



# 孫子兵法

The art of war of browser fingerprinting



# Who we are



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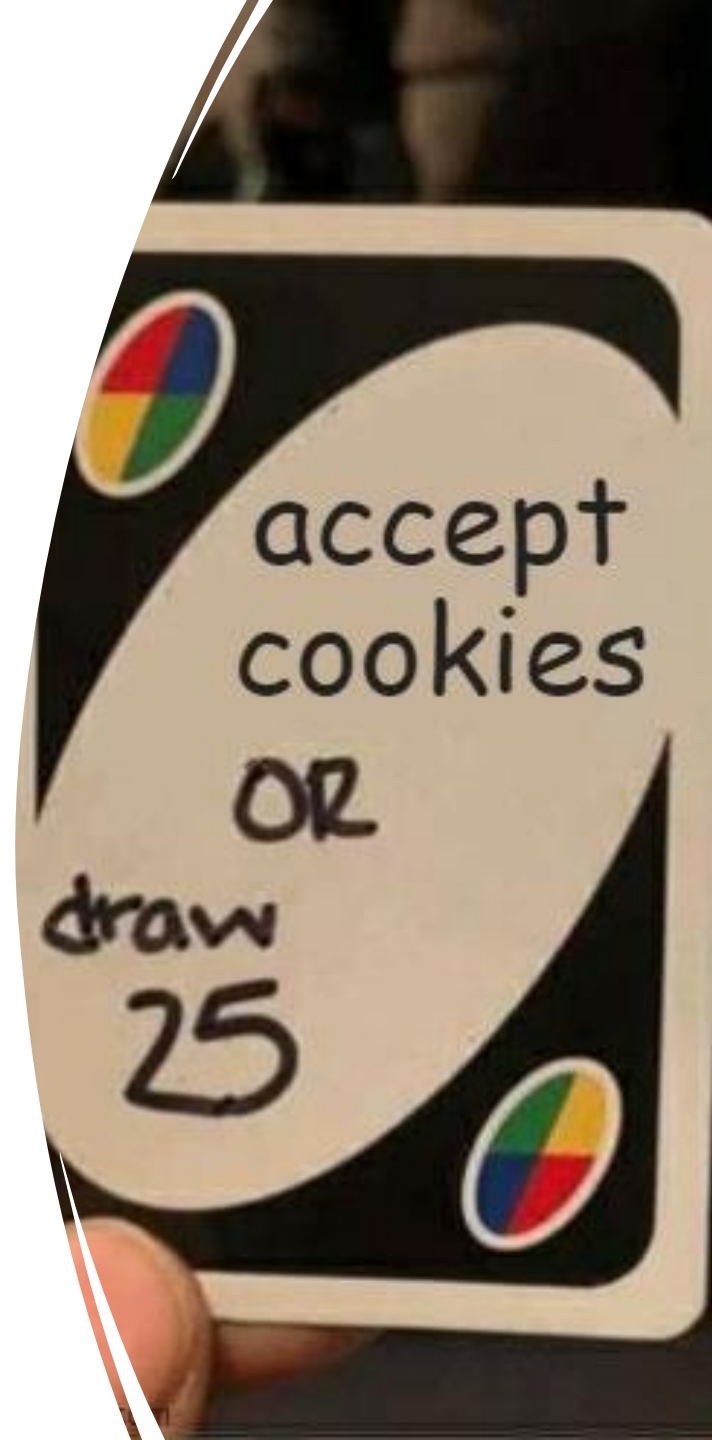
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# Agenda

- **Introduction**
  - What's browser fingerprinting?
  - Some basic terminology and concepts
- **State of the art in terms of browser fingerprinting**
  - Fingerprinting surface
  - Current methods
  - Identifying the anti-fingerprint actions
- **Nailing the fingerprints (for profit)**
  - Stability analysis over a specified period
  - Uniqueness analysis of the fingerprint dataset
- **Conclusions**
  - Long term identification
  - Strategy to win the arms race

# Introduction



# What's browser fingerprinting?

 browser fingerprinting

*/'braʊzə 'fɪŋgəprɪntɪŋ/*

See definitions in:

Device Recognition Authentication Tracking

*noun*

1. refers to the process of calculating or assigning unique and reasonably stable identifiers to each browser/device that visits a website through various methods and techniques.

*uses*

1. these techniques are done for the purpose of correlating future visits from the same person or device with historical data and can be used in adaptive and continuous authentication schemes to strengthen security, but they can also be used to do tracking and damage the privacy of users.

# Some basic terminology and concepts

## Browser fingerprint

*Set of information (attributes) related to a user's device from the hardware to the operating system to the browser and its configuration.*

It's usually represented  
as a hash

List of attributes

```
hash: fdfe284e5ca4fa0f1b13359d6cdf931353d118355e326f9279875022d74e6d7c
{
  adBlock: true,
  browser: Chrome,
  canvas_result: 147814394,
  operating_system: Windows 10,
  screen_resolution: 1240x755,
  webGL_result: 123993414,
  ...
}
```

# Some basic terminology and concepts

## Passive fingerprinting

*It is based on characteristics observable in the contents of Web requests, without the use of any code executed on the client.*

*E.g. getting info from the HTTP headers*

## Active fingerprinting

*Techniques where a site runs some code on the local client to observe additional characteristics about the browser, user, device or other context..*

