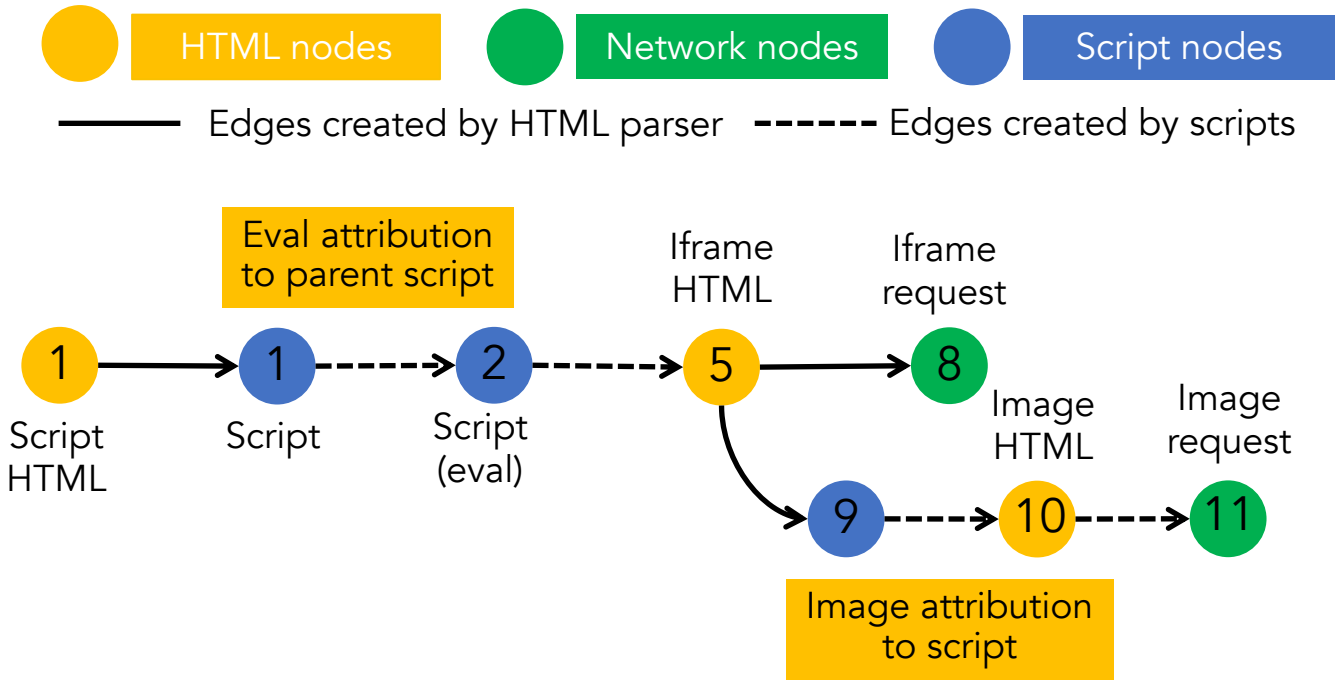
Build cross-layer context as a graph

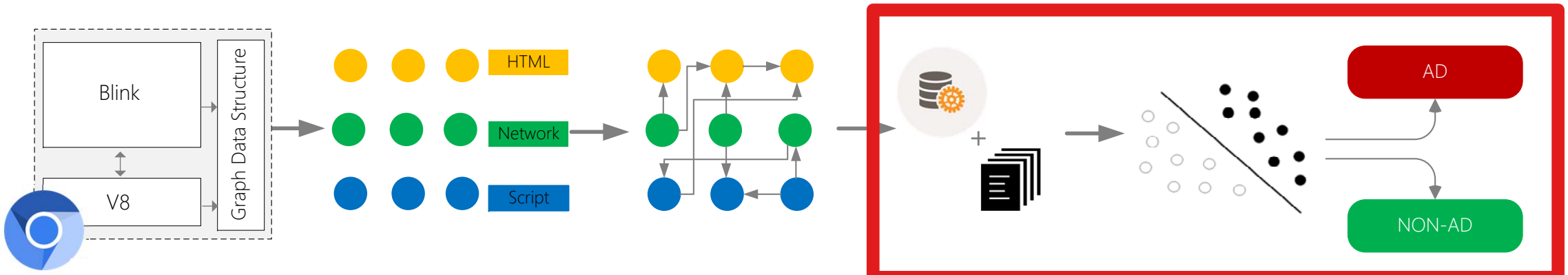
HTML modifications, Network requests, JS attributions

```
1   <script>
2       eval("
3         var iframe = document.createElement("iframe");
4         iframe.src = "adnetwork.com/load_ads";
5         document.body.append(iframe);
6       ");
7   </script>
8   <iframe src = "adnetwork.com/load_ads">
9       <script>
10        var img = document.createElement("img");
11        iframe.src = "adnetwork.com/load_ads";
12      </script>
13  </iframe>
```



