FP-RowHammer: DRAM-Based Device Fingerprinting

Hari Venugopalan, **Kaustav Goswami**, Zainul Abi Din, Jason Lowe-Power, Samuel T. King and Zubair Shafiq

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Background

Fingerprinting

"*A device fingerprint or machine fingerprint is information collected about the software and hardware of a remote computing device for the purpose of identification.*"

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Stateful identifiers

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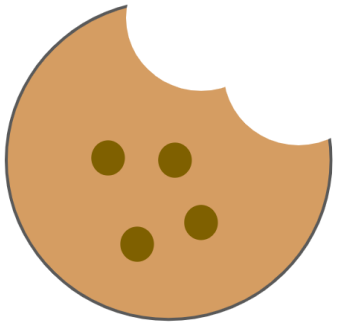

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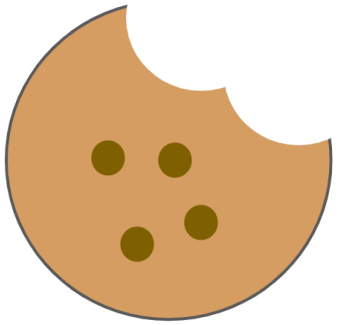

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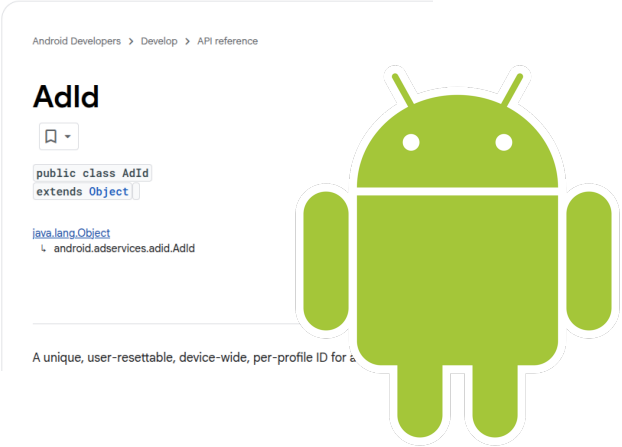

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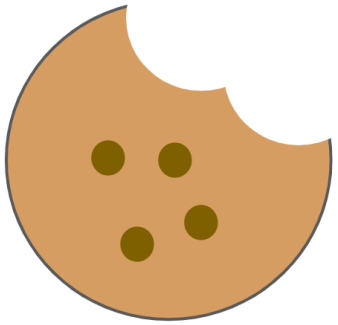

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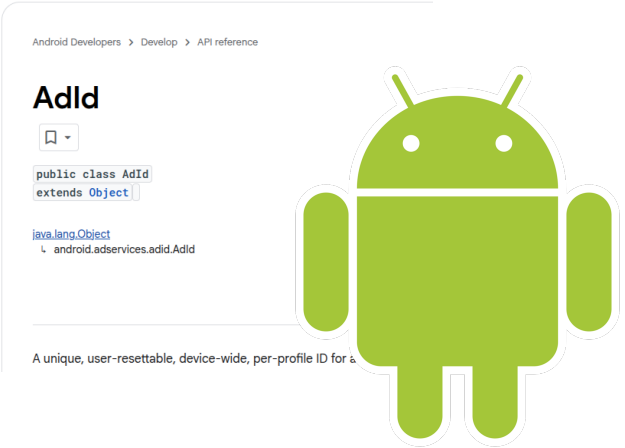

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DRAWNAPART: A Device Identification Technique based on Remote GPU Fingerprinting

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[3] Laor *et al*. DRAWNAPART: A Device Identification Technique based on Remote GPU Fingerprinting, NDSS 2022

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DeMiCPU: Device Fingerprinting with Magnetic Signals Radiated by CPU

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Yi-Chao Chen University of Texas at Austin yichao@utexas.edu