*E.g. JavaScript*

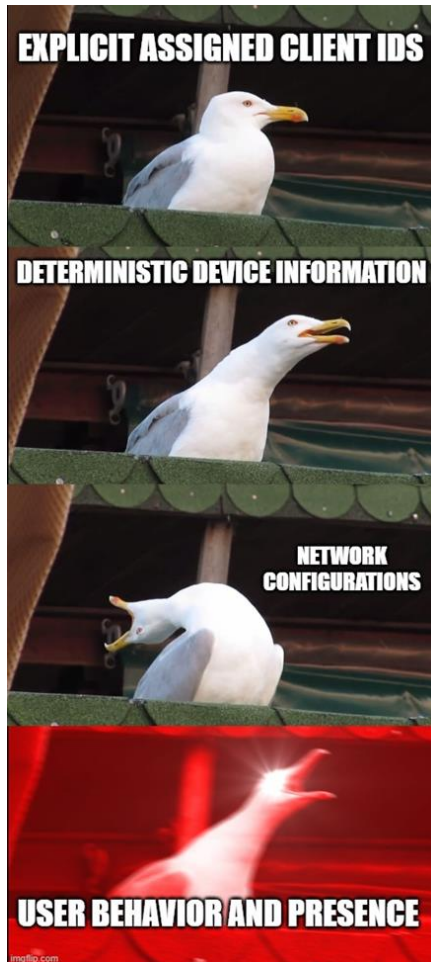
# State of the art in terms of browser fingerprinting

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# Fingerprinting surface



**Explicitly assigned client-side identifiers** or the cookie-like style.

**Deterministic device information** that includes the characteristics of the device, the operating system and the browser.

**Network configurations** related to the architecture and lower-level configuration of the local network.

**User behavior and preferences** such as online behaviors or local preferences.

# Current methods

Explicitly assigned client-side identifiers	Deterministic Device Information	Network Configurations	User Behavior
Etag/Last-Modified headers	Canvas	Geolocation API	Keystroke dynamics
HTTP cookies	ClientRects	TCP/IP & TLS	Accelerometer readings
Flash cookies	Error messages	DNS Leaks	Mouse gesture dynamics
	Feature lists	STAR-ECHO	
	Header signature		
	Image encoding & decoding		
	Installed system fonts		
	Number of CPU virtual cores		
	Screen resolution and color depth		
	User-Agent/Client hints		
	Web Audio API		
	WebGL – Vertex shader – Fragment shader		

# Identifying the anti-fingerprinting actions

**Problem...** the new web specifications developed by standard organizations and the features and APIs implemented by the browsers not only expanded the web capabilities but also increased the surface of fingerprinting.

What are the initiatives to mitigate fingerprinting that major **browsers vendors** are taking?

What are the countermeasures that **standard organizations** are implementing?

What are the third-party anti-fingerprint **browser extensions** available on the market?

**What we see?...** All main players involved in the WWW are carrying out different actions to prevent or mitigate the fingerprinting techniques.

**What are their key concepts?**

Trackers blocking

Cookie policies

Anti-fingerprinting initiatives

# Identifying the anti-fingerprinting actions

## Trackers Blocking

The main approach is blocking all third-party requests to companies that are known to participate in tracking.


- Mozilla Firefox implements **Enhanced Tracking Protection** using the Disconnect open-source list.
- Edge also uses Disconnect open-source list in its **Tracking Prevention** feature.
- WebKit implements **Intelligent Tracking Prevention** to detect trackers accordingly to its own model.



# Identifying the anti-fingerprinting actions

## Cookie policies


Third-party cookies' days are numbered...

 The Verge


Apple updates Safari's anti-tracking tech with full third-party cookie blocking

According to Apple's John Wilander, the WebKit engineer behind the ... In addition to blocking third-party cookies across the board and by...

24 mar. 2020




The cookies are dead, long live the cookies

 The Verge

Google Chrome third-party cookies block delayed until 2023

Google is announcing today that it is delaying its plans to phase out third-party cookies in the Chrome browser until 2023, a year or so later than...

24 jun. 2021



# Identifying the anti-fingerprinting actions

## Anti-fingerprinting initiatives

### Chrome



#### *Privacy Sand Box*

- Privacy Budget
- Removing passive fingerprinting surfaces
- Reducing entropy from surfaces
- IP Address

### WebKit/Safari



#### *Intelligent Tracking Prevention*



“The first line of defense against fingerprinting is to not implement web features which increase fingerprintability and offer no safe way to protect the user”

### Mozilla Firefox

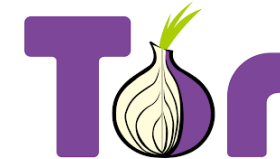


#### *Enhanced Tracking Protection*



*Fingerprinting Protection (experimental)*

### Tor



#### *Privacy by design*

# The Do Not Track paradox

Do Not Track was a proposed HTTP header field, designed to allow users to opt-out of tracking by websites, which includes the collection of data regarding their activity, and the retention, use, or sharing of data derived from that activity outside the context in which it occurred.



A close-up shot of a human hand, palm up, holding a single red pill. The hand is positioned on the left side of the frame. The background is dark and out of focus, with some green foliage visible on the right.

**AUTHENTICATION**

A close-up shot of a human hand, palm up, holding a single blue pill. The hand is positioned on the right side of the frame. The background is dark and out of focus, with some green foliage visible on the right.

**TRACKING**



Nailing the  
fingerprints  
(for profit)

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# Some (other) basic concepts

## Uniqueness

- *It has an attribute whose value is only present once in the whole dataset.*
- *The combination of all its attributes is unique in the whole dataset*