AdGraph

ML to automatically learn ad/tracker behavior



Chromium instrumentation

Graph representation

Model training

Classification decision

Features Extraction

Extract two types of features

Structural & Content

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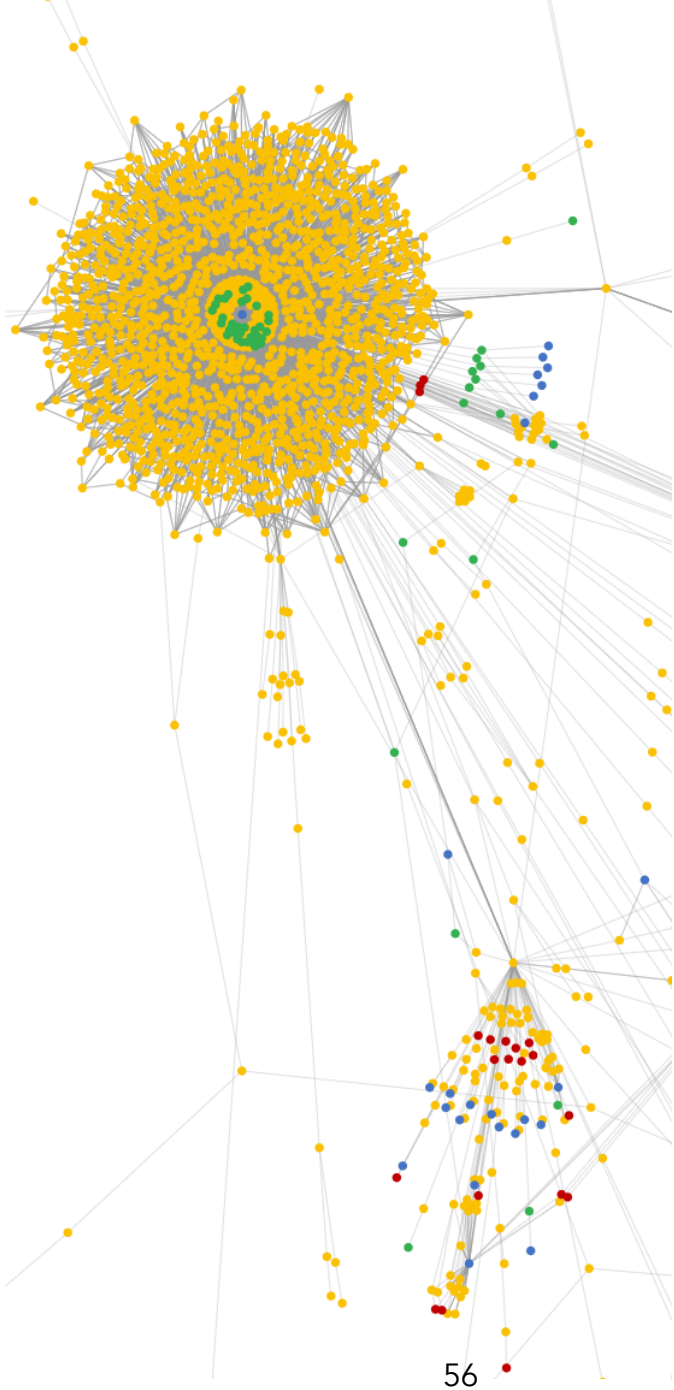
Structural & Content

Structural features capture graph properties



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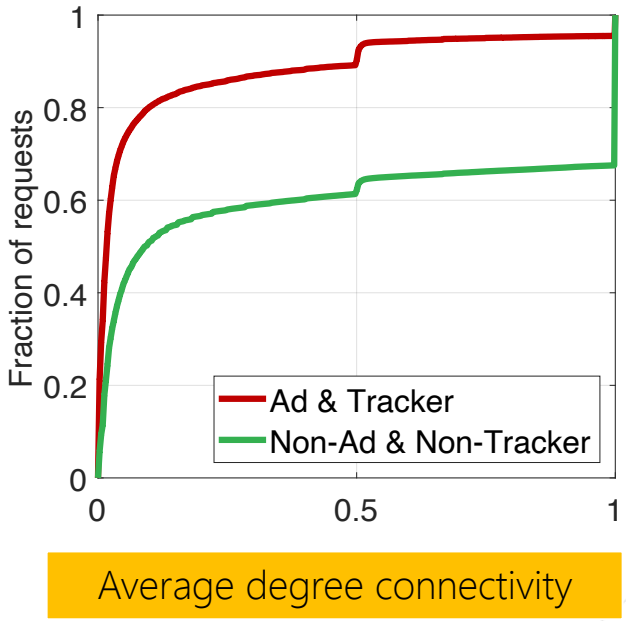

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```
https://events.bouncex.net/track.gif/bid_selected?partner=index&deployment=masthead&deal_id=106202001&price=3.50000&auction_number=1&ad_unit_id=26&source=ads&campaignid=917423&agent=user&mode=0&websiteid=340&visitid=1588398576368654&deviceid=2799665660403664656&pageviewid=1&sequenceid=17&clienttimestamp=1588398589360&clientapiversion=tag3&device=d
```

```
https://maxcdn.bootstrapcdn.com/bootstrap/3.3.7/css/bootstrap.min.css
```

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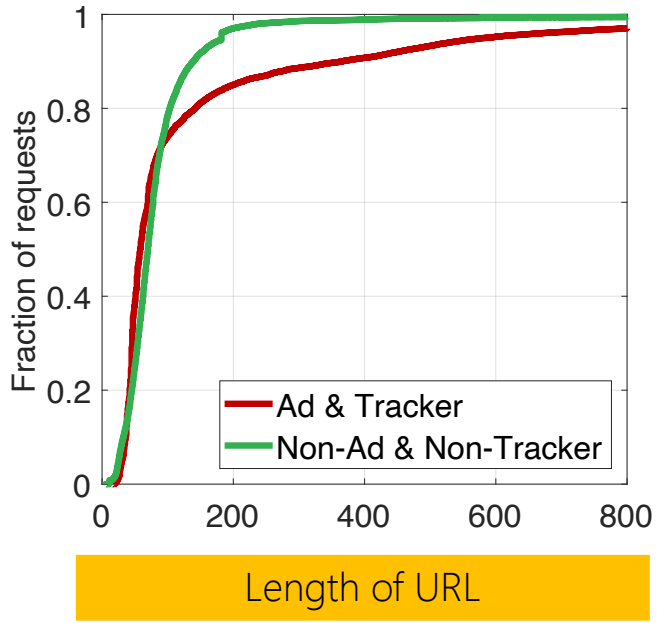
length of URL