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[4] Y. Cheng *et al.*, DeMiCPU: Devie Fingerprinting with Magnetic Signals Radiated by CPU, ACM CCS 2019

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Wenyuan Xu Zhejiang University wyxu@zju.edu.cn
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Clock Around the Clock: Time-Based Device Fingerprinting

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Igor Santos Deustotech, University of Deusto isantos@deusto.es
Davide Balzarotti Eurecom davide.balzarotti@eurecom.fr

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[5] I. Sanchez-Rola *et al.*, clock Around the clock: Time-Based Device Fingerprinting, ACM CCS 2018

What is a good fingerprint?

Uniqueness

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Uniqueness: Different users must have different IDs

001	002	003

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Stable

What is a good fingerprint?

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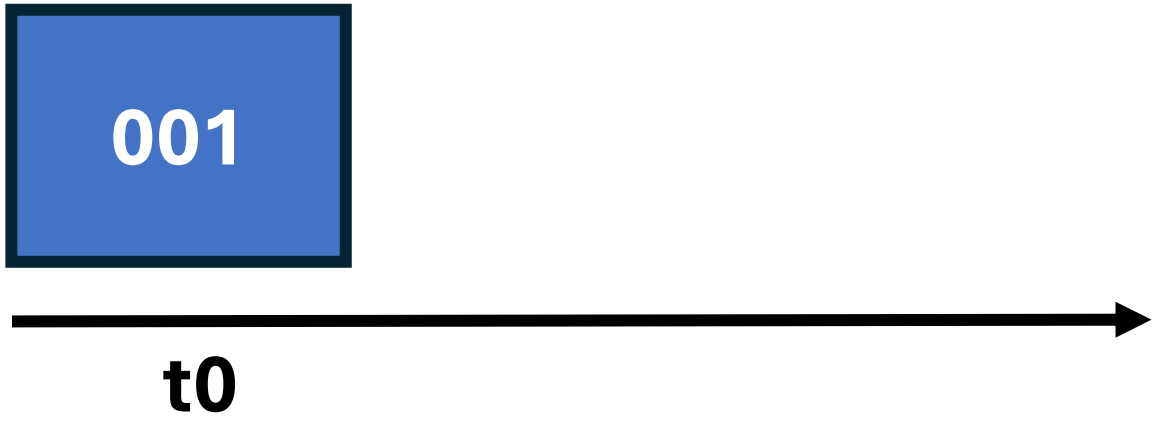
Stable: The fingerprint of a device should never change.



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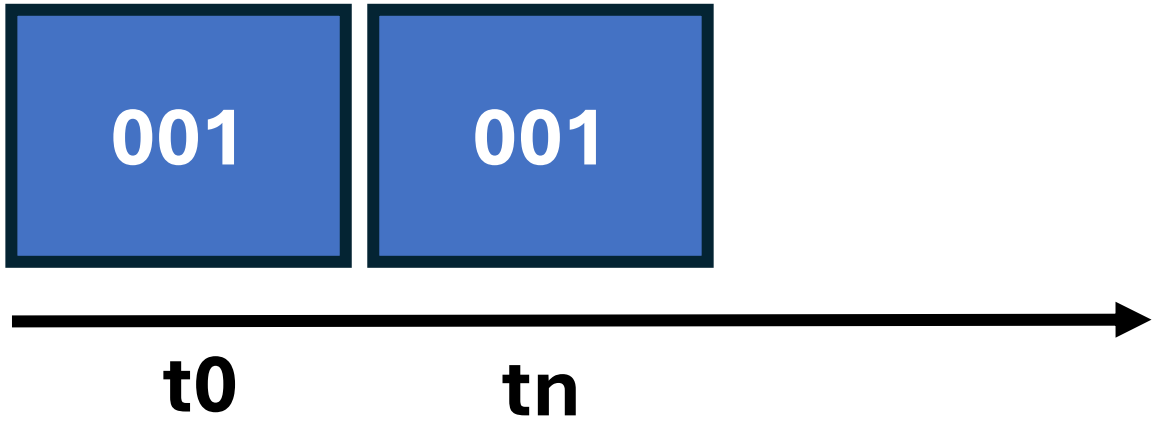

