How Tracking Companies Circumvented Ad Blockers Using WebSockets

Muhammad Ahmad Bashir, Sajjad Arshad, Engin Kirda,
William Robertson, Christo Wilson

Northeastern University

Online Tracking

Online Tracking

- Boom in online advertising.
  - Ad networks pour in billions of dollars.
- Value for their investment?

Online Tracking

- Boom in online advertising.
  - Ad networks pour in billions of dollars.
- Value for their investment?
  - Extensive tracking to serve targeted ads.

Online Tracking

- Boom in online advertising.
  - Ad networks pour in billions of dollars.
- Value for their investment?
  - Extensive tracking to serve targeted ads.
- User concern over tracking
  - This has led to the proliferation of ad blockers

Online Tracking

- Boom in online advertising.
  - Ad networks pour in billions of dollars.
- Value for their investment?
  - Extensive tracking to serve targeted ads.
- User concern over tracking
  - This has led to the proliferation of ad blockers
- Ad networks fight back
  - E.g Using anti-ad blocking scripts

Google & Safari

- Google evaded Safari's third-party cookie blocking policy (Jonathan Mayer)
- … by submitting a form in an invisible iFrame
- Google was fined $22.5M by FTC

This Talk

How **Ad Networks** leveraged a bug in Chrome API to **bypass Ad Blockers** using **WebSockets**

This Talk

How **Ad Networks** leveraged a bug in Chrome API to **bypass Ad Blockers** using **WebSockets**

- What caused this?
- How this bug was leveraged by ad networks?

Web Sockets

Web Sockets

HTTP/S

Web Sockets

HTTP/S

Web Sockets

HTTP/S

Web Sockets

HTTP/S

Web Sockets

HTTP/S

Web Sockets

HTTP/S

Web Socket

Web Sockets

HTTP/S

Web Socket

- Both client and server can send/receive data
- This is a persistent connection

Ad Blockers

Ad Blockers

- Chrome extension **chrome.webRequest** API
  - Extension can inspect / modify / drop outgoing requests

Ad Blockers

- Chrome extension **chrome.webRequest** API
  - Extension can inspect / modify / drop outgoing requests

webRequest API

Ad Blockers

- Chrome extension **chrome.webRequest** API
  - Extension can inspect / modify / drop outgoing requests

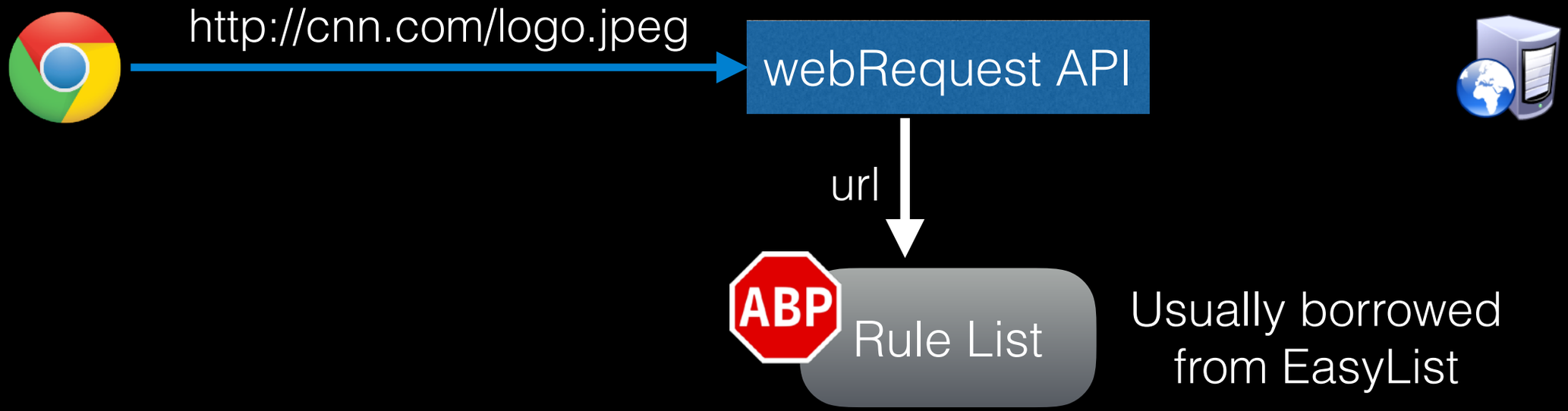
Ad Blockers

- Chrome extension **chrome.webRequest** API
  - Extension can inspect / modify / drop outgoing requests

Usually borrowed from EasyList

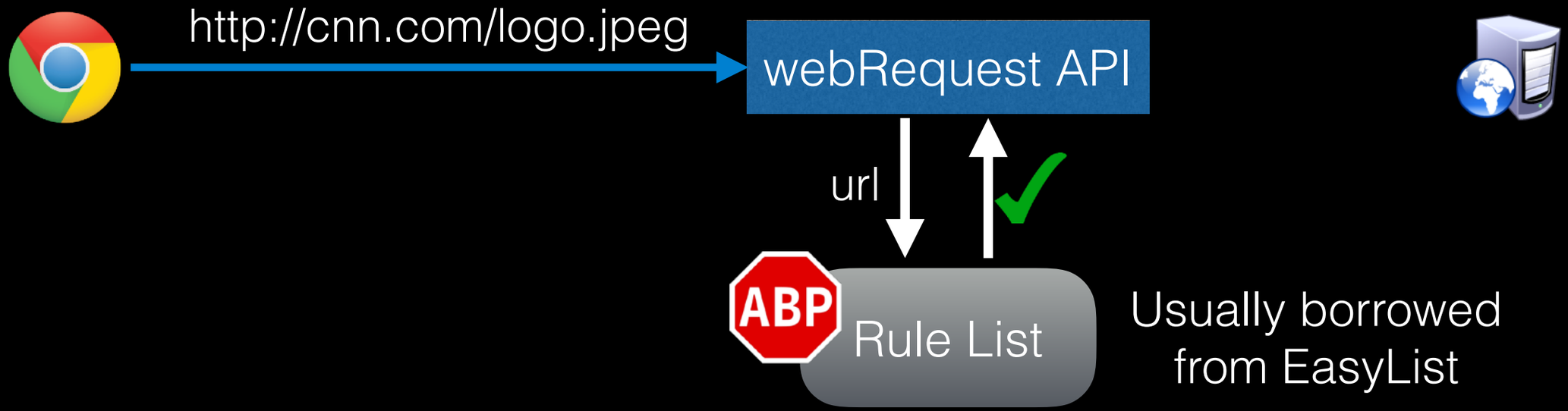
Ad Blockers

- Chrome extension **chrome.webRequest** API
  - Extension can inspect / modify / drop outgoing requests



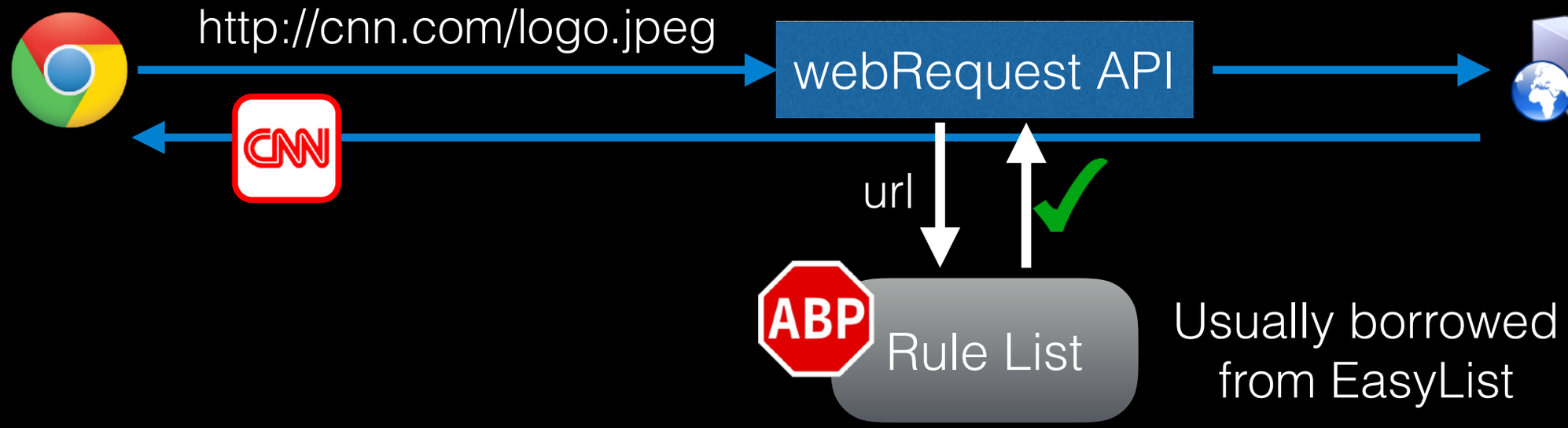
Ad Blockers

- Chrome extension **chrome.webRequest** API
  - Extension can inspect / modify / drop outgoing requests



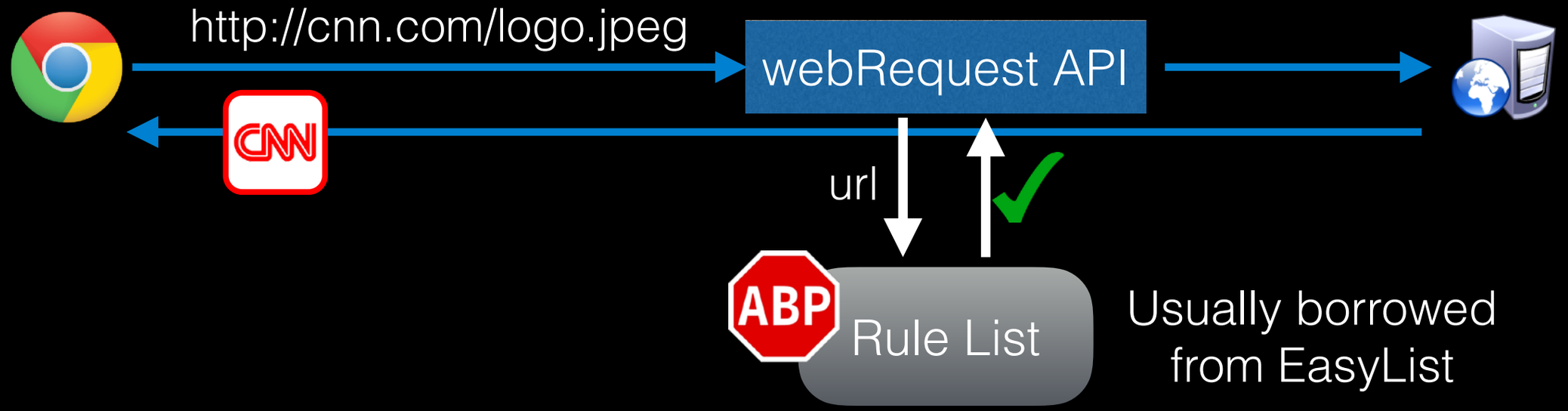
Ad Blockers

- Chrome extension **chrome.webRequest** API
  - Extension can inspect / modify / drop outgoing requests