```
https://events.bouncex.net/track.gif/bid_selected?partner=index&deployment=masthead&deal_id=106202001&price=3.50000&auction_number=1&ad_unit_id=26&source=ads&campaignid=917423&agent=user&mode=0&websiteid=340&visitid=1588398576368654&deviceid=2799665660403664656&pageviewid=1&sequenceid=17&clienttimestamp=1588398589360&clientapiversion=tag3&device=d
```

```
https://maxcdn.bootstrapcdn.com/bootstrap/3.3.7/css/bootstrap.min.css
```



Machine Learning

Ground truth

- Filter lists – despite shortcomings [Iqbal et al. ‘17, Snyder et al. ‘20]
- Manual evaluation of disagreements with classifier

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Random forest classifier

- 10-fold cross validation

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Accuracy is more than 95.33%

Recall 86.6% – Precision 89.1%

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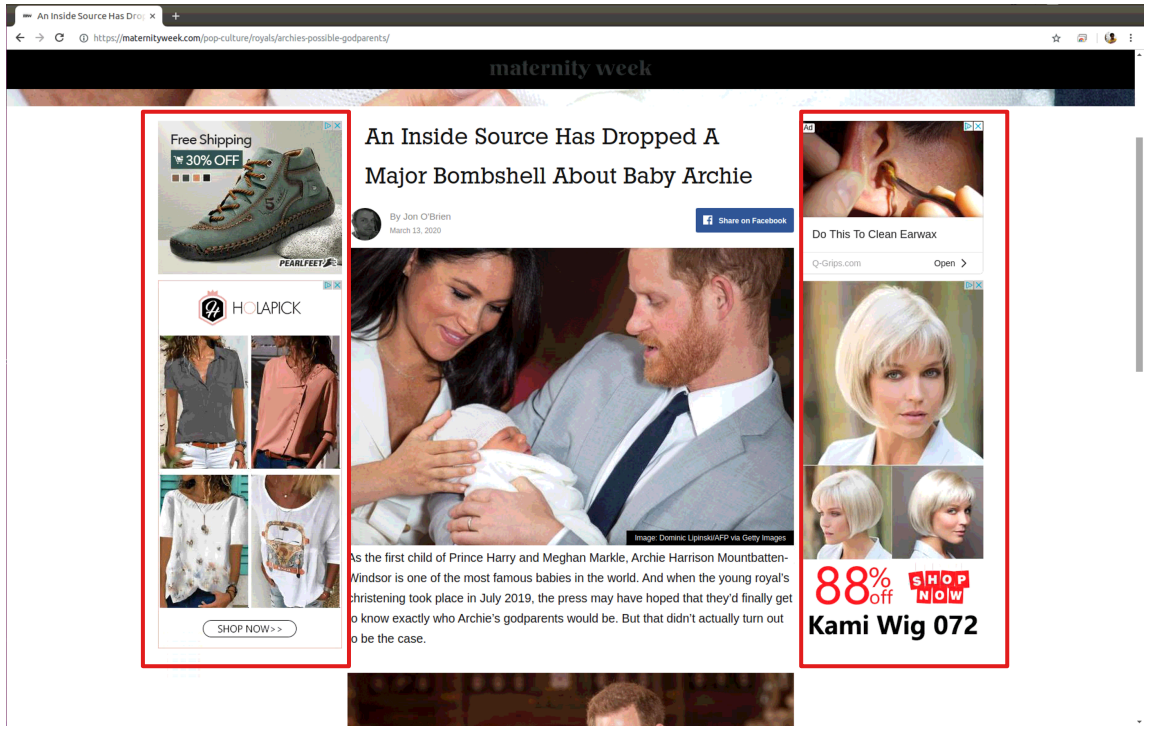
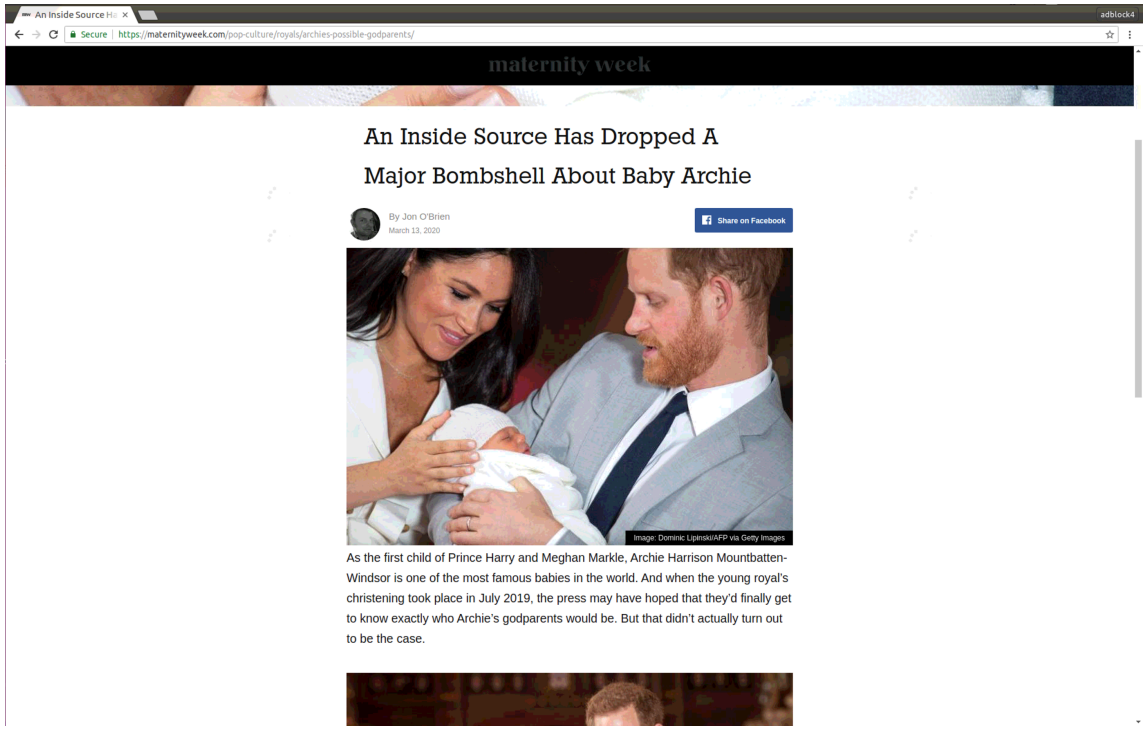


Stock Chromium



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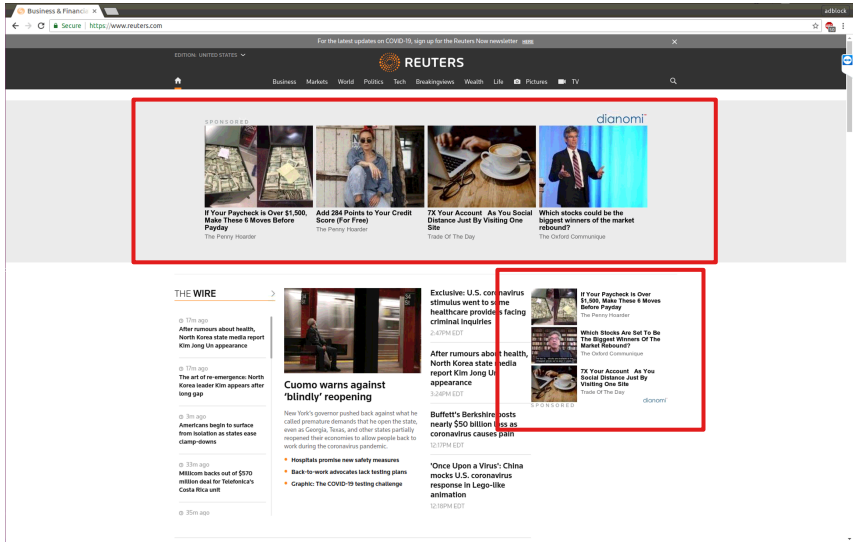
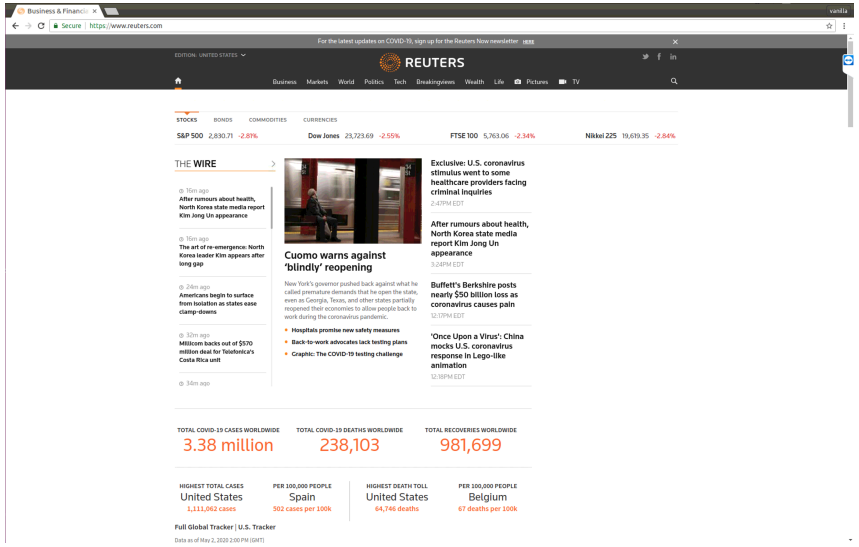


Filter Lists