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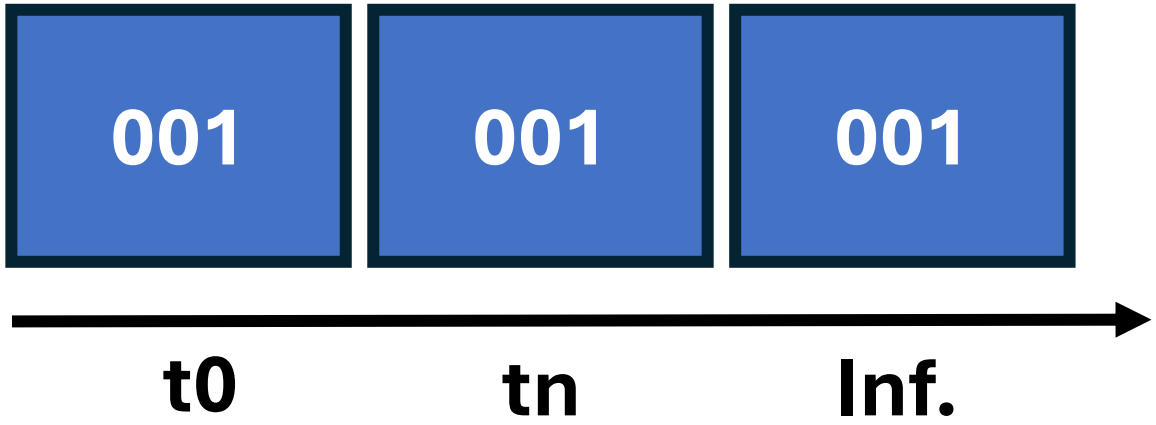

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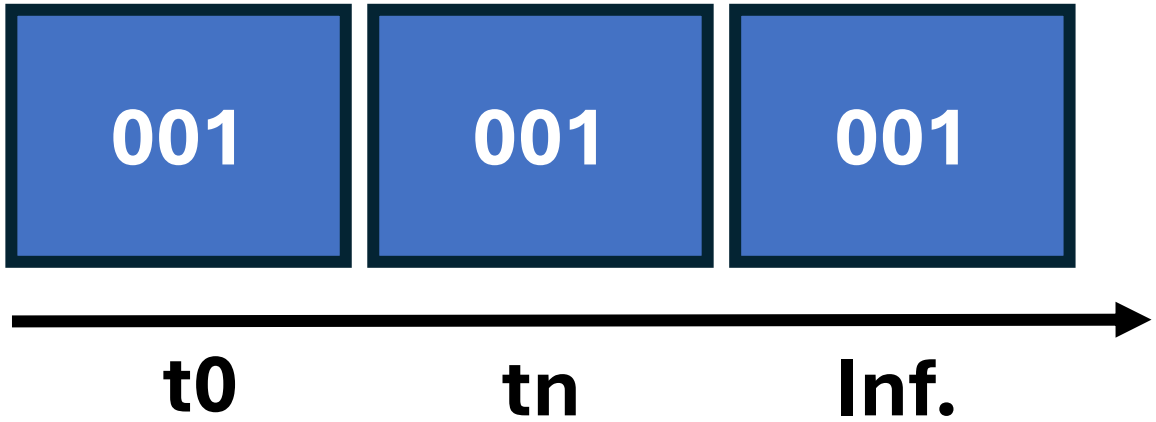
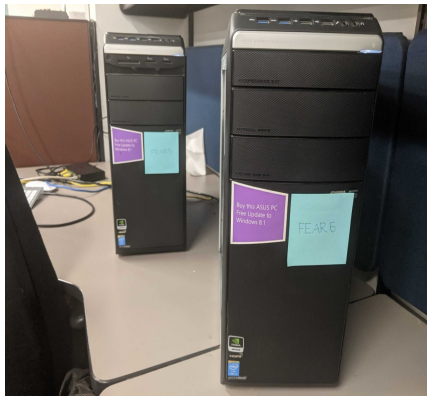