Ad Blockers

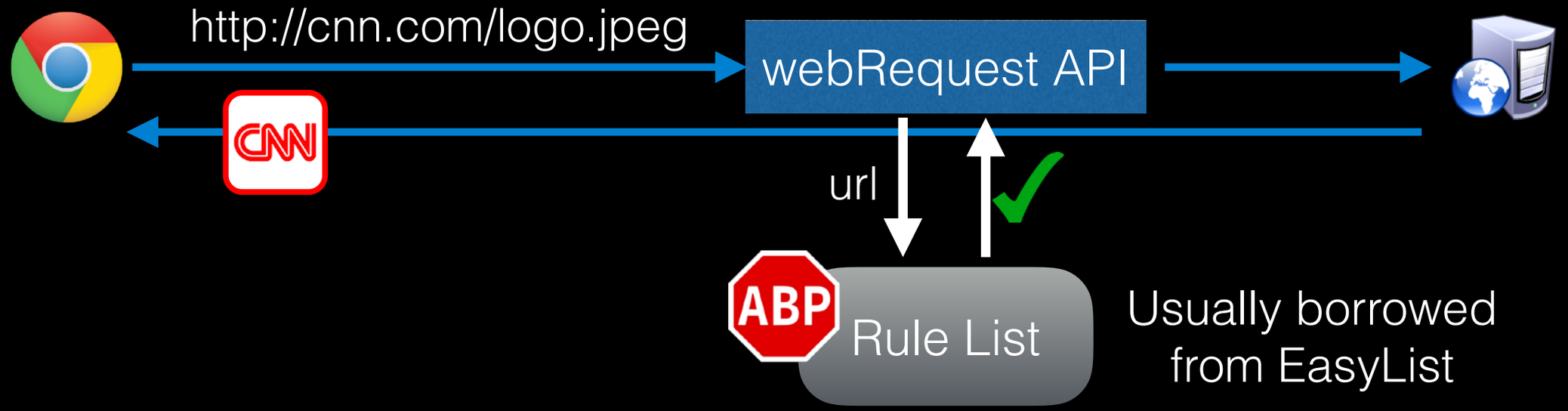
- Chrome extension **chrome.webRequest** API
  - Extension can inspect / modify / drop outgoing requests



webRequest API

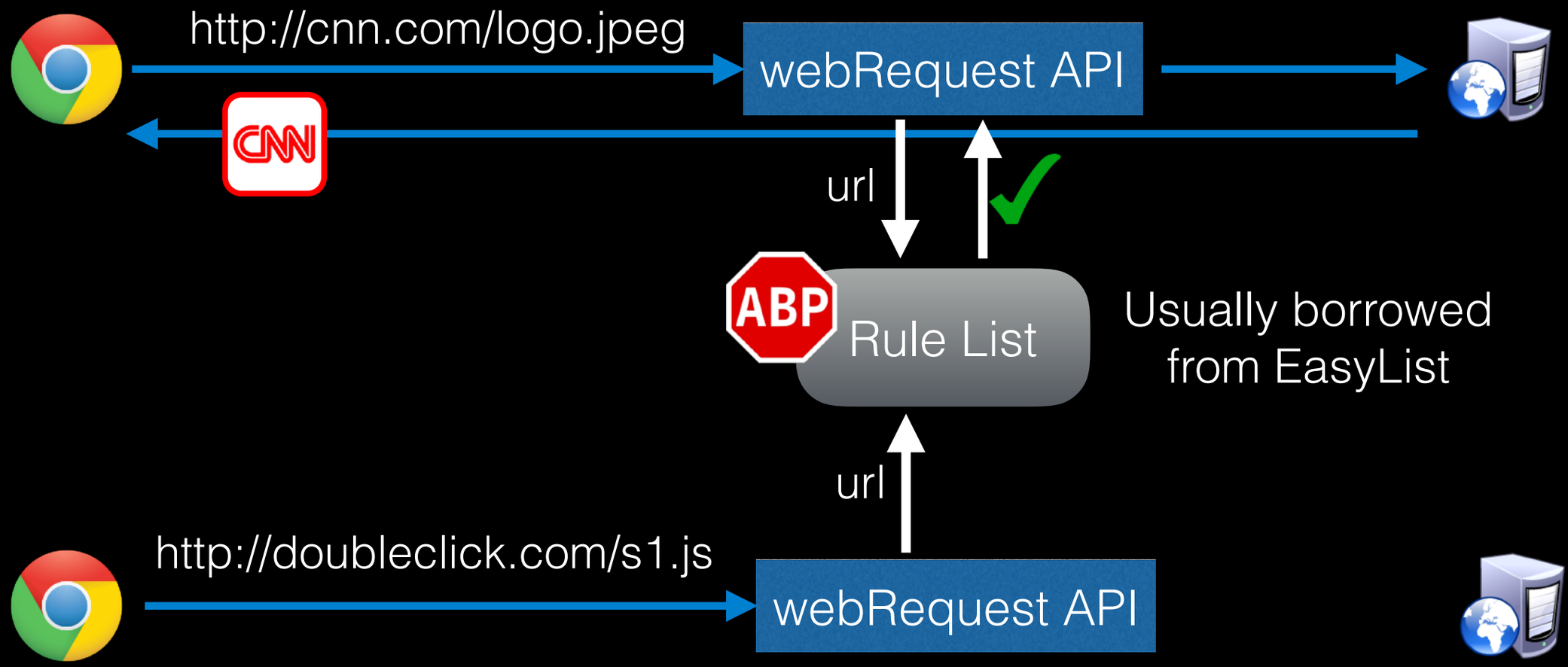
Ad Blockers

- Chrome extension **chrome.webRequest** API
  - Extension can inspect / modify / drop outgoing requests



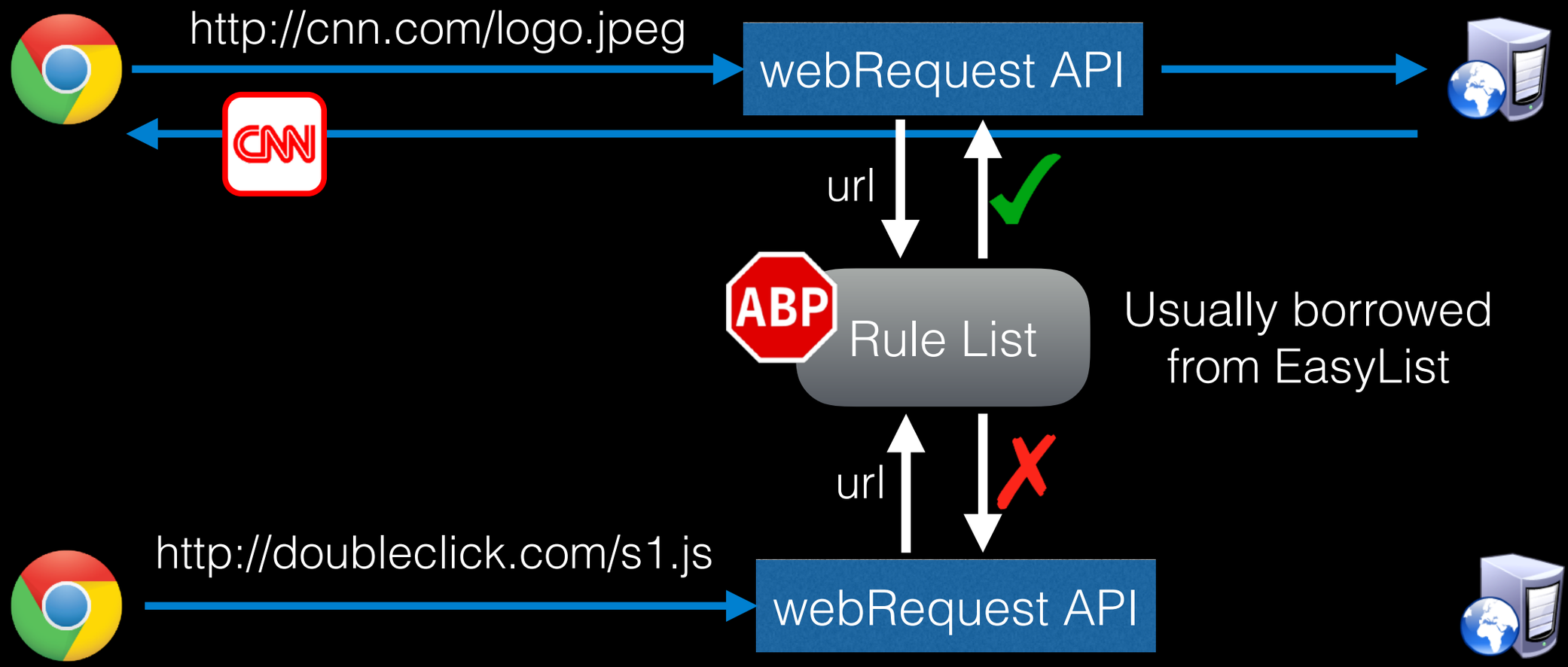
Ad Blockers

- Chrome extension **chrome.webRequest** API
  - Extension can inspect / modify / drop outgoing requests