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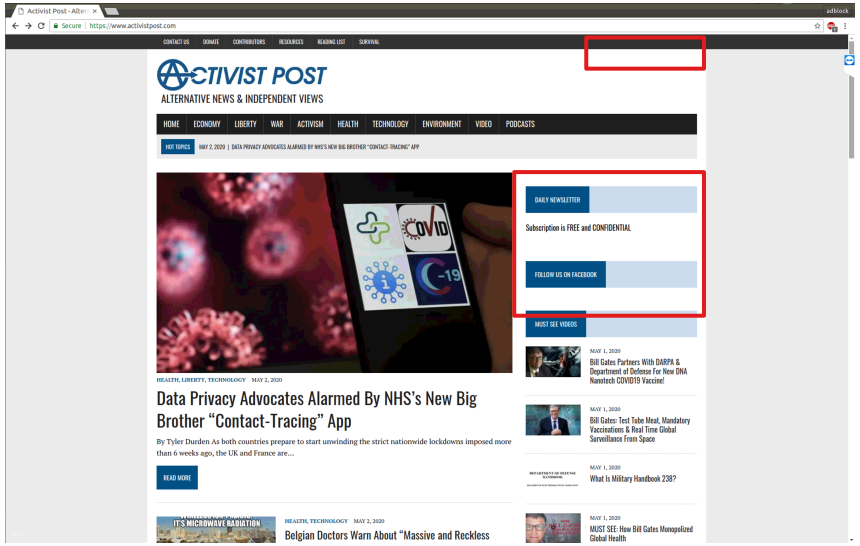

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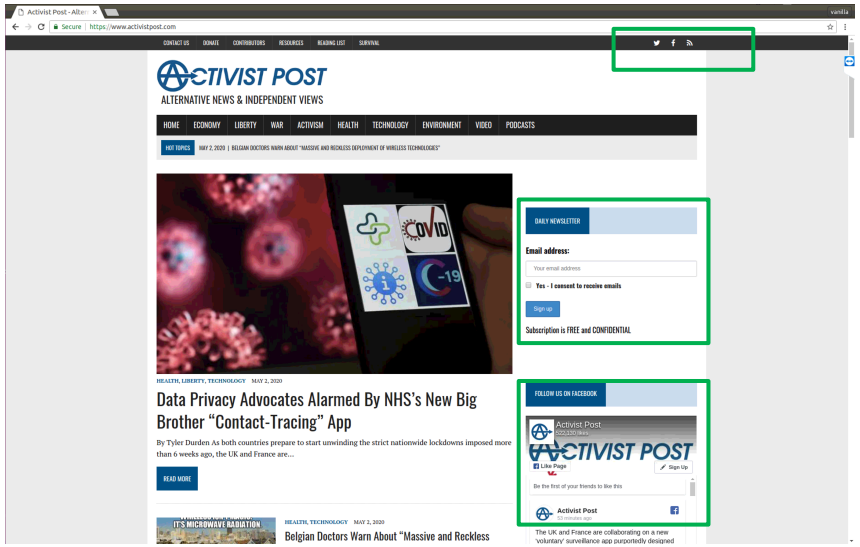

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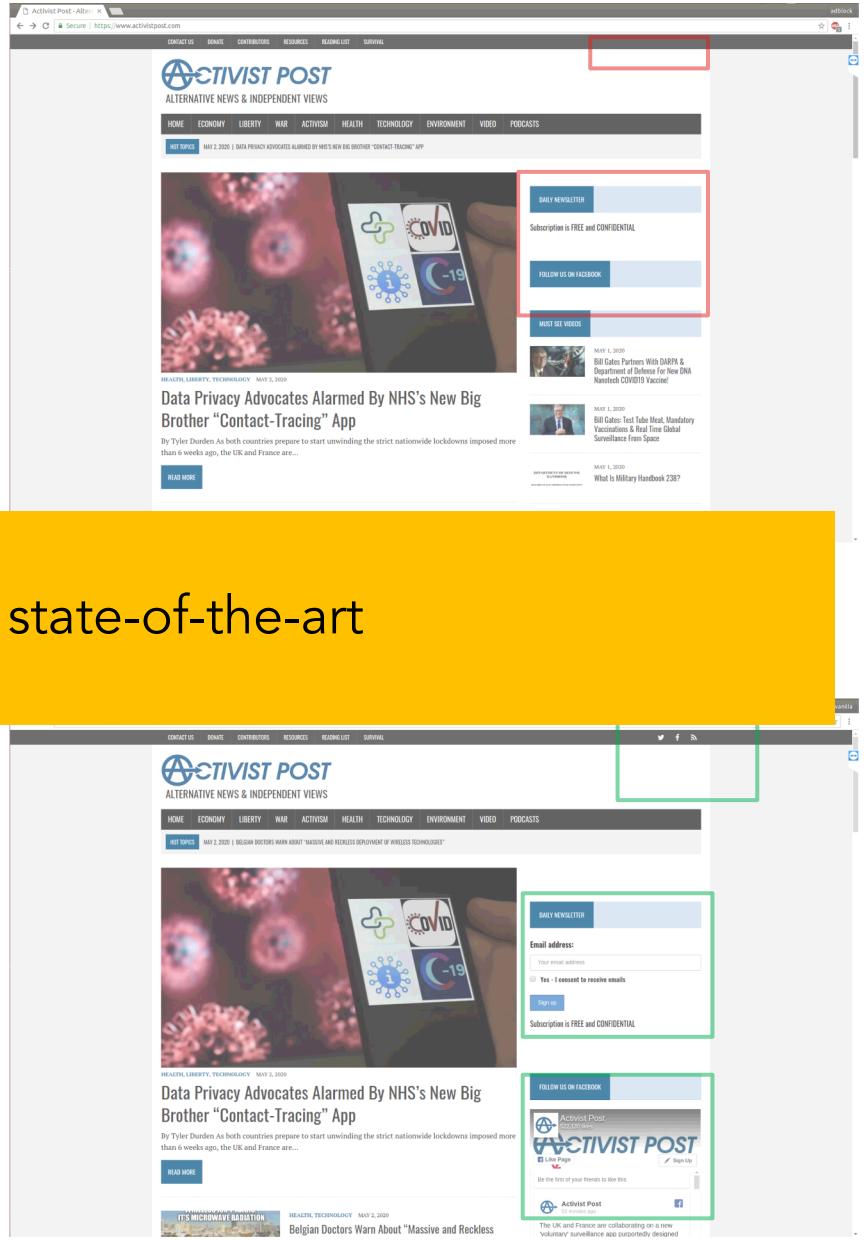

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Real time ad and tracker blocking with ML

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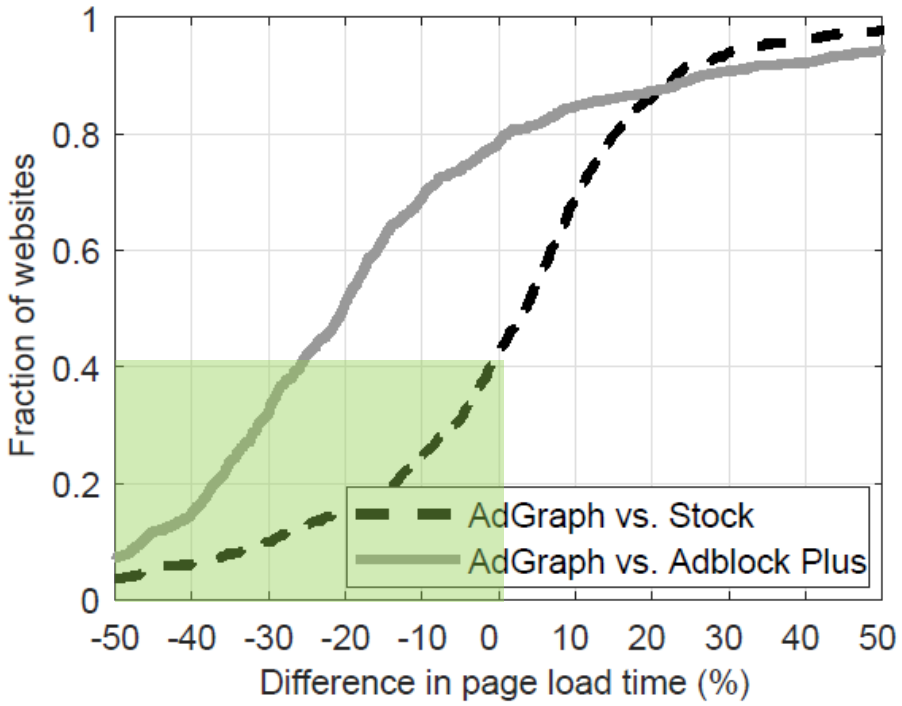

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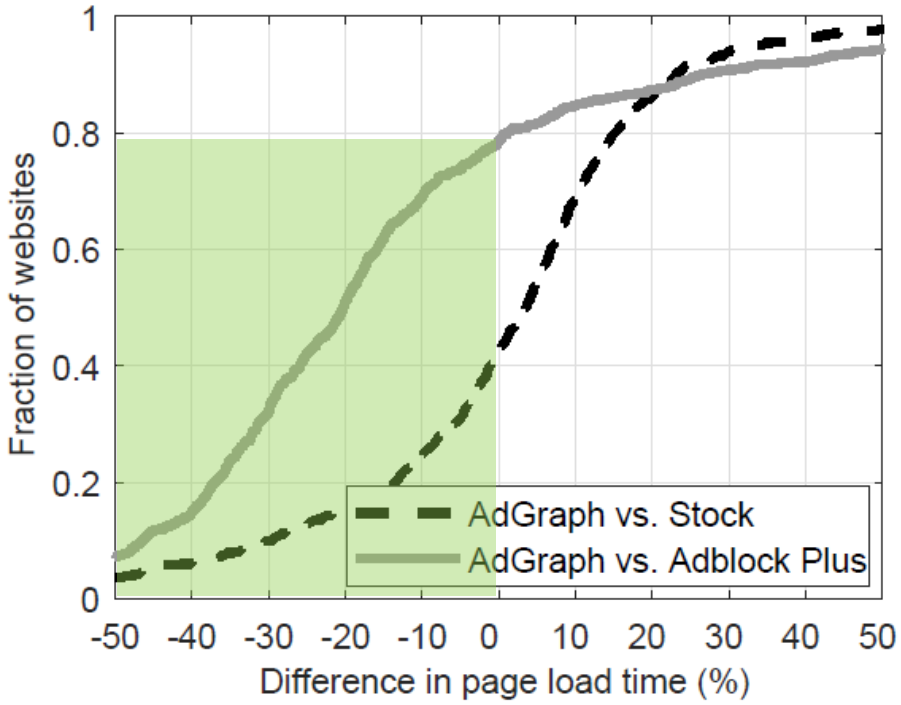

