



IMC '26 · Karlsruhe, Germany

Eadem, Sed Aliter: “the same, but different”

Investigating the Instability of Browser Fingerprinting

Xu Lin¹ · Shujiang Wu² · Jacob Eckfeldt¹ · Pengfei Sun² · Jason Polakis³

¹ Washington State University · ² F5, Inc. · ³ University of Illinois Chicago

Two logins from the same Mac. Same device?

Login 1	
user-agent	Chrome 127
platform	MacIntel
screen	1440 × 900
avail. screen	1440 × 807
canvas	a7f3...91c2
Fingerprint	?



Login 2	
user-agent	Chrome 127
platform	MacIntel
screen	1440 × 900
avail. screen	1440 × 809
canvas	a7f3...91c2
Fingerprint	?

Spot the difference.

Illustrative example

A 2-pixel change makes it a “new” device

Login 1	
user-agent	Chrome 127
platform	MacIntel
screen	1440 × 900
avail. screen	1440 × 807
canvas	a7f3...91c2
Fingerprint	7c1e 09a4



Login 2	
user-agent	Chrome 127
platform	MacIntel
screen	1440 × 900
avail. screen	1440 × 809 +2px
canvas	a7f3...91c2
Fingerprint	d04b 63f2

Nothing on this Mac changed.

→ extra 2FA

7,054 devices at Bank-A had exactly this change

Real logins at five high-value services

184M

login sessions

7M+

users

18

attributes per login

Sessions per service, Aug 2023 – Feb 2024

Bank-A
169.2M

Bank-B
8.1M

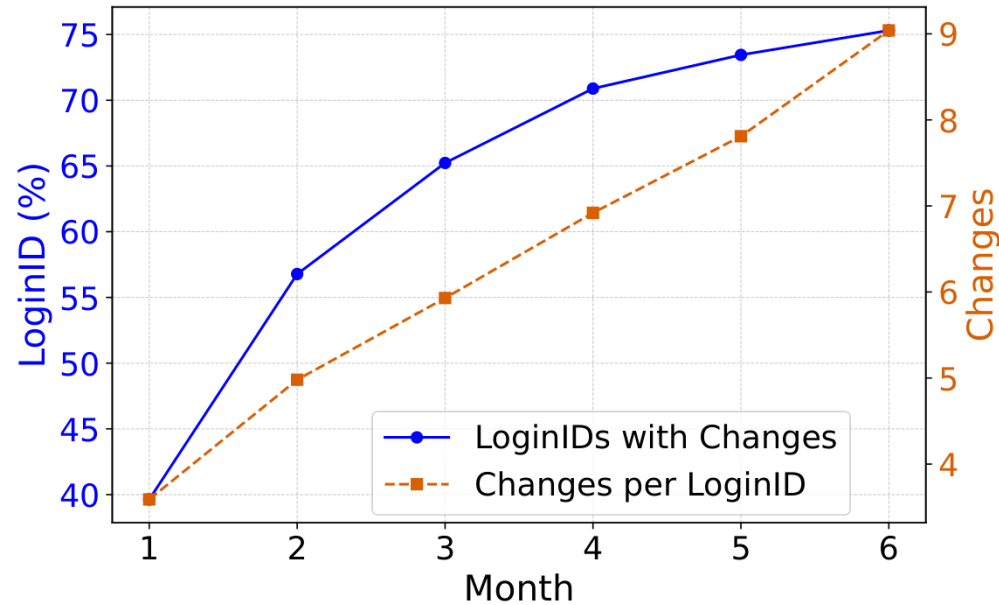
Credit-A
6.1M

Retail-A
449K

Bank-C
193K

Legitimate sessions only · anonymized

Fingerprints change, even without updates



75% changed by month 6

Same user-agent (August):