## Entropy

*The entropy of a random variable is the average level of information inherent in the variable's possible outcomes.*

$$H(X) = - \sum_i P_X(x_i) \log_b P_X(x_i)$$

# Some (other) basic concepts

## Stability

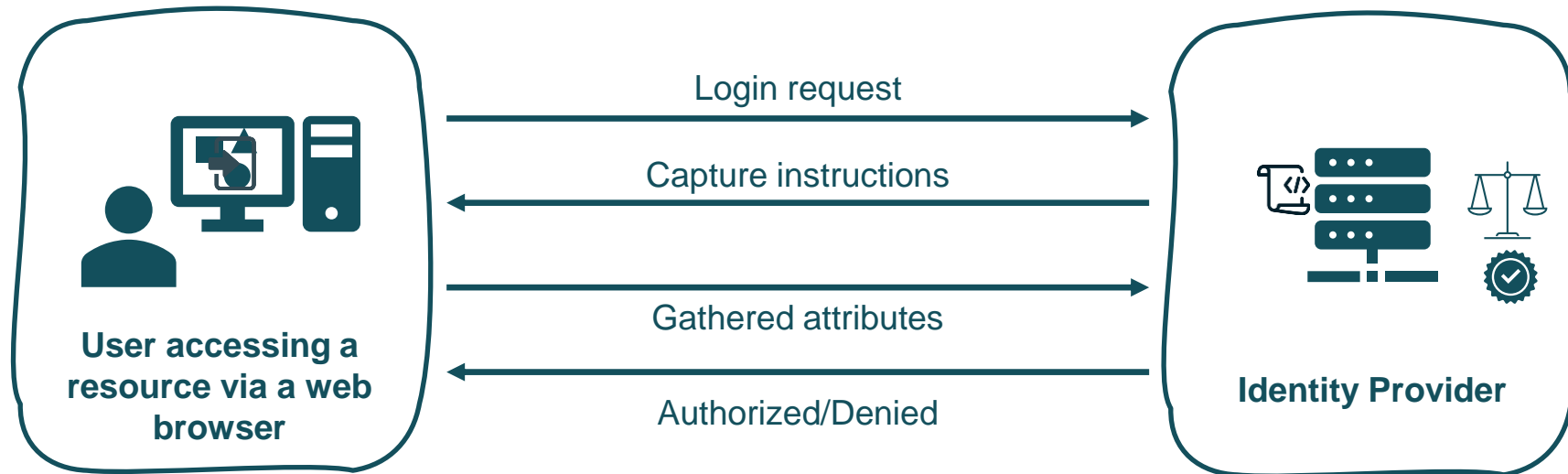
*As users update their devices, operating systems or browsers, or customize them, the collected fingerprints will change.*

*To link browser fingerprints of the same device, the quantity of modified information should be as small as possible*

## Effectiveness

- *A technique is effective in the terms of its ability to say that a fingerprint is unique.*
- What affects the effectiveness?*
- *Natural evolution of web technologies.*
  - *Choices of the users*

# Browser Fingerprint Authentication



# Nailing the fingerprints

We need to analyze in deep the way attributes change over time, so we can spot which are more likely to change and less predictive. The less predictive are the attributes, the less should we weight them.

## Efficiency



To measure the method efficiency, we use **entropy** and **distance**

**Entropy** defines the amount of uniqueness a specific property exposed by the browser

**Distance** checks the similarity of all the attributes of one user's fingerprint to another one

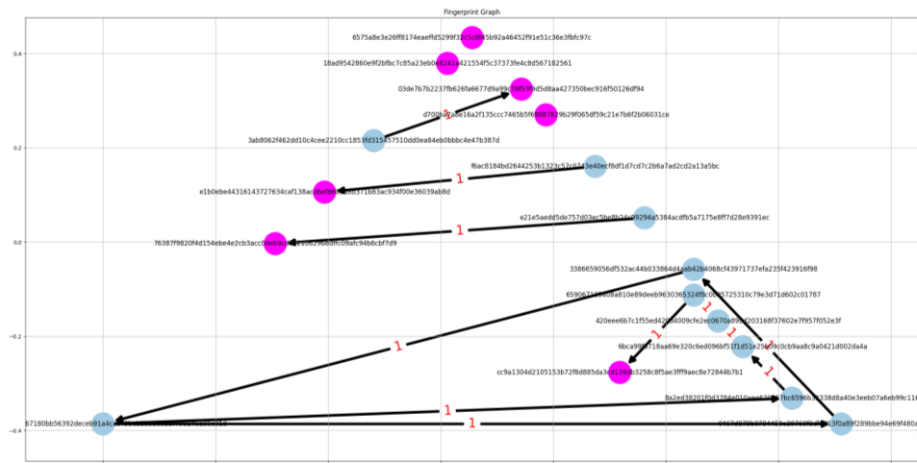
## Stability



To see the stability of the attributes we map the fingerprints of each user through the time that the tests lasted.