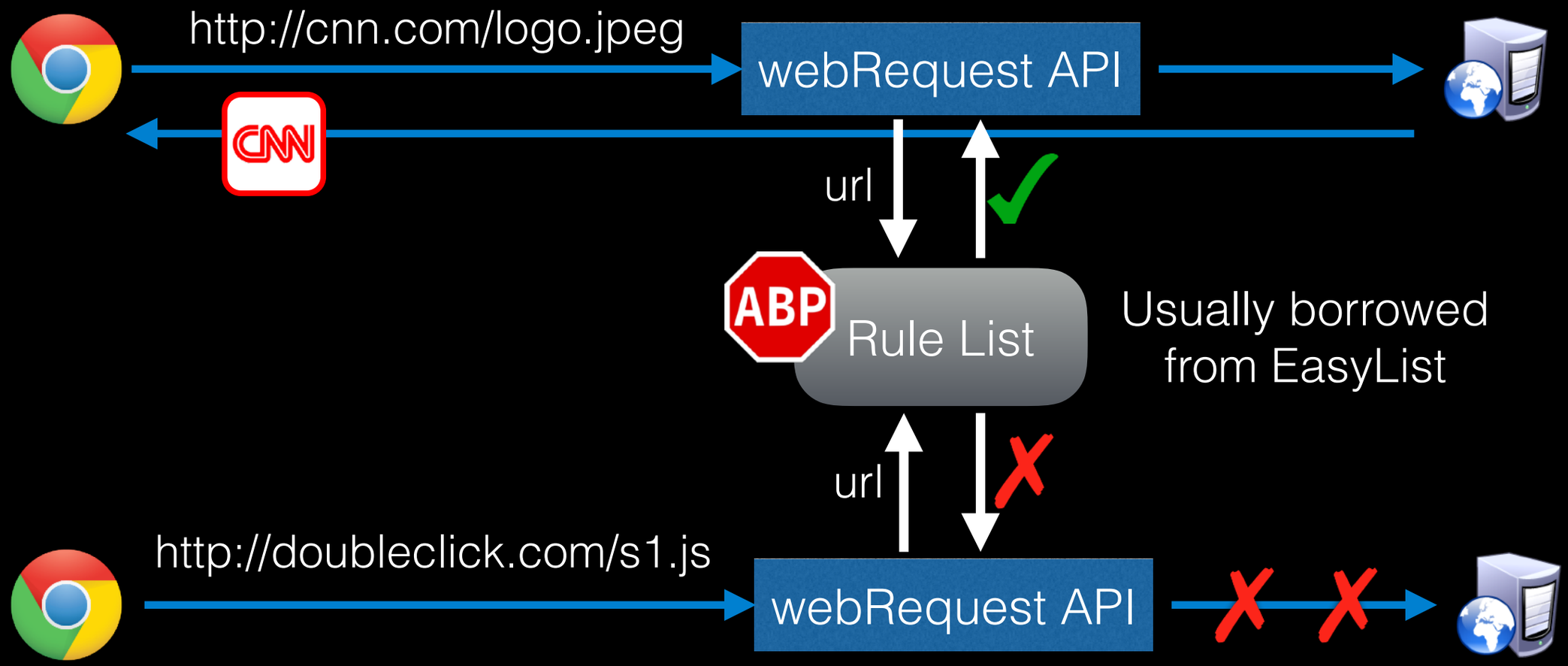
Ad Blockers

- Chrome extension **chrome.webRequest** API
  - Extension can inspect / modify / drop outgoing requests



Ad Blockers

- Chrome extension **chrome.webRequest** API
  - Extension can inspect / modify / drop outgoing requests



AdBlock Evasion

AdBlock Evasion

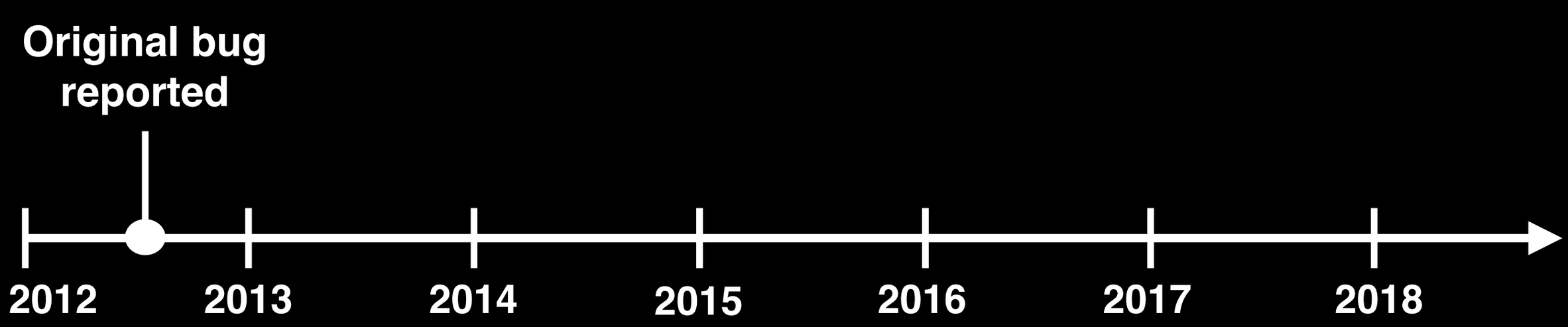
- Due to a bug in **chrome.webRequest** API
  - All ws/wss requests bypassed this extension

AdBlock Evasion

- Due to a bug in **chrome.webRequest** API
  - All ws/wss requests bypassed this extension

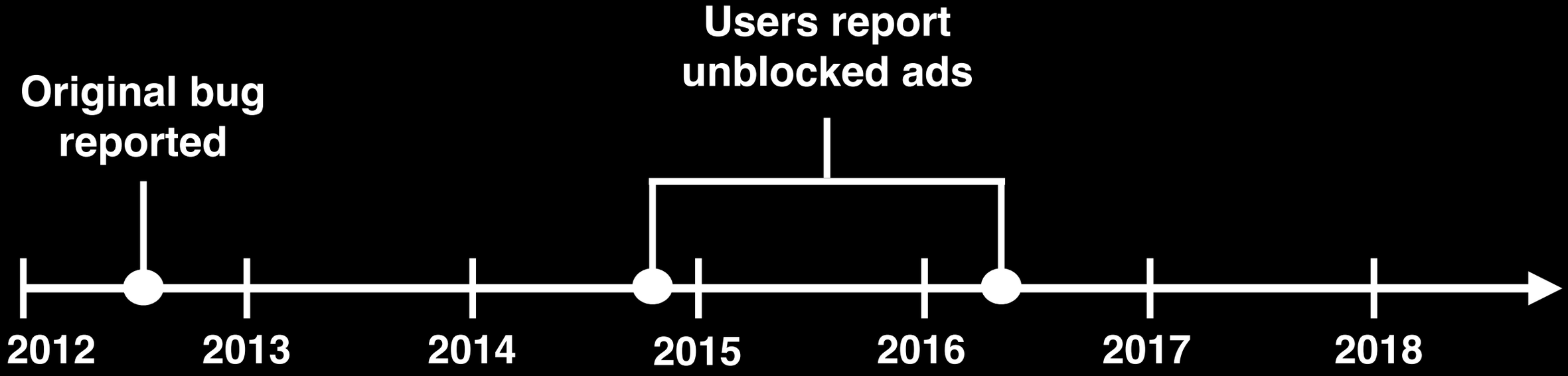
AdBlock Evasion

- Due to a bug in **chrome.webRequest** API
  - All ws/wss requests bypassed this extension



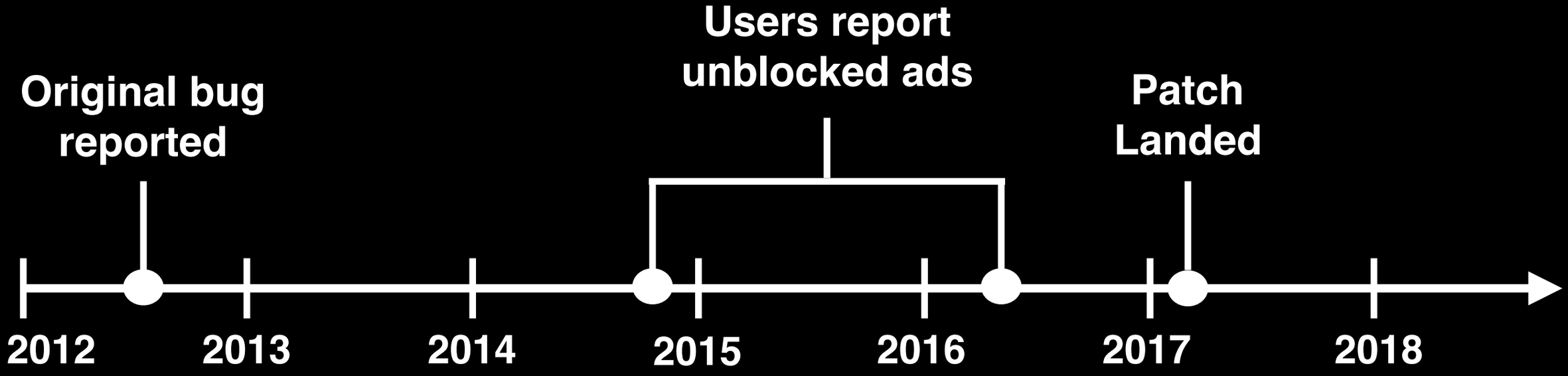
AdBlock Evasion

- Due to a bug in **chrome.webRequest** API
  - All ws/wss requests bypassed this extension



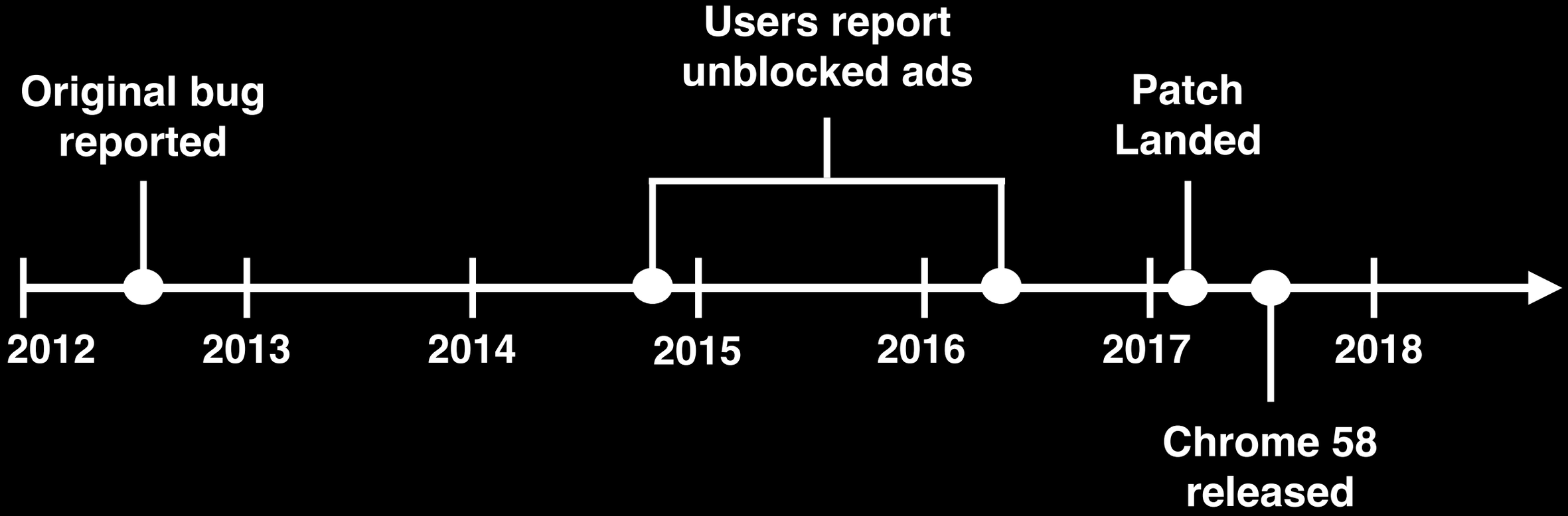
AdBlock Evasion

- Due to a bug in **chrome.webRequest** API
  - All ws/wss requests bypassed this extension