avail. resolution **up to 9.10%**

canvas **up to 5.88%**

pixel ratio **2.02%**

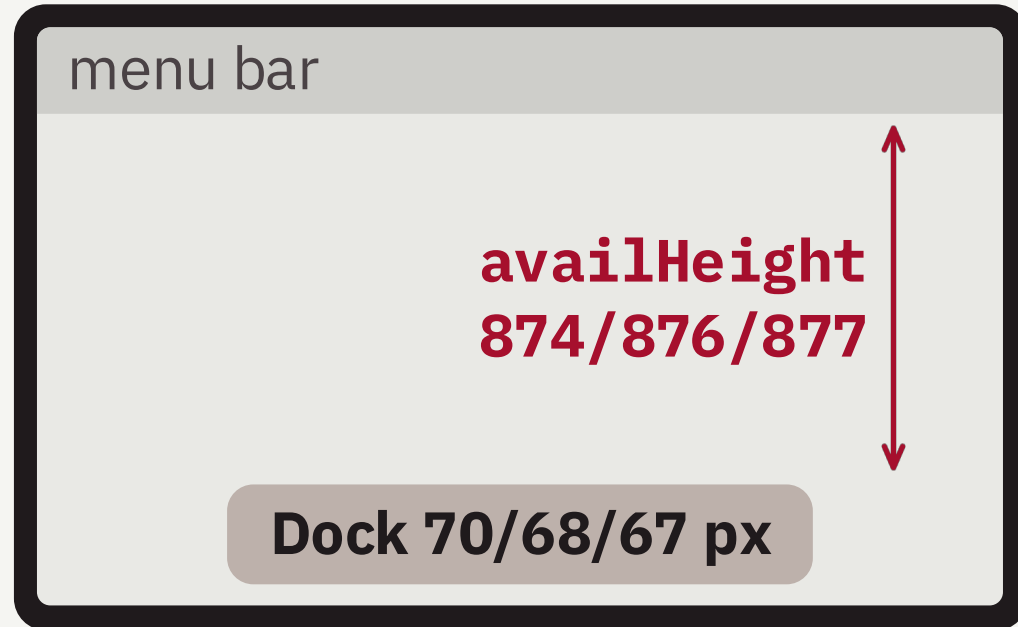
fonts **1.25%**

WebGL **<1%**

Unstable values last 2–5 days.

Finding 1 Attributes change even with the same user-agent

Those 2 pixels come from the macOS Dock



>**90%** of these Mac changes had an unchanged user-agent

Seen before, never explained:



“Unfortunately, we don’t know a way to make it 100% stable yet.”

FingerprintJS maintainer, 2021

Samsung Internet perturbs canvas on purpose

1 Xa9!~r&T(4qL@z*

2 Xa9!~r&T(4qL@z*, 😊

3 Jived fox nymph grabs quick waltz, 😊
Xa9!~r&T(4qL@z*, 😊

4 Jived fox nymph grabs quick waltz, 😊
Xa9!~r&T(4qL@z*, 😊



6 test images, 10 visits, Galaxy A15

But anti-fp defenses cause few changes:
≤4.03% of all canvas-changing accounts

6 of 6

changed across 10 visits

$(0, 0, 0, 0) \rightarrow (0, 2, 0, 0)$

$(0, 3, 0, 0) \rightarrow (0, 0, 0, 0)$

85%

unstable canvas on Samsung
Internet at Bank-A

More causes inside browsers and platforms

Firefox on Windows · fonts

Fonts swap or load late

Helvetica → Arial

22%

of Windows Firefox devices at Bank-A

In-app browsers · platform

iPhones claiming Linux

iPhone UA + Linux aarch64

1,344

iOS devices flipping armv8l ↔ aarch64

Finding 2 Instability clusters in specific browser–OS combos

Changed values tend to flip back

We call these **FP-flips**.

canvas hash over 5 logins

3f9c **b81e** **3f9c** **3f9c** **b81e**

value pair

7 of 16

attributes: top pair reverts
>80% of the time

Top pair reverted in 6 months, Bank-A

canvas		89.66%
pixel ratio		86.25%
fonts		86.08%
avail. res.		84.79%
screen res.		84.33%
plugins		83.83%
hist. timestamp		82.36%
user-agent		0.28%

Finding 3 Values flip-flop among a small set of value pairs

Unstable, but *predictable*.