# Stability

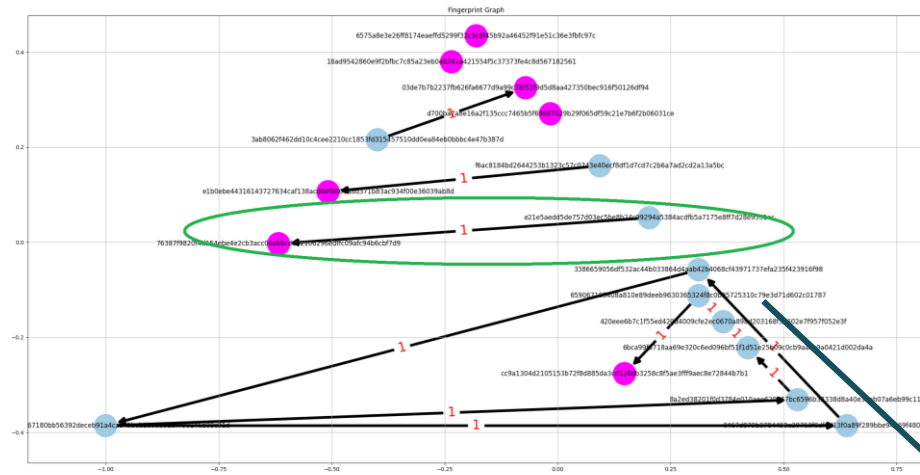
## User X



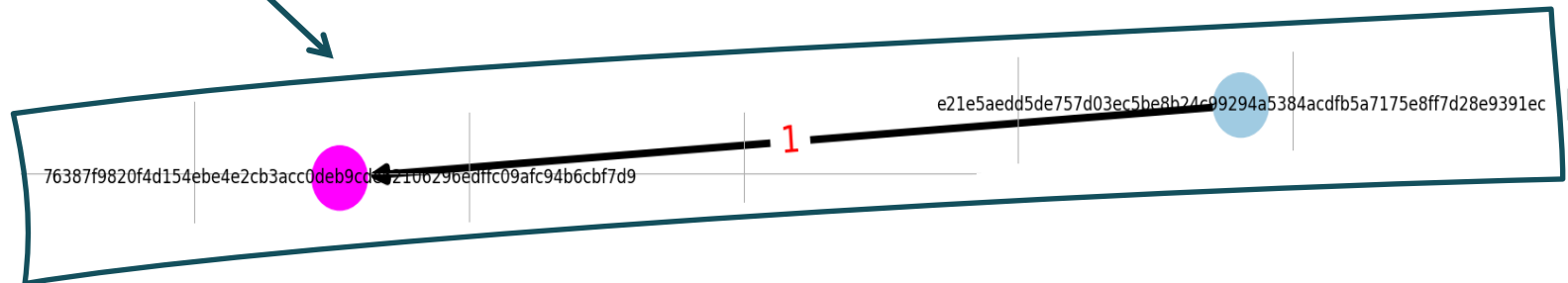
DFP Id	Active	Parent	Date	Different attributes	Similarity
0467d879...	FALSE	80ce403f...	12/9/2020 19:41	{'availableScreenResolution': '1920x976', 'featureDetection': '1411500350'}	0.966667
33866590...	FALSE	0467d879...	12/9/2020 19:45	{'availableScreenResolution': '1920x973'}	0.983333
80ce403f...	FALSE	33866590...	12/11/2020 17:06	{'availableScreenResolution': '1920x1080', 'featureDetection': '-1999845871'}	0.966667
e1b0ebe4...	TRUE	f6ac8184...	12/11/2020 17:25	{'featureDetection': '-98490647'}	0.983333
76387f98...	TRUE	e21e5aed...	12/14/2020 14:37	{'availableScreenResolution': '1680x942', 'canvas': '-544809853', 'featureDetection': '-254964415', 'pixelRatio': 2, 'screenResolution': '1680x1050', 'timezoneOffset': 300, 'webGL': '1839438861'}	0.883333
03de7b7b...	TRUE	3ab8062f...	12/17/2020 15:09	{'availableScreenResolution': '1920x1080', 'canvas': '1484948844', 'clientRects': '-1266107803', 'featureDetection': '1405118453', 'pixelRatio': 1, 'screenResolution': '1920x1080', 'webGL': '-1416715110'}	0.883333
8a2ed382...	FALSE	80ce403f...	12/21/2020 0:47	{'featureDetection': '1411500350', 'timezoneOffset': 300, 'timezone': 'America/New_York'}	0.95
6bca99f8...	FALSE	8a2ed382...	12/22/2020 15:22	{'availableScreenResolution': '1920x972', 'featureDetection': '300603130'}	0.966667
420eee6b...	FALSE	6bca99f8...	12/28/2020 15:27	{'availableScreenResolution': '1680x1050', 'canvas': '577105717', 'featureDetection': '1411500350', 'pixelRatio': 2, 'screenResolution': '1680x1050', 'webGL': '1528745659'}	0.9
65906710...	FALSE	420eee6b...	12/29/2020 12:48	{'featureDetection': '1756784159'}	0.983333
cc9a1304...	TRUE	65906710...	1/13/2021 14:26	{'availableScreenResolution': '1680x947', 'colorDepth': 30}	0.966667

# Stability

## User X

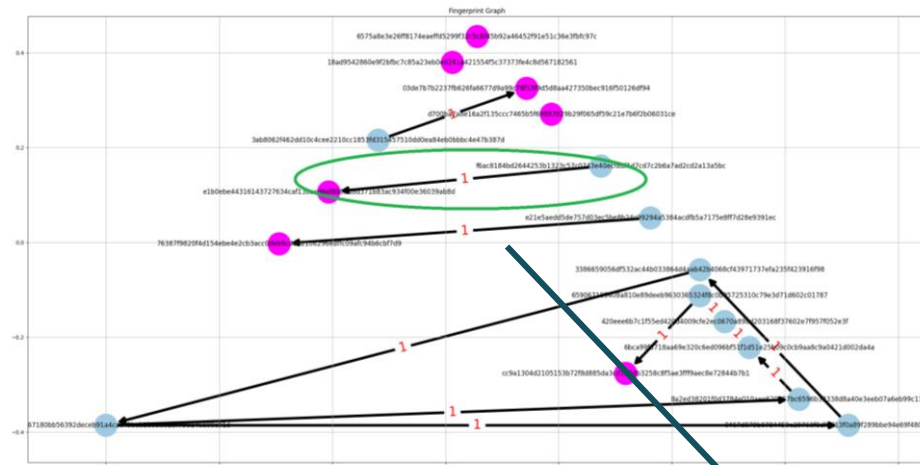


DFP Id	Active	Parent	Date	Different attributes	Similarity
76387f98...	TRUE	e21e5aed...	12/14/2020 14:37	{'availableScreenResolution': '1680x942', 'canvas': '-544809853', 'featureDetection': '-254964415', 'pixelRatio': 2, 'screenResolution': '1680x1050', 'timezoneOffset': 300, 'webGl': '1839438861'}	0.883333