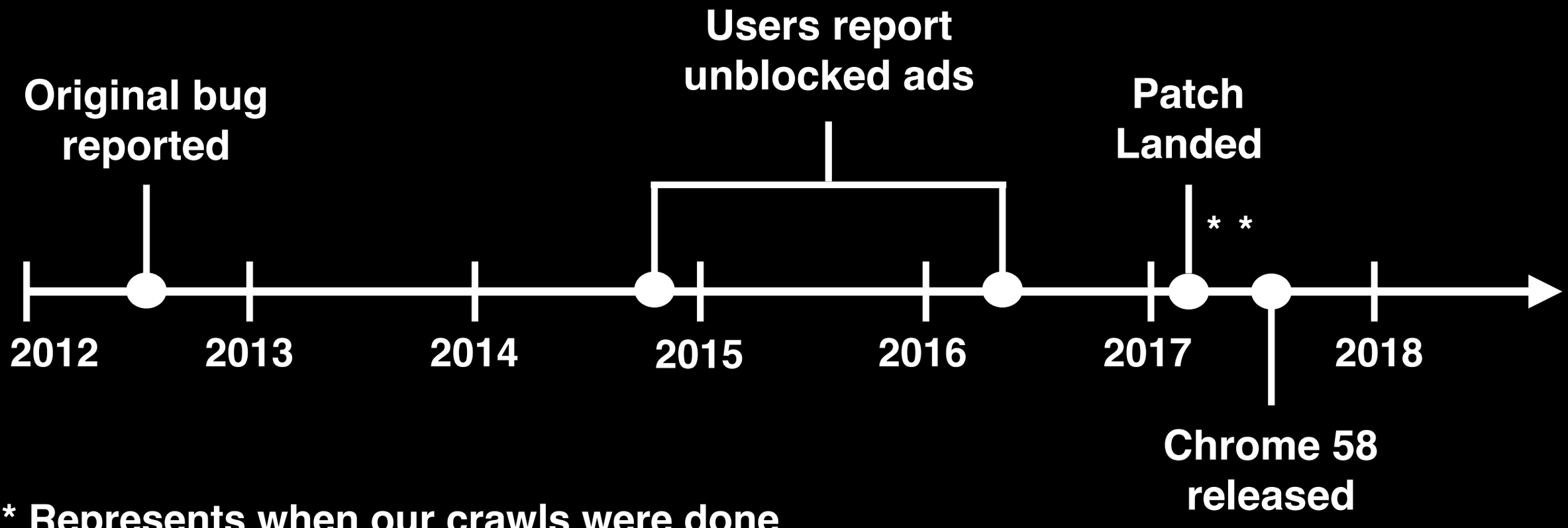
AdBlock Evasion

- Due to a bug in **chrome.webRequest** API
  - All ws/wss requests bypassed this extension



AdBlock Evasion

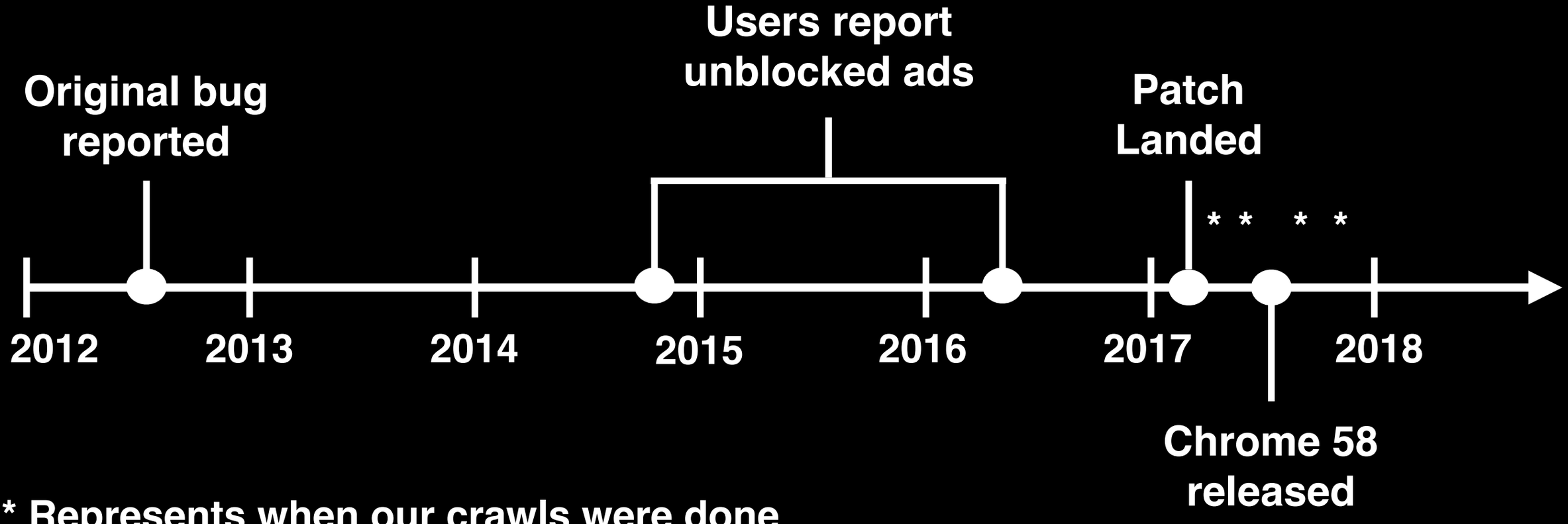
- Due to a bug in **chrome.webRequest** API
  - All ws/wss requests bypassed this extension



*** Represents when our crawls were done**

AdBlock Evasion

- Due to a bug in **chrome.webRequest** API
  - All ws/wss requests bypassed this extension



*** Represents when our crawls were done**

Data Crawling

Data Crawling

100K websites
sampled from Alexa

Data Crawling

Data Crawling

This means we know which resource included which other resource

Data Crawling

This means we know which resource included which other resource

100K websites sampled from Alexa

Visit 15 links / website

Collected chains for all inclusion resources

Filter WebSockets

Filter all resources which end in web sockets

Data Crawling

This means we know which resource included which other resource

100K websites sampled from Alexa

Visit 15 links / website

Collected chains for all inclusion resources

Filter WebSockets

Filter all resources which end in web sockets

Detect A&A WebSockets

Mark web sockets which are used by A&A domains

Companies involved in Advertising and Analytics are collectively referred as **A&A**

High-Level Numbers

High-Level Numbers

	Crawl Dates	%Websites with sockets	% Sockets with A&A Initiators	% Sockets with A&A Receivers	#Unique A&A Initiators	#Unique A&A Receivers
Before Chrome 58	Apr 02-05, 2017	2.1	60.2	72.0	72	14
	Apr 11-16, 2017	2.4	61.0	73.0	61	16

High-Level Numbers

	Crawl Dates	%Websites with sockets	% Sockets with A&A Initiators	% Sockets with A&A Receivers	#Unique A&A Initiators	#Unique A&A Receivers
Before Chrome 58	Apr 02-05, 2017	2.1	60.2	72.0	72	14
	Apr 11-16, 2017	2.4	61.0	73.0	61	16
After Chrome 58	May 07-12, 2017	1.6	60.2	68.3	17	13
	Oct 12-16, 2017	2.5	54.9	55.1	19	14

High-Level Numbers

	Crawl Dates	%Websites with sockets	% Sockets with A&A Initiators	% Sockets with A&A Receivers	#Unique A&A Initiators	#Unique A&A Receivers
Before Chrome 58	Apr 02-05, 2017	2.1	60.2	72.0	72	14
	Apr 11-16, 2017	2.4	61.0	73.0	61	16
After Chrome 58	May 07-12, 2017	1.6	60.2	68.3	17	13
	Oct 12-16, 2017	2.5	54.9	55.1	19	14

- ~2% websites use web sockets.

High-Level Numbers

	Crawl Dates	%Websites with sockets	% Sockets with A&A Initiators	% Sockets with A&A Receivers	#Unique A&A Initiators	#Unique A&A Receivers
Before Chrome 58	Apr 02-05, 2017	2.1	60.2	72.0	72	14
	Apr 11-16, 2017	2.4	61.0	73.0	61	16
After Chrome 58	May 07-12, 2017	1.6	60.2	68.3	17	13
	Oct 12-16, 2017	2.5	54.9	55.1	19	14

- ~2% websites use web sockets.
- 55-61 % sockets are initiated by A&A domains

High-Level Numbers

	Crawl Dates	%Websites with sockets	% Sockets with A&A Initiators	% Sockets with A&A Receivers	#Unique A&A Initiators	#Unique A&A Receivers
Before Chrome 58	Apr 02-05, 2017	2.1	60.2	72.0	72	14
	Apr 11-16, 2017	2.4	61.0	73.0	61	16
After Chrome 58	May 07-12, 2017	1.6	60.2	68.3	17	13
	Oct 12-16, 2017	2.5	54.9	55.1	19	14

- ~2% websites use web sockets.
- 55-61 % sockets are initiated by A&A domains
- 55-73 % sockets contact an A&A domain

High-Level Numbers

	Crawl Dates	%Websites with sockets	% Sockets with A&A Initiators	% Sockets with A&A Receivers	#Unique A&A Initiators	#Unique A&A Receivers
Before Chrome 58	Apr 02-05, 2017	2.1	60.2	72.0	72	14
	Apr 11-16, 2017	2.4	61.0	73.0	61	16
After Chrome 58	May 07-12, 2017	1.6	60.2	68.3	17	13
	Oct 12-16, 2017	2.5	54.9	55.1	19	14

- ~2% websites use web sockets.
- 55-61 % sockets are initiated by A&A domains
- 55-73 % sockets contact an A&A domain
- # Initiators drops after Chrome 58 release.

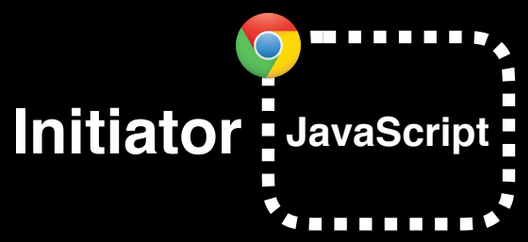
High-Level Numbers

	Crawl Dates	%Websites with sockets	% Sockets with A&A Initiators	% Sockets with A&A Receivers	#Unique A&A Initiators	#Unique A&A Receivers
Before Chrome 58	Apr 02-05, 2017	2.1	60.2	72.0	72	14
	Apr 11-16, 2017	2.4	61.0	73.0	61	16
After Chrome 58	May 07-12, 2017	1.6	60.2	68.3	17	13
	Oct 12-16, 2017	2.5	54.9	55.1	19	14

- ~2% websites use web sockets.
- 55-61 % sockets are initiated by A&A domains
- 55-73 % sockets contact an A&A domain
- # Initiators drops after Chrome 58 release.
- Small but persistent A&A receivers.