20 pairs

account for half of all font changes

89%

of devices changing from Linux armv8l
switched to just 2 other values

Predictive-FP anticipates the flips

1 • Learn

Learn flips from all users

armv8**1** (letter **1**)
→armv8**1** (number **1**)
→aarch64
89.2% of 10,859



2 • Expand

Store each value's anticipated set

{armv8**1**,
armv8**1**,
aarch64, ...}
7 values: 99.93%



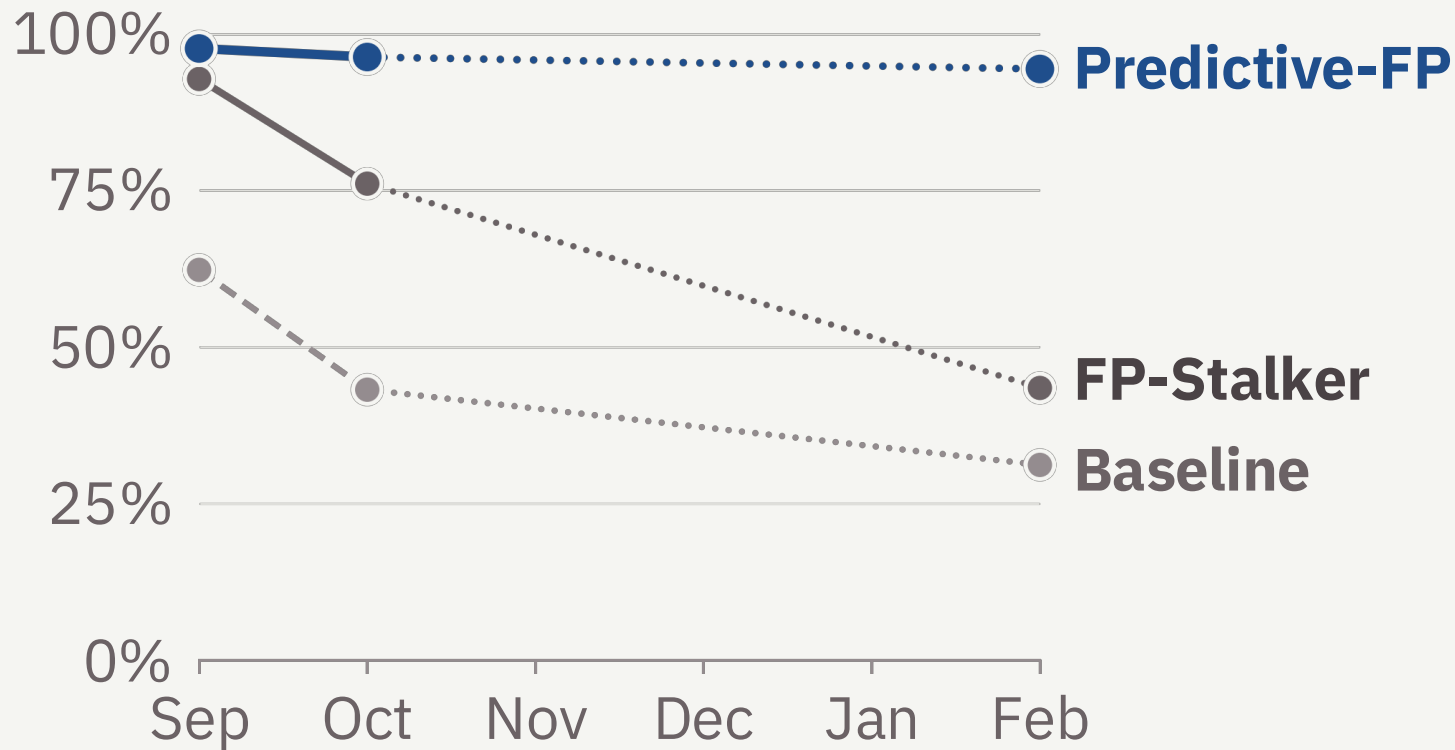
3 • Match

Values in the set keep the ID

aarch64 ∈ set
✓ **same ID**

Learned from Bank-A's August data · Fixed for six months

After six months, **94%** keep a consistent ID



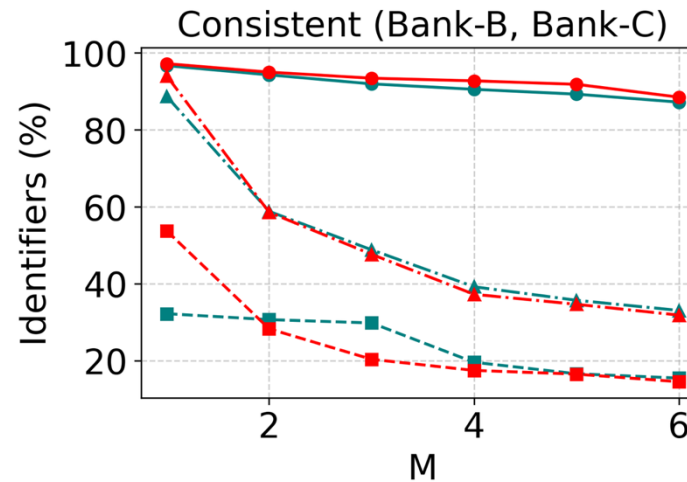
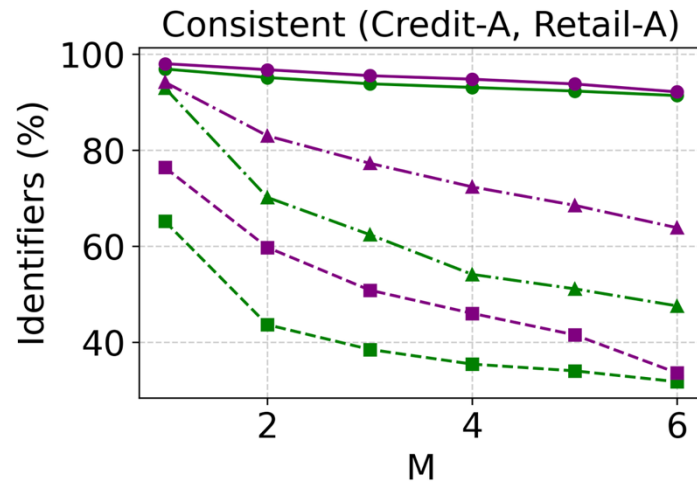
+51 pts

over FP-Stalker¹

Bank-A, 6.84M returning accounts; cookie as the device reference

¹ Vastel et al. FP-Stalker: Tracking Browser Fingerprint Evolutions. IEEE S&P 2018

It generalizes without adding collisions



Solid: Predictive-FP · dashed: Baseline
dash-dot: FP-Stalker

Unique IDs (distinct consistent IDs): higher than Baseline and FP-Stalker at all five services, every month

91.4%

Credit-A, month 6
baseline: 31.5%

672

shared IDs, Bank-C
baseline: 2,002
accounts affected:
35.21% → 32.21%

Durable fingerprints can also help trackers

So we built a browser extension defense:

-  **Randomize every session**
user-agent, fonts, canvas, WebGL, screen
-  **Allowlist trusted sites**