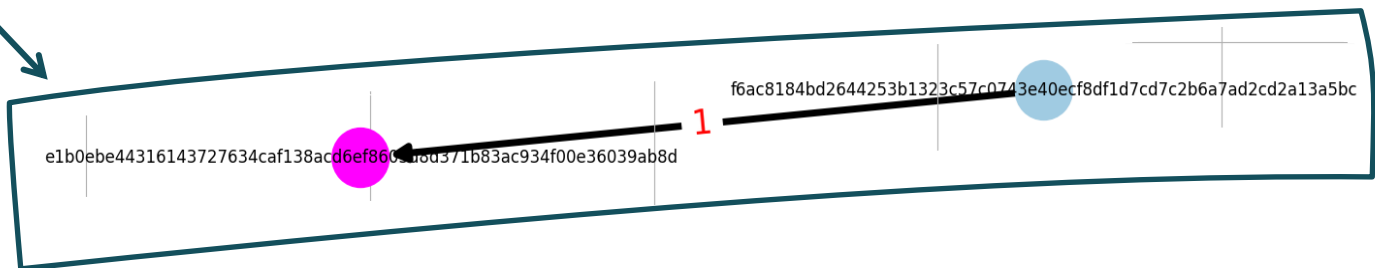


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## User X



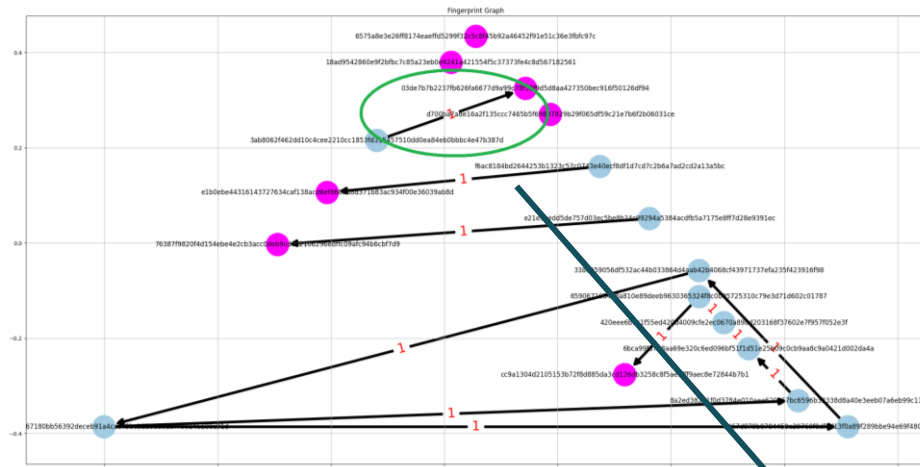
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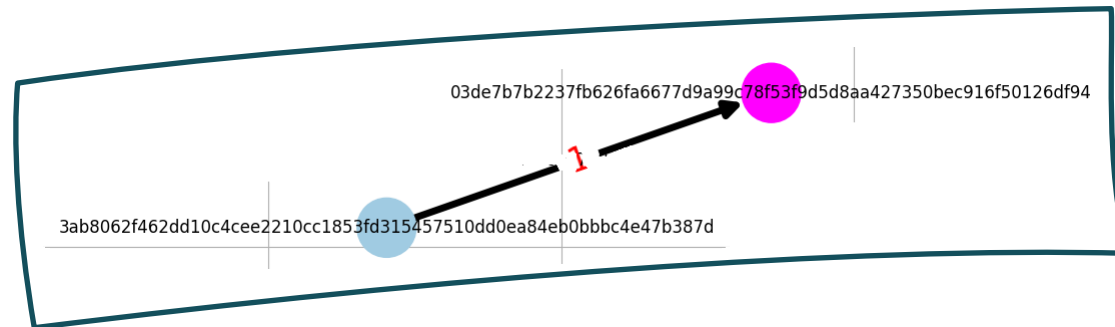