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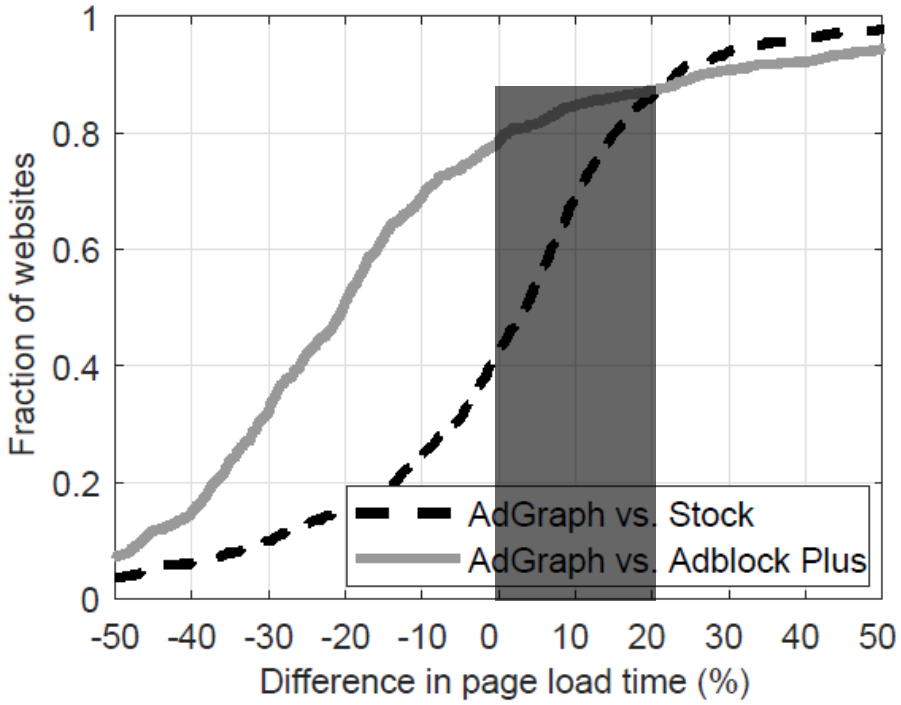

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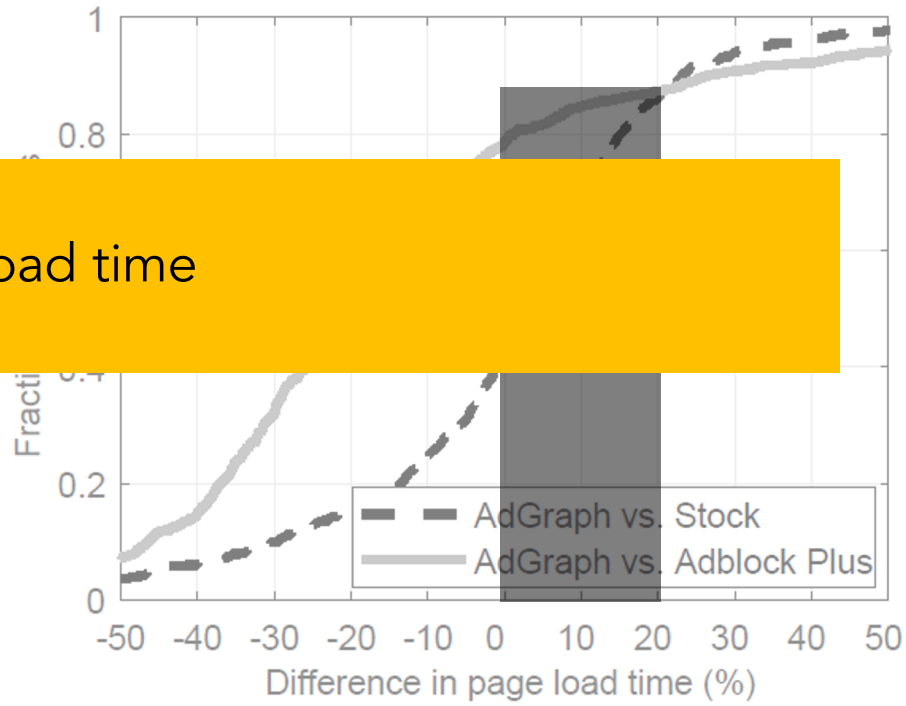
AdGraph improves page load time



Key Takeaways

Use cross-layer context to address **accuracy** issues

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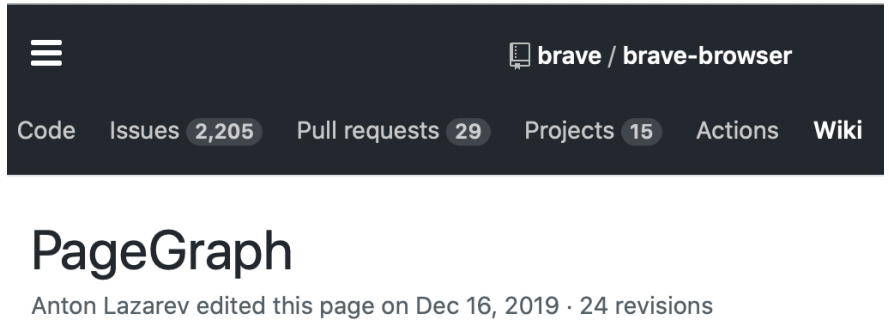

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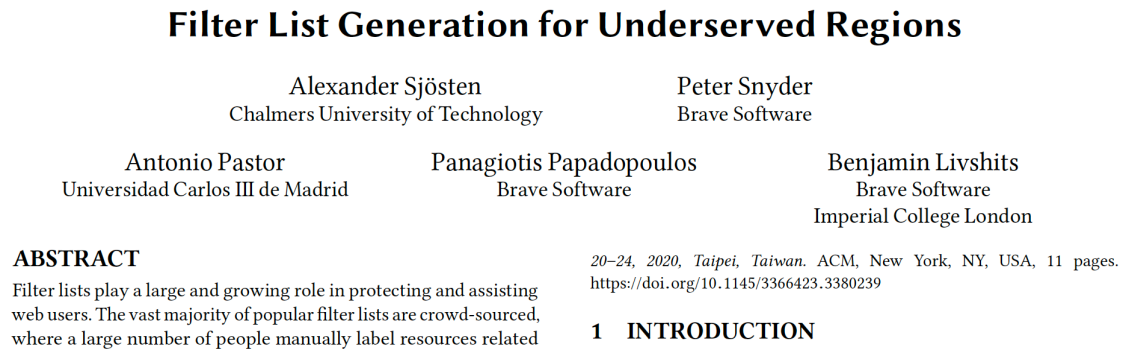
Filter list generation



Filter List Generation for Underserved Regions

Alexander Sjösten
Chalmers University of Technology