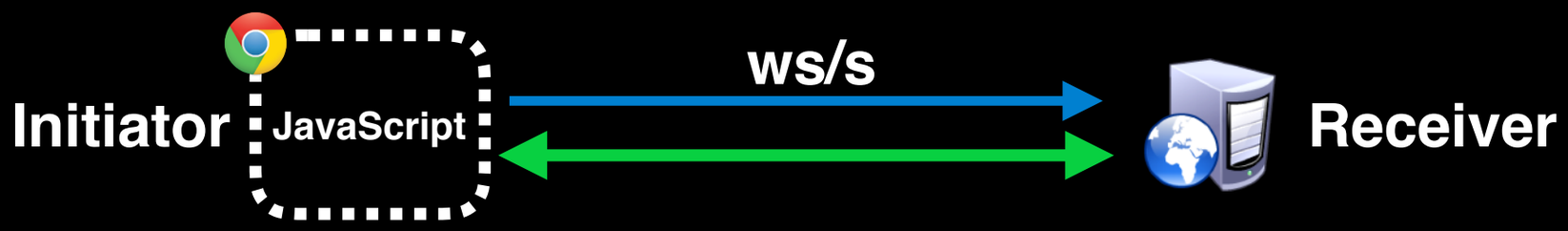
Initiators and Receivers

Initiators and Receivers

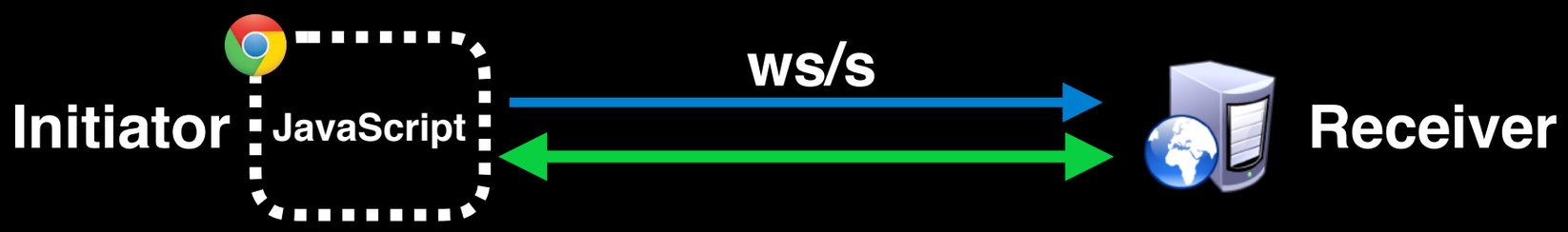


Initiators and Receivers

Initiators and Receivers



Initiators and Receivers



Top A&A Initiators

A&A Initiator	#A&A Receivers
facebook	11
google	11
doubleclick	9
youtube	8
addthis	8
hotjar	6
googlesyndication	6
cloudfront	4
sharethis	4
adnxs	3

Initiators and Receivers

Top A&A Initiators

A&A Initiator	#A&A Receivers
facebook	11
google	11
doubleclick	9
youtube	8
addthis	8
hotjar	6
googlesyndication	6
cloudfront	4
sharethis	4
adnxs	3

Initiators and Receivers

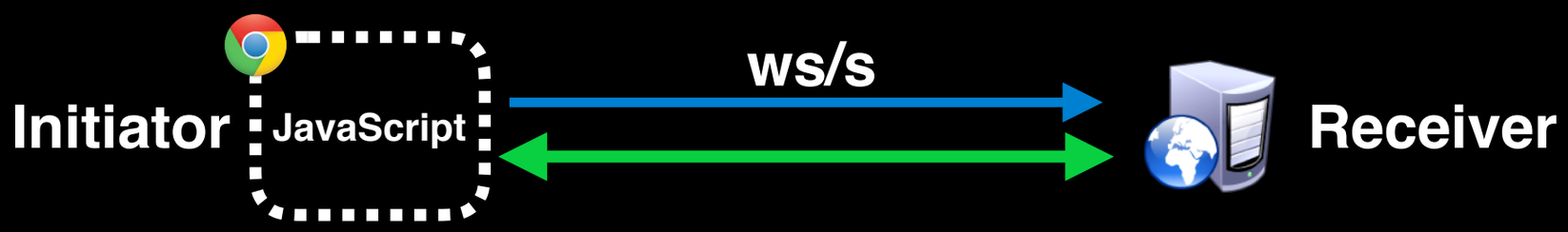
Top A&A Initiators

A&A Initiator	#A&A Receivers
facebook	11
google	11
doubleclick	9
youtube	8
addthis	8
hotjar	6
googlesyndication	6
cloudfront	4
sharethis	4
adnxs	3

Top A&A Receivers

A&A Receiver	#A&A Initiators
realtime	27
33across	19
intercom	15
disqus	13
zopim	12
hotjar	11
feedjit	10
lockerdome	8
inspectlet	6
smartsupp	4

Initiators and Receivers



Top A&A Initiators

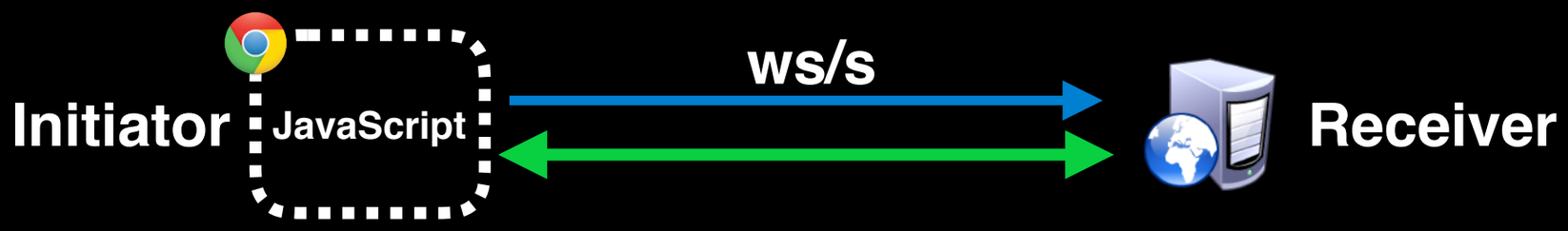
A&A Initiator	#A&A Receivers
facebook	11
google	11
doubleclick	9
youtube	8
addthis	8
hotjar	6
googlesyndication	6
cloudfront	4
sharethis	4
adnxs	3

Top A&A Receivers

A&A Receiver	#A&A Initiators
realtime	27
33across	19
intercom	15
disqus	13
zopim	12
hotjar	11
feedjit	10
lockerdome	8
inspectlet	6
smartsupp	4

- **Disqus** provides comment board services.

Initiators and Receivers



Top A&A Initiators

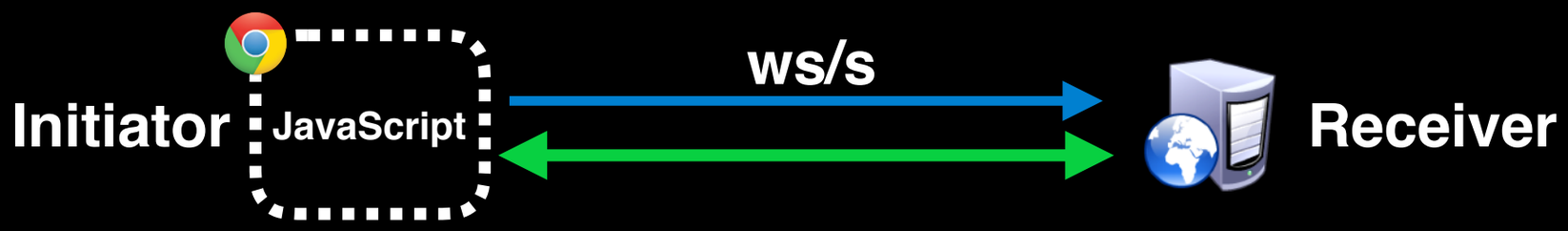
A&A Initiator	#A&A Receivers
facebook	11
google	11
doubleclick	9
youtube	8
addthis	8
hotjar	6
googlesyndication	6
cloudfront	4
sharethis	4
adnxs	3

Top A&A Receivers

A&A Receiver	#A&A Initiators
realtime	27
33across	19
intercom	15
disqus	13
zopim	12
hotjar	11
feedjit	10
lockerdome	8
inspectlet	6
smartsupp	4

- **Disqus** provides comment board services.
- **Zopim, Intercom, Smartsupp** provide live chat services.

Initiators and Receivers



Top A&A Initiators

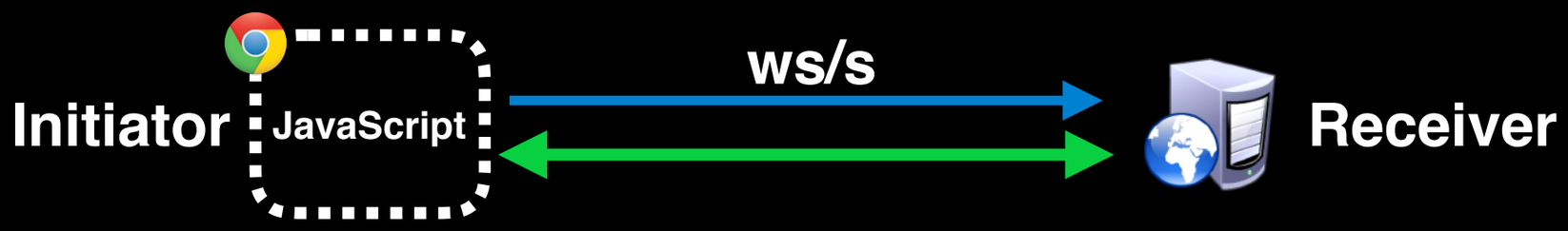
A&A Initiator	#A&A Receivers
facebook	11
google	11
doubleclick	9
youtube	8
addthis	8
hotjar	6
googlesyndication	6
cloudfront	4
sharethis	4
adnxs	3

Top A&A Receivers

A&A Receiver	#A&A Initiators
realtime	27
33across	19
intercom	15
disqus	13
zopim	12
hotjar	11
feedjit	10
lockerdome	8
inspectlet	6
smartsupp	4

- **Disqus** provides comment board services.
- **Zopim, Intercom, Smartsupp** provide live chat services.
- **33across** & **Lockerdome** are advertising platforms.