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## User X



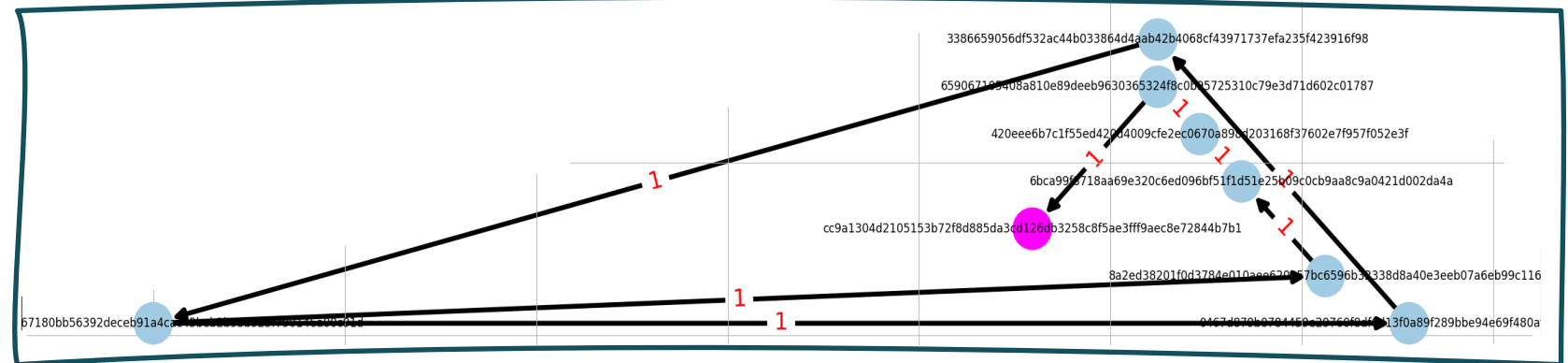
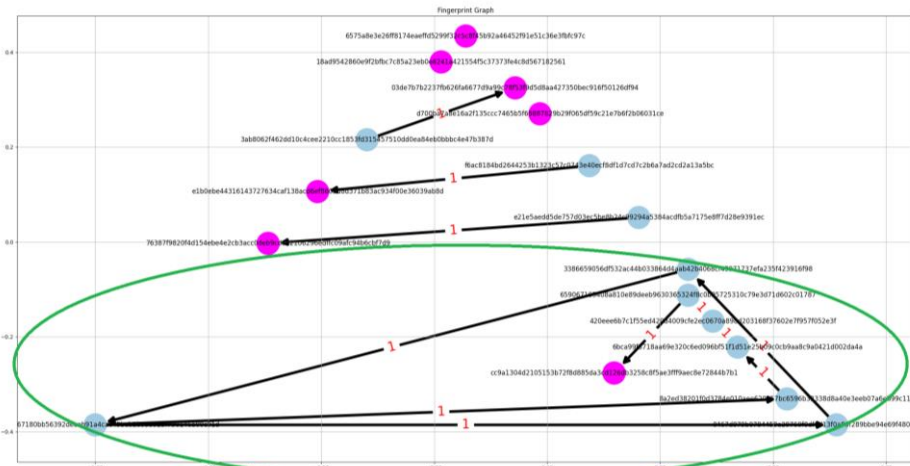
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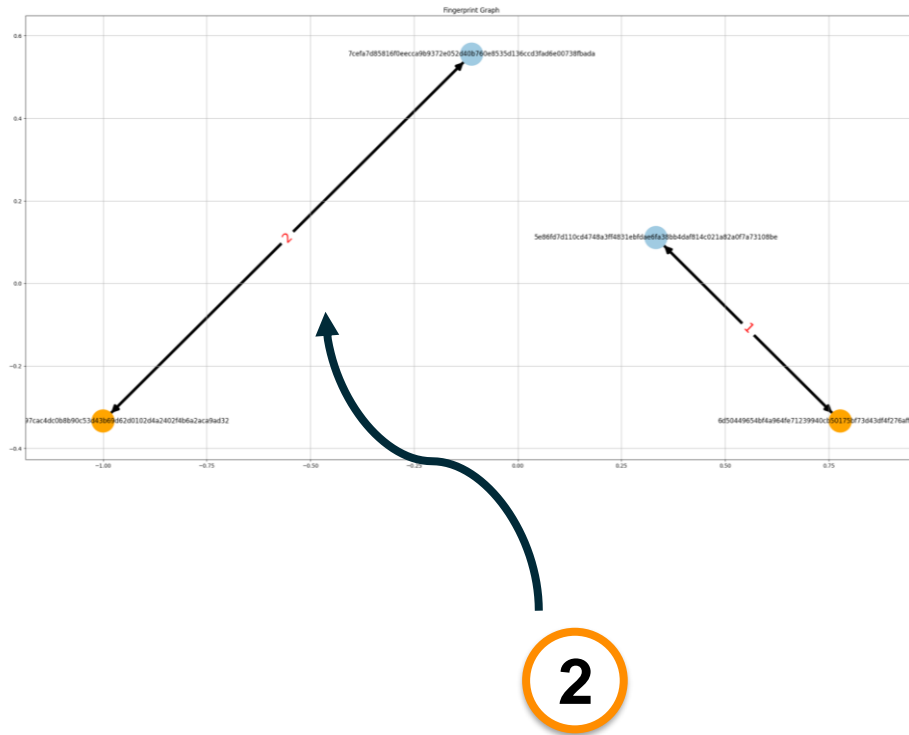
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# Stability