Peter Snyder
Brave Software

Antonio Pastor
Universidad Carlos III de Madrid

Panagiotis Papadopoulos
Brave Software

Benjamin Livshits
Brave Software
Imperial College London

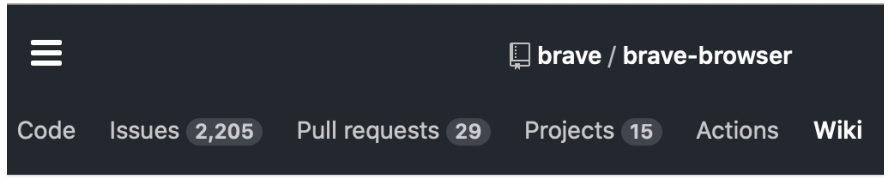
ABSTRACT

Filter lists play a large and growing role in protecting and assisting web users. The vast majority of popular filter lists are crowd-sourced, where a large number of people manually label resources related

20–24, 2020, Taipei, Taiwan. ACM, New York, NY, USA, 11 pages. https://doi.org/10.1145/3366423.3380239

1 INTRODUCTION

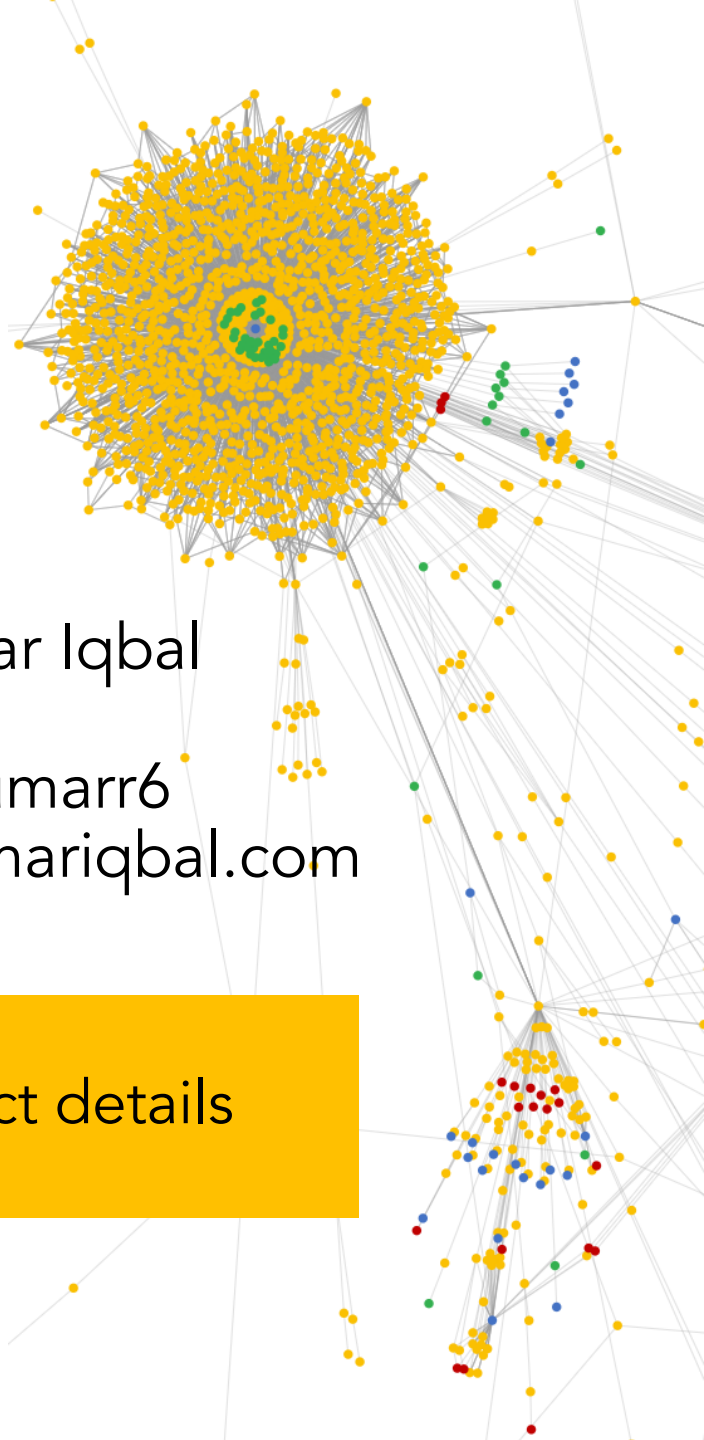
https://uiowa-irl.github.io/AdGraph/



PageGraph

Anton Lazarev edited this page on Dec 16, 2019 · 24 revisions

Questions?



Paper link:
https://www.umariqbal.com/papers/adgraph-sp2020.pdf

Source code:
https://uiowa-irl.github.io/AdGraph/

Contact details

Umar Iqbal

@umarr6
www.umariqbal.com

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13. Li, Bo, et al. "JSgraph: Enabling Reconstruction of Web Attacks via Efficient Tracking of Live In-Browser JavaScript Executions." NDSS. 2018.
14. Icon made by Pixel perfect from www.flaticon.com