no randomization on your bank's website
-  **Choose the session length**
for example, one day

30 Tranco top-50 sites +
Chase

31/31

worked for browsing and
sign-in

6 sign-up flows needed
extra checks

Takeaways

1 Unstable even when nothing changes

40% change within a month; some change with no user action

2 The instability follows patterns

Values often return; a few transitions explain many changes

3 Anticipating flips makes fingerprints durable

94% consistent IDs after 6 months (no canvas); privacy extension



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Thank you!

Questions?

Contact

xu.lin@wsu.edu

Canvas and Chrome 120

94.37%

Bank-A, month 6, canvas excluded

67.66%

Bank-A, month 6, canvas included

Chrome 120 arrived in month 4 and produced canvas values that the August knowledge base had never seen.

Possible fix: use several canvas images; across Chrome versions, they did not all change at once.

Why collisions decrease

Baseline: one device, many IDs

Every change creates a new short-lived ID. More IDs, more accidental matches.

35.21% → 32.21%

Bank-C accounts affected by ID collisions

Unique ID counts distinct, consistent identifiers.

Predictive-FP: one device, one ID

Anticipated changes stay in one small value set: one stable, high-entropy ID per device.

17.98%

Unique IDs, Bank-A, month 6
Baseline 10.99% · FP-Stalker 10.30%
higher at all five services, every month