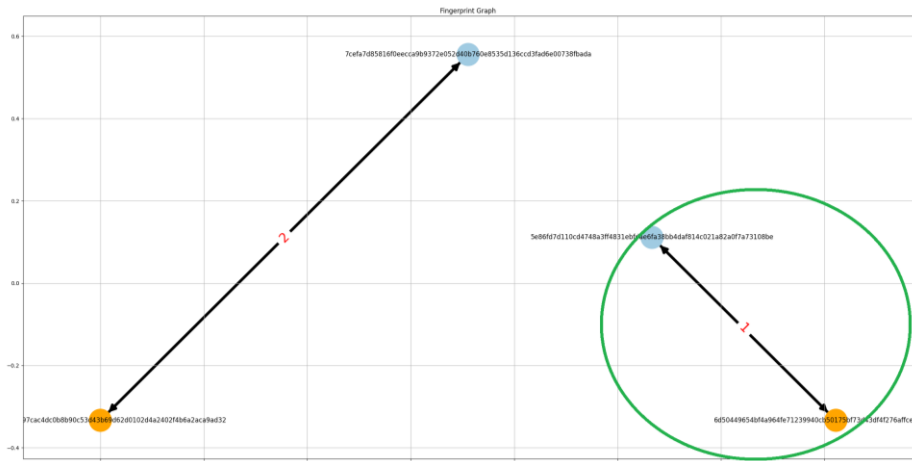
## User Y



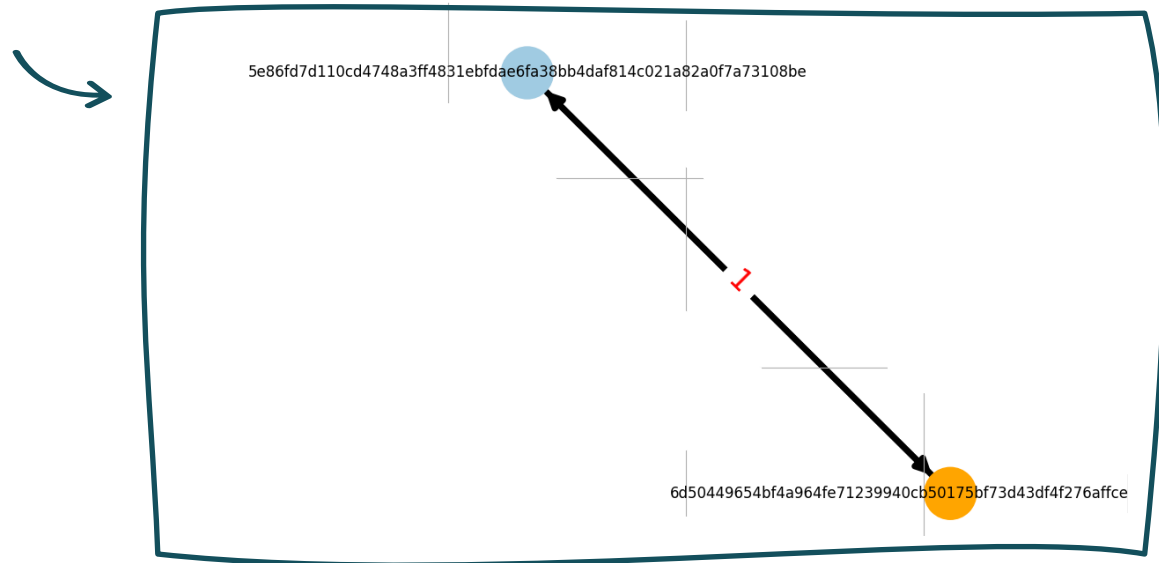
DFP Id	Active	Parent	Date	Different attributes	Similarity
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602735e1...	FALSE	7cefa7d8...	12/16/2020 15:11	{'availableScreenResolution': '1280x680', 'clientRects': '496178633', 'featureDetection': '617885179', 'pixelRatio': 2, 'screenResolution': '1280x720'}	0.916667
7cefa7d8...	FALSE	602735e1...	12/18/2020 13:30	{'availableScreenResolution': '1920x1040', 'clientRects': '-427815704', 'featureDetection': '1794663496', 'pixelRatio': 1, 'screenResolution': '1920x1080'}	0.916667
602735e1...	<b>TRUE</b>	7cefa7d8...	12/21/2020 13:17	{'availableScreenResolution': '1280x680', 'clientRects': '496178633', 'featureDetection': '617885179', 'pixelRatio': 2, 'screenResolution': '1280x720'}	0.916667
5e86fd7d...	FALSE	6d504496...	1/14/2021 17:41	{'featureDetection': '741488953'}	0.983333
6d504496...	<b>TRUE</b>	5e86fd7d...	1/18/2021 13:04	{'featureDetection': '617885179'}	0.983333

# Stability

## User Y

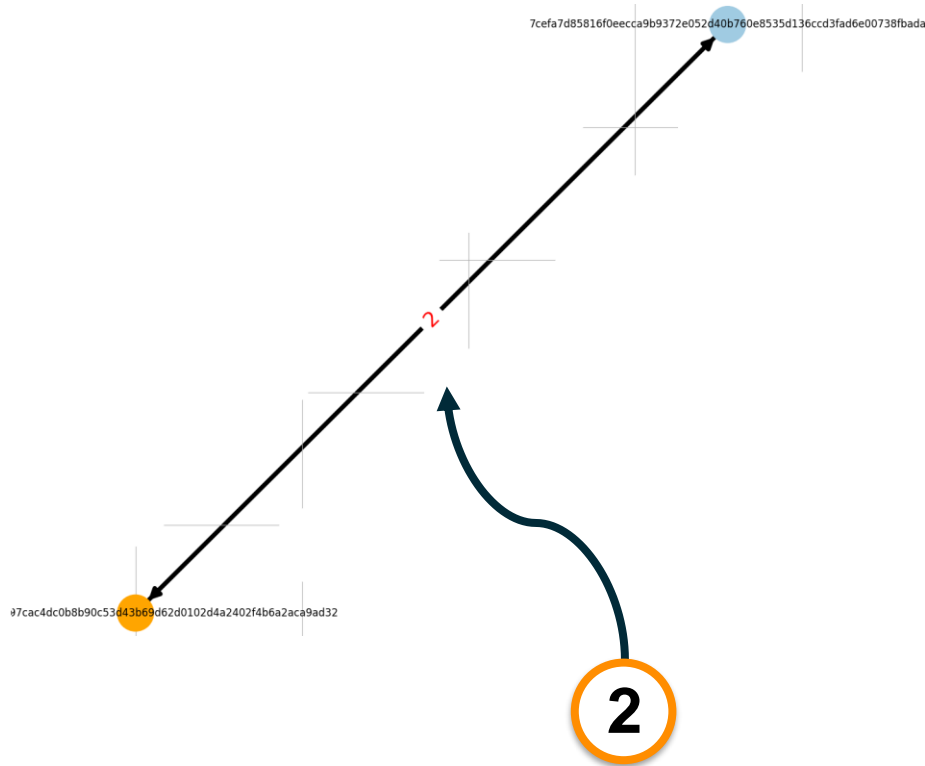


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# Stability

## User Y




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602735e1...	<b>TRUE</b>	7cefa7d8...	12/21/2020 13:17	{'availableScreenResolution': '1280x680', 'clientRects': '496178633', 'featureDetection': '617885179', 'pixelRatio': 2, 'screenResolution': '1280x720'}	0.916667