Test: Homogeneous Devices



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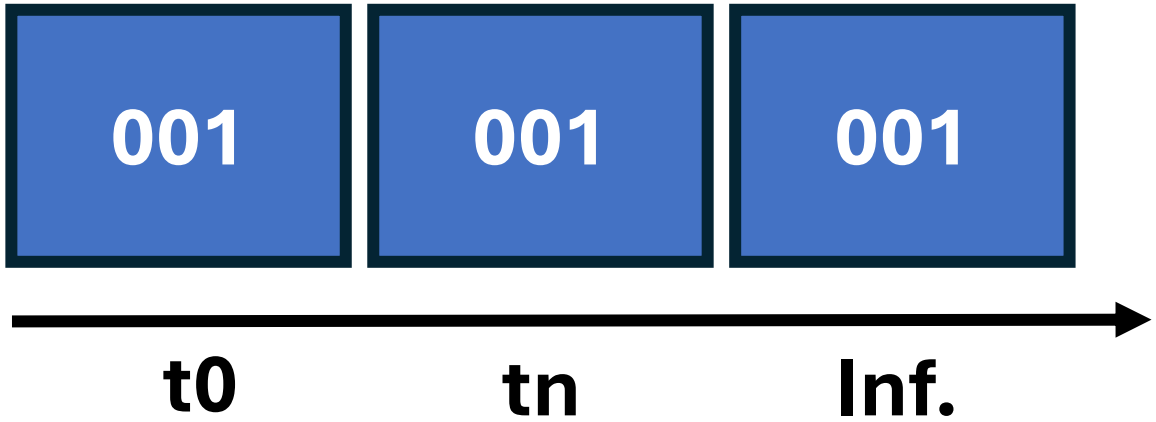

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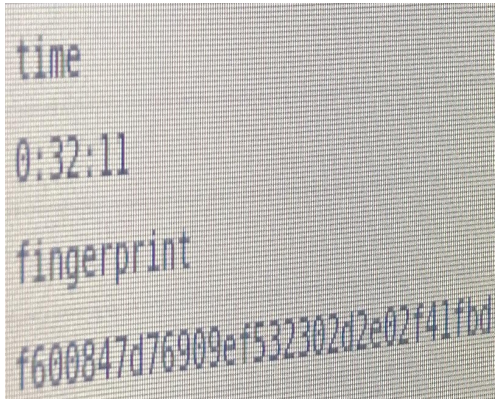

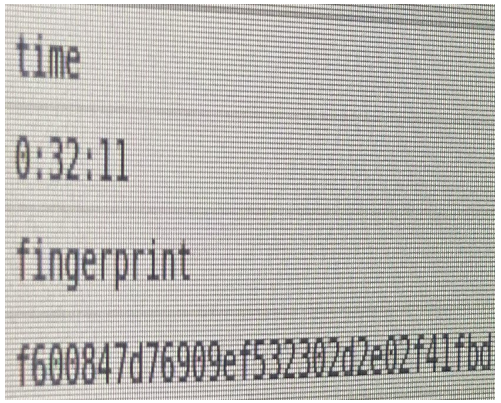

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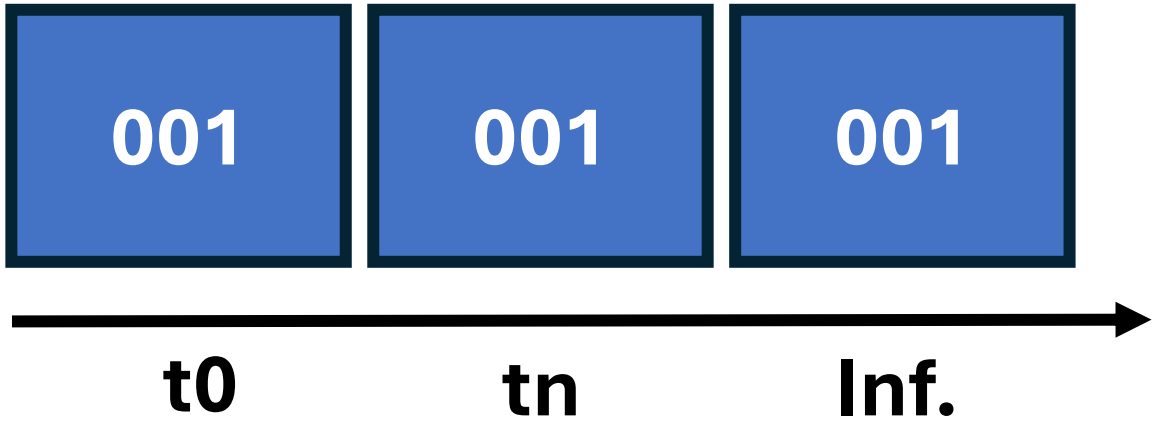

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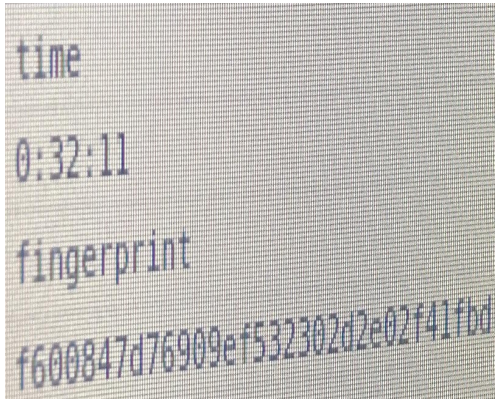

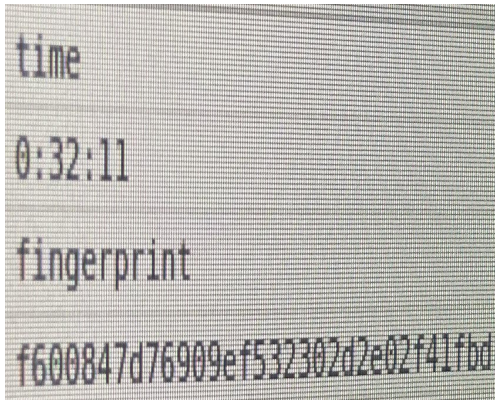

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Enter FP-RowHammer

Double **D**ata **R**ate **4** **D**ual
In-Line **M**emory **M**odule

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DDR4 DIMM

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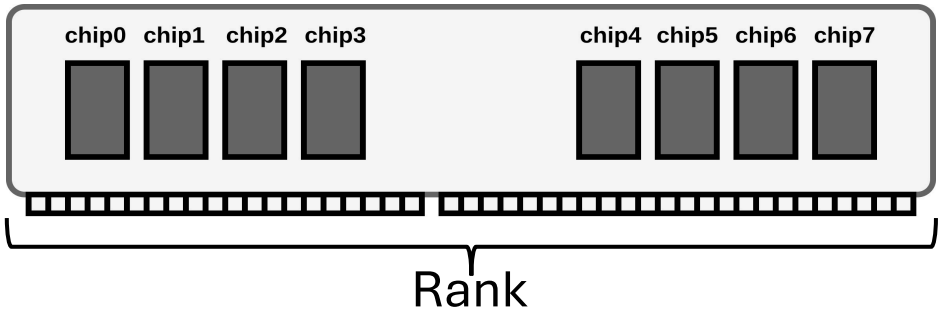

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