Initiators and Receivers



Top A&A Initiators

A&A Initiator	#A&A Receivers
facebook	11
google	11
doubleclick	9
youtube	8
addthis	8
hotjar	6
googlesyndication	6
cloudfront	4
sharethis	4
adnxs	3

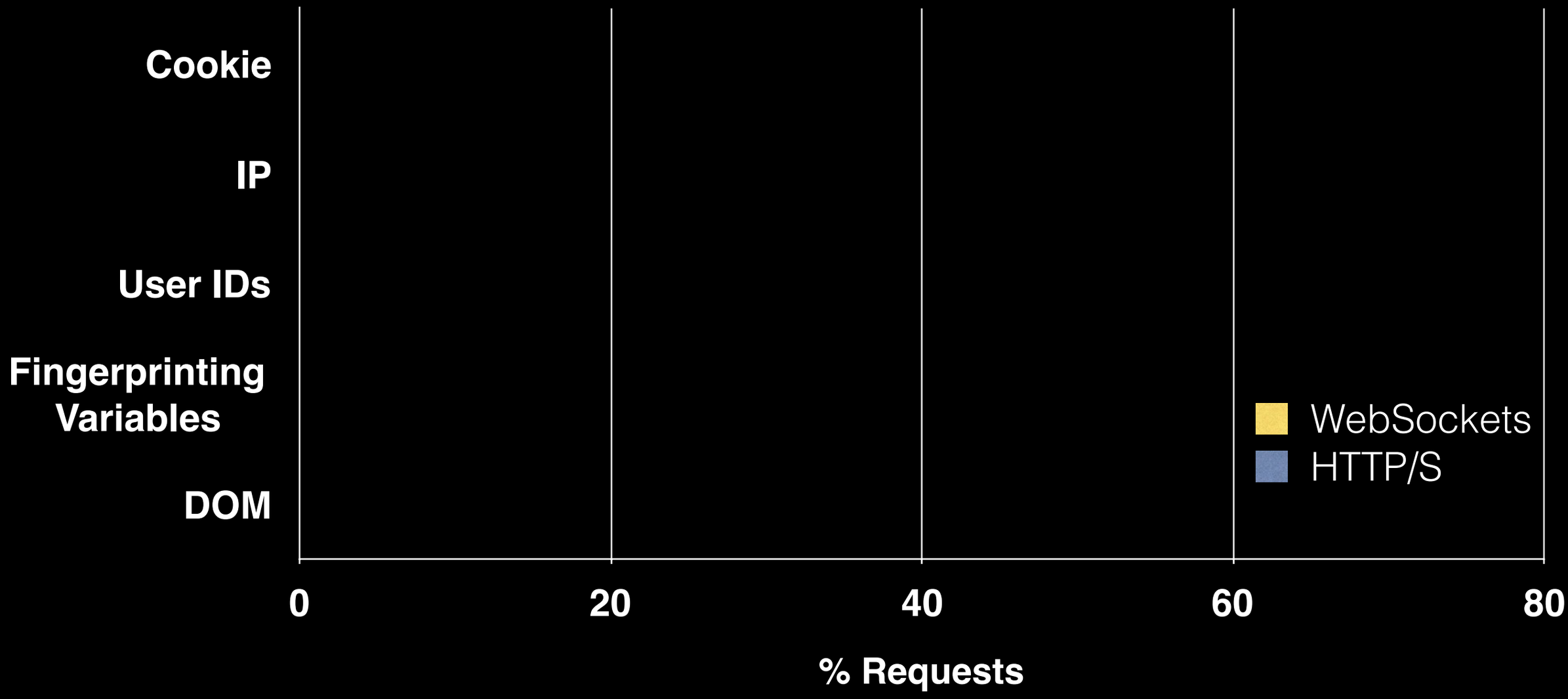
Top A&A Receivers

A&A Receiver	#A&A Initiators
realtime	27
33across	19
intercom	15
disqus	13
zopim	12
hotjar	11
feedjit	10
lockerdome	8
inspectlet	6
smartsupp	4

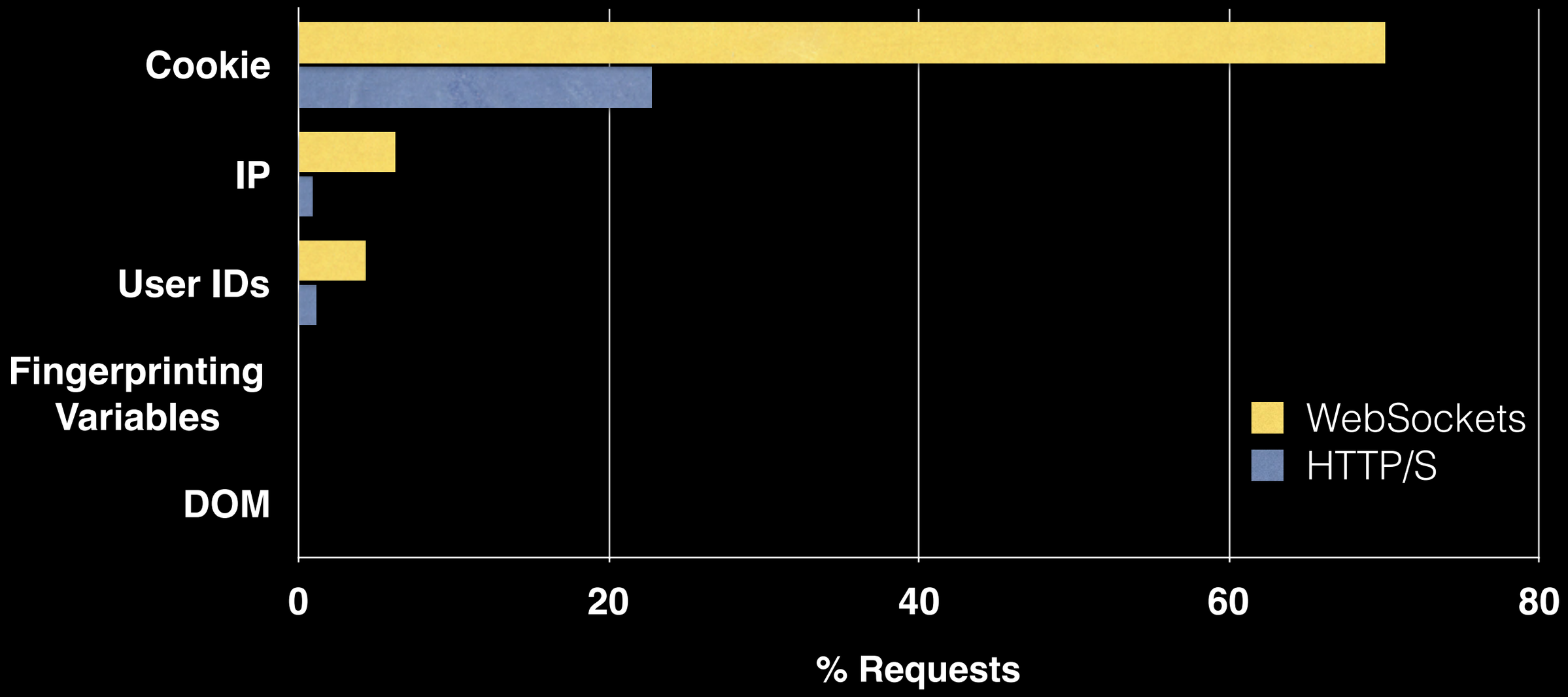
- **Disqus** provides comment board services.
- **Zopim, Intercom, Smartsupp** provide live chat services.
- **33across** & **Lockerdome** are advertising platforms.
- **Inspectlet** & **Hotjar** are session replay services.

Sent Items Over Web Sockets

Sent Items Over Web Sockets

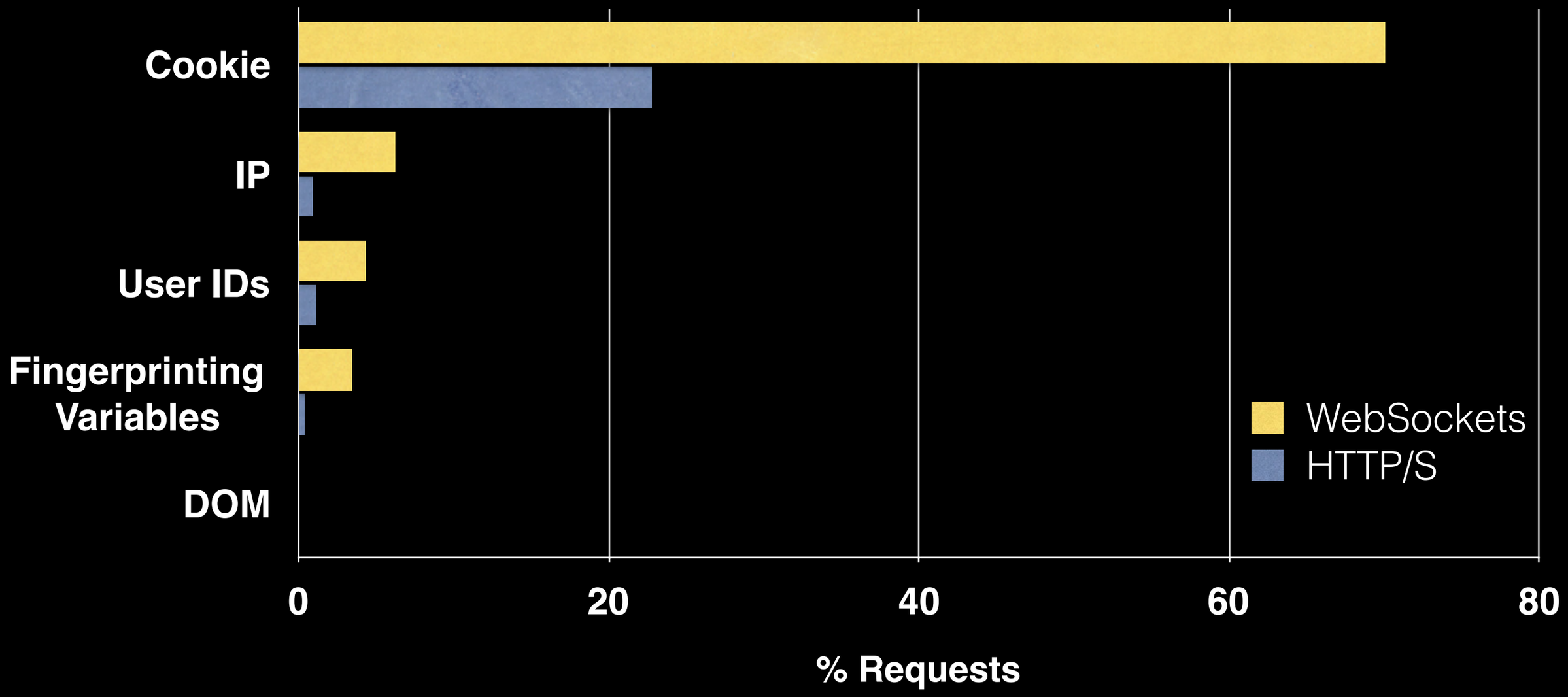


Sent Items Over Web Sockets



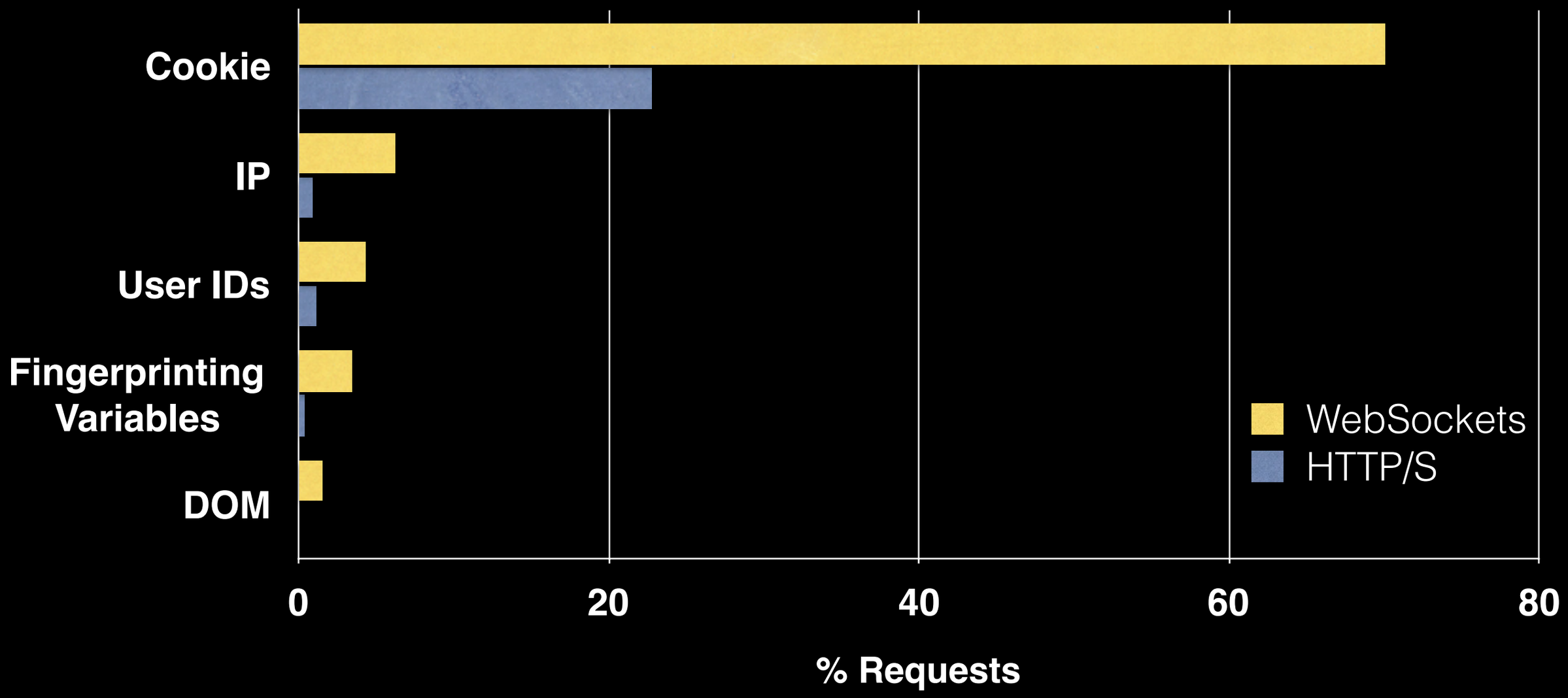
- Stateful Identifiers like Cookie and User IDs

Sent Items Over Web Sockets



- Stateful Identifiers like Cookie and User IDs
- Fingerprinting data in ~3.4% WebSockets.
  97% is **33across**

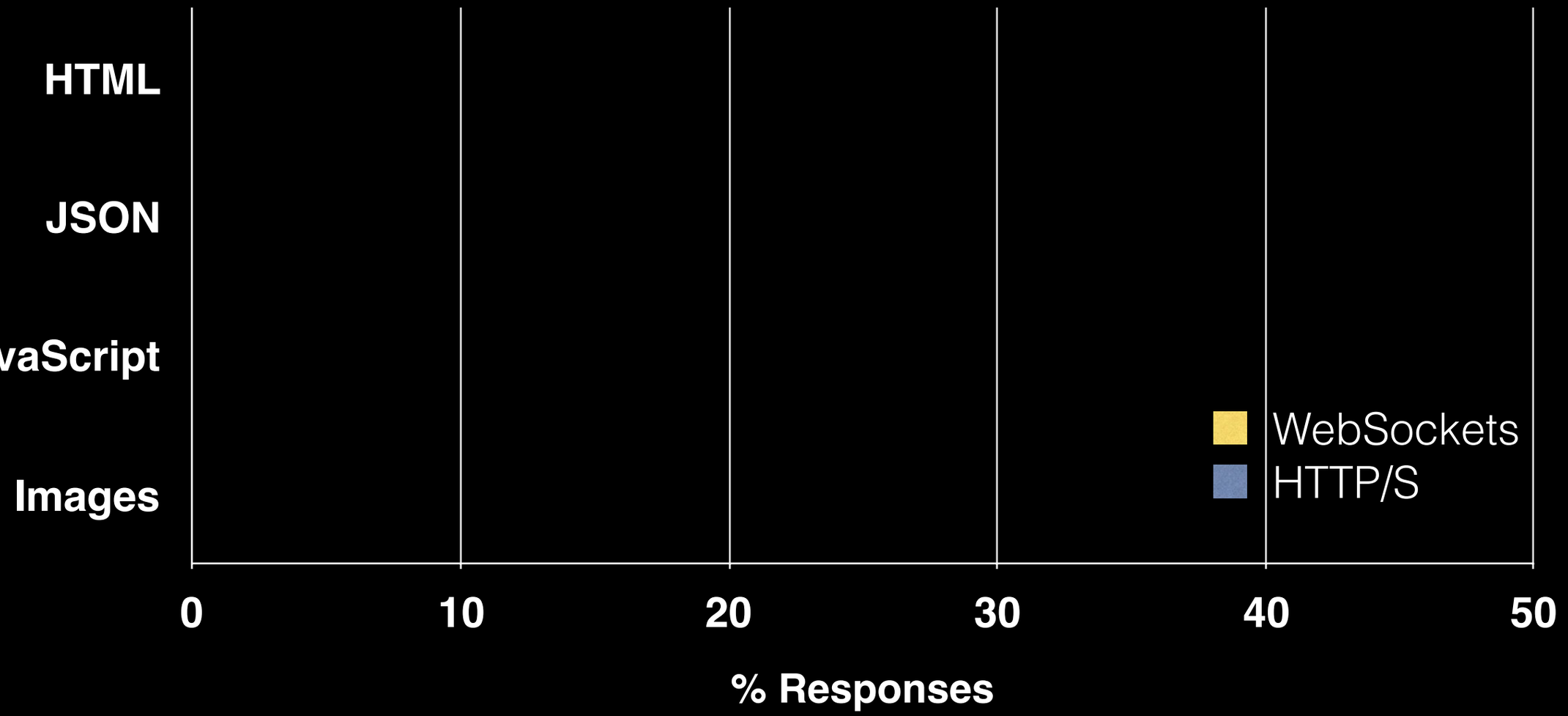
Sent Items Over Web Sockets



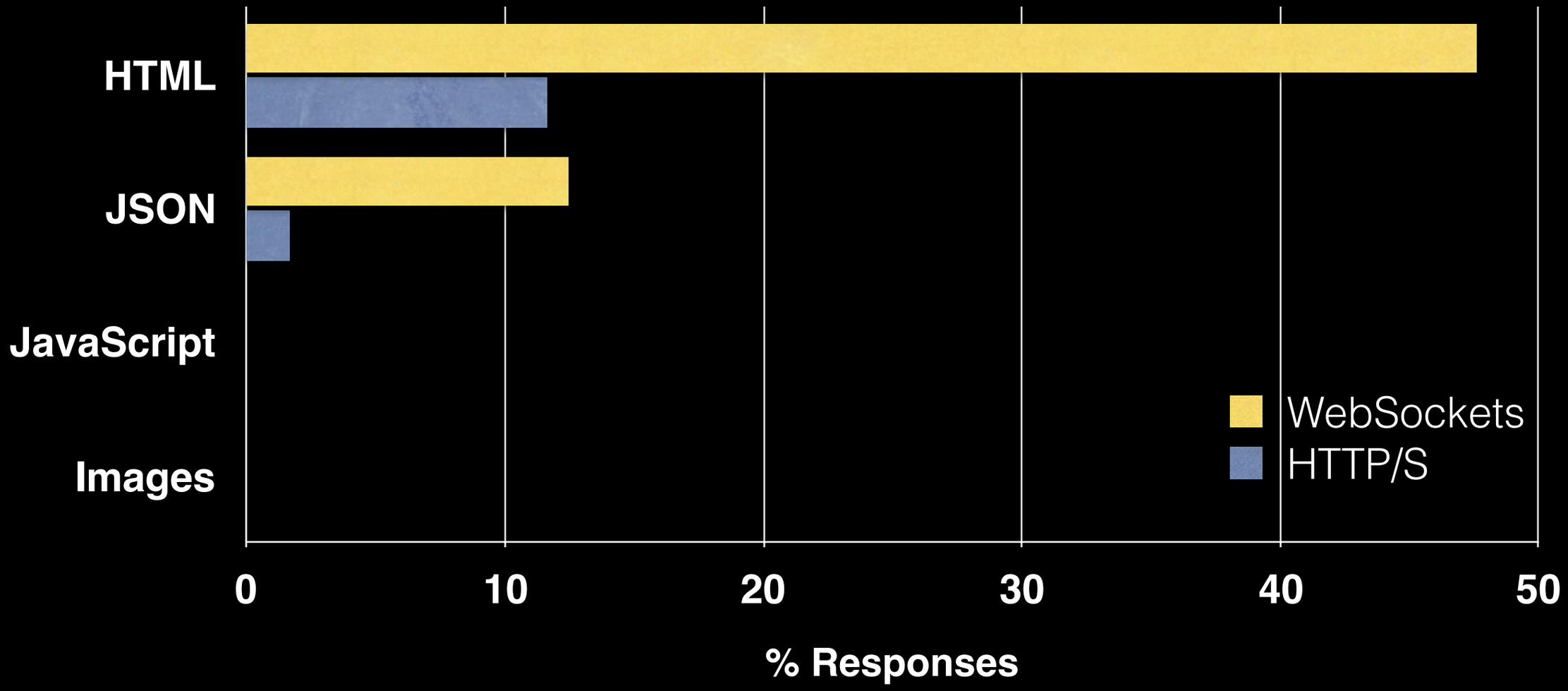
- Stateful Identifiers like Cookie and User IDs
- Fingerprinting data in ~3.4% WebSockets.
  97% is **33across**
- ~1.5% WebSockets sends the entire DOM to **Hotjar**

Received Items Over Web Sockets

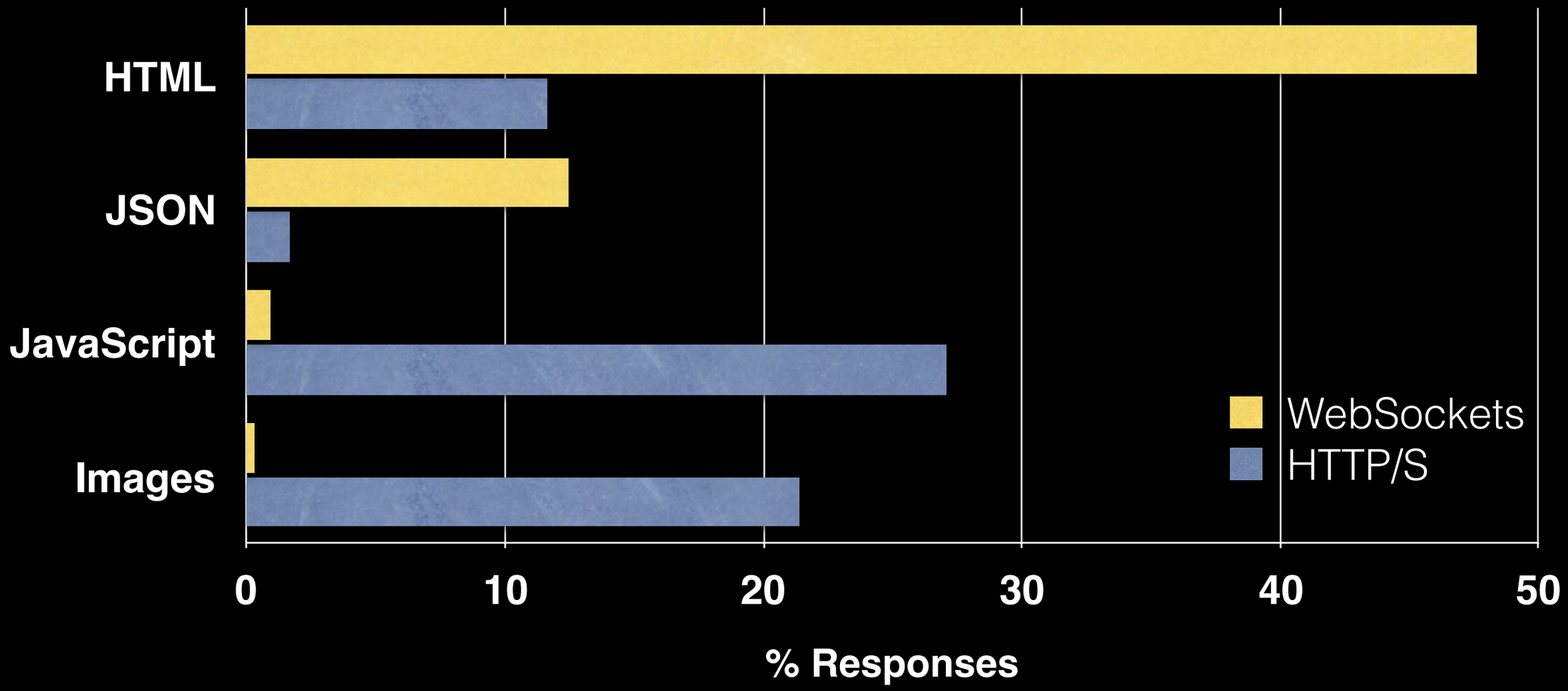
Received Items Over Web Sockets



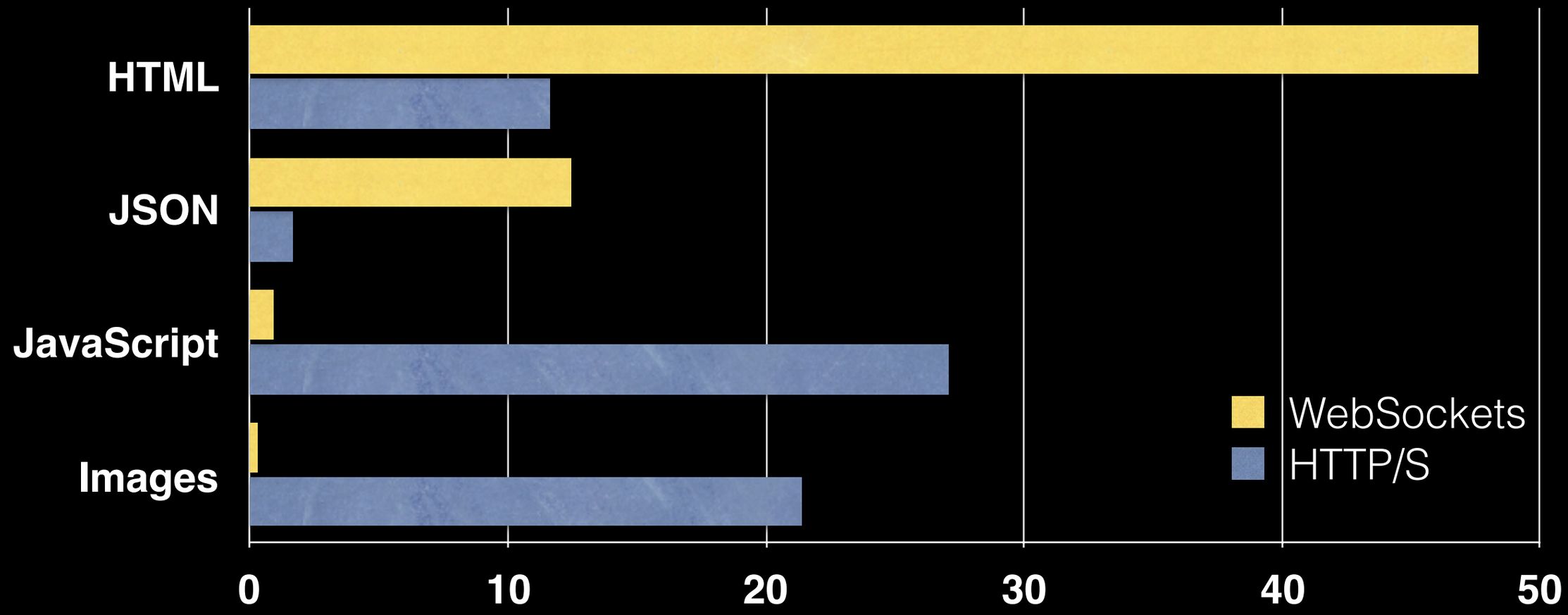
Received Items Over Web Sockets

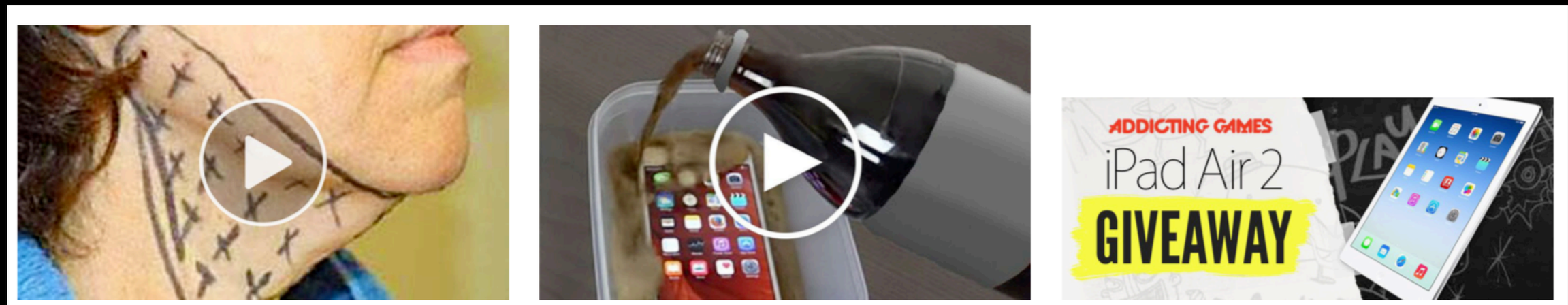


Received Items Over Web Sockets



Received Items Over Web Sockets





Ads served from **Lockerdome**

Summary

- ~67% of socket connections are initiated or received by A&A domains.
- Major companies like Google, Facebook, Addthis adopted WebSockets.
  Abandoned after Chrome 58 was released.
- The culprits:
  - **33across** was harvesting fingerprinting data.
  - **HotJar** was exfiltrating the entire DOM
  - **Lockerdome** downloaded URLs to serve ads.
- We need to keep with the current practices of A&A companies.

Summary

- ~67% of socket connections are initiated or received by A&A domains.
- Major companies like Google, Facebook, Addthis adopted WebSockets.
  Abandoned after Chrome 58 was released.
- The culprits:
  - **33across** was harvesting fingerprinting data.
  - **HotJar** was exfiltrating the entire DOM
  - **Lockerdome** downloaded URLs to serve ads.
- We need to keep with the current practices of A&A companies.

Questions?

ahmad@ccs.neu.edu

Discussion Points

- What's Next?
  - Can these findings be used to fine advertisers or shape new policies?
- Major Ad Exchanges abandoned WebSockets — Why?
- New web standards.
  - Can be problematic? Where should we intervene?
- Surprising that it took few years to patch this bug
- WebRTC aspect of it.

Backup Slides

Inclusion Chain

DOM Tree

```
<html>
  <body>
    <script src="tracker/script.js" </script>
    <img src="tracker/img.jpg"> </img>

    <script src="ads/script.js"> </script>
    <iframe src="frame.html">
      <html> <body>
        <script src="script_12.js"> </script>
        <img src="img_a.jpg"> </img>
      </body> </html>
    </iframe>
  </body>
</html>
```

Source code for ads/script_12.js

```
let ws =
  new WebSocket("ws://adnet/data.ws", …);
  ws.onopen = function (e) {ws.send("…");}
```

Inclusion Tree