# Entropy

 **209** fingerprints

 **7.484**  
entropy

 **1.92**  
avg entropy

**11** low entropy attributes 

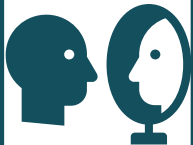
**4** zero entropy attributes 

# Distance



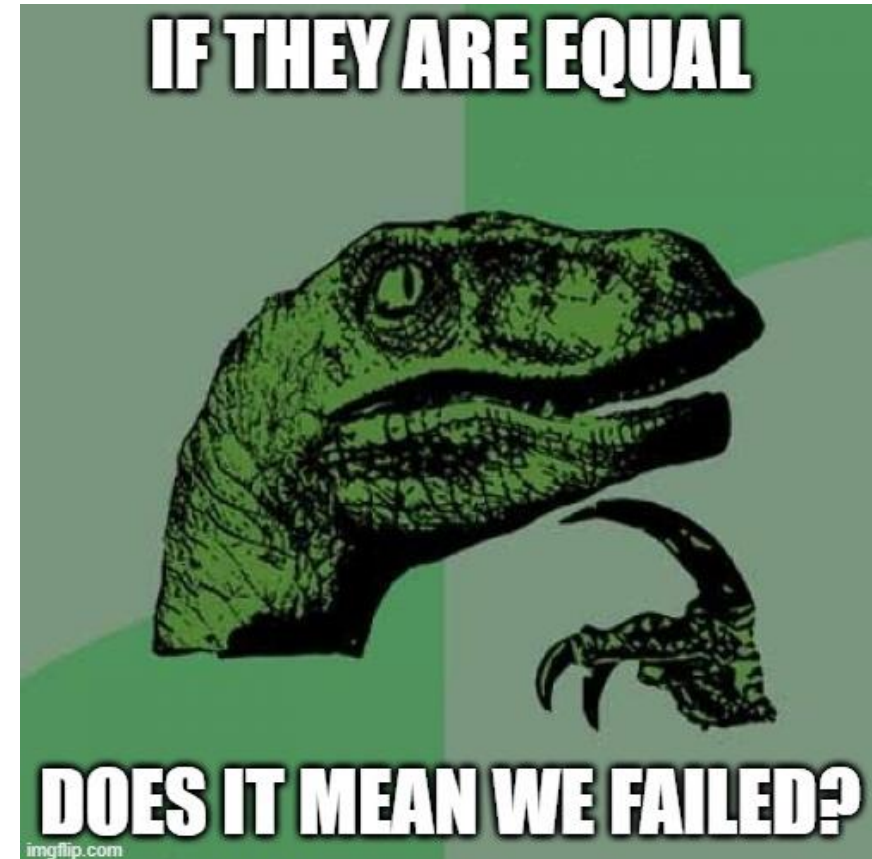
84 comparisons are above 0.9 threshold

0.083 is the minimum similarity achieved



2 users with the same hash

2 correlations almost equal 0.99, with the difference lying in the fonts



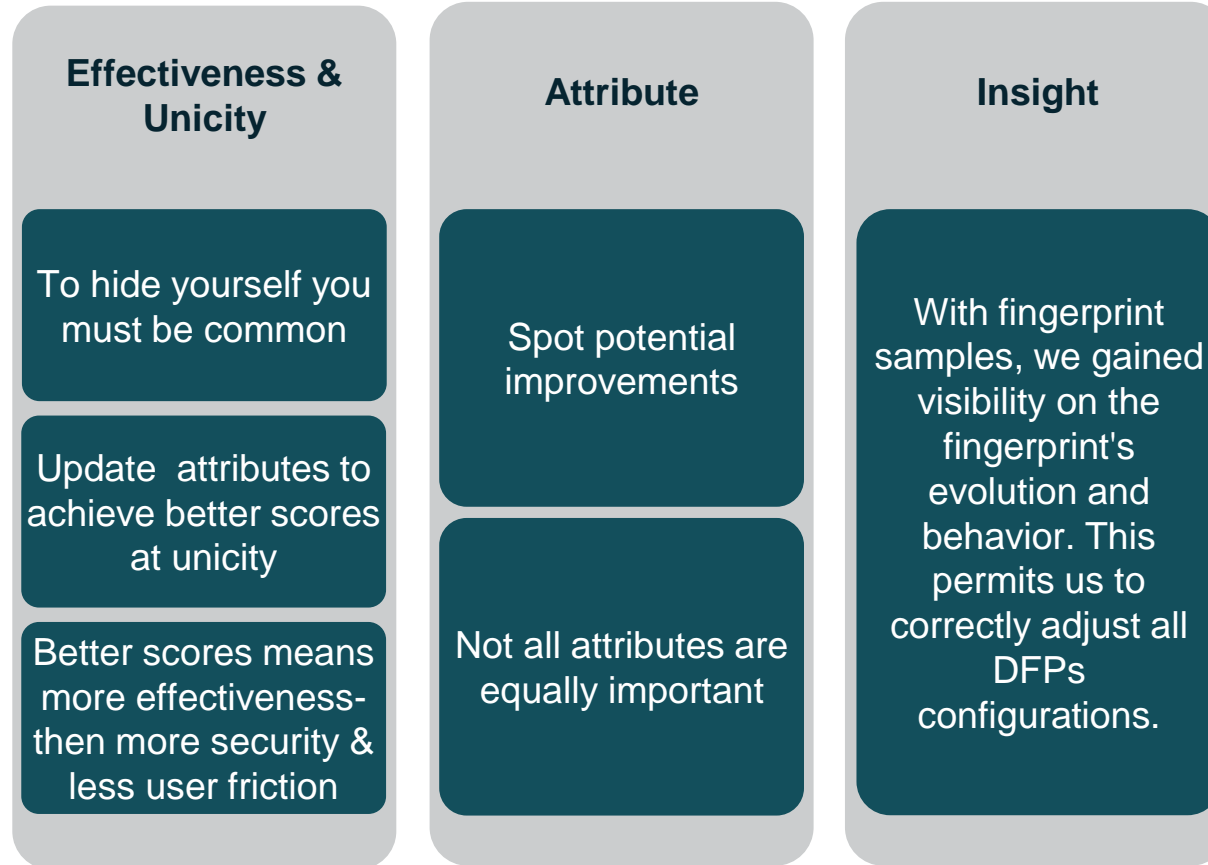
# Conclusions

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# Conclusions



# Some links



## **blog:**

The arms race of Browser Fingerprinting

<https://www.secureauth.com/blog/the-arms-race-of-browser-fingerprinting/>



## **website:**

SecureAuth Innovation Labs

<https://www.secureauth.com/labs/>



## **get in touch!**

- E-mail: [frao@secureauth.com](mailto:frao@secureauth.com)
- E-mail: [lcuzzo@secureauth.com](mailto:lcuzzo@secureauth.com) | Twitter: [@0xdeaddood](https://twitter.com/0xdeaddood)

**DOES ANYONE HAVE ANY**

**“QUESTIONS”?**

**Hasta La Vista**



**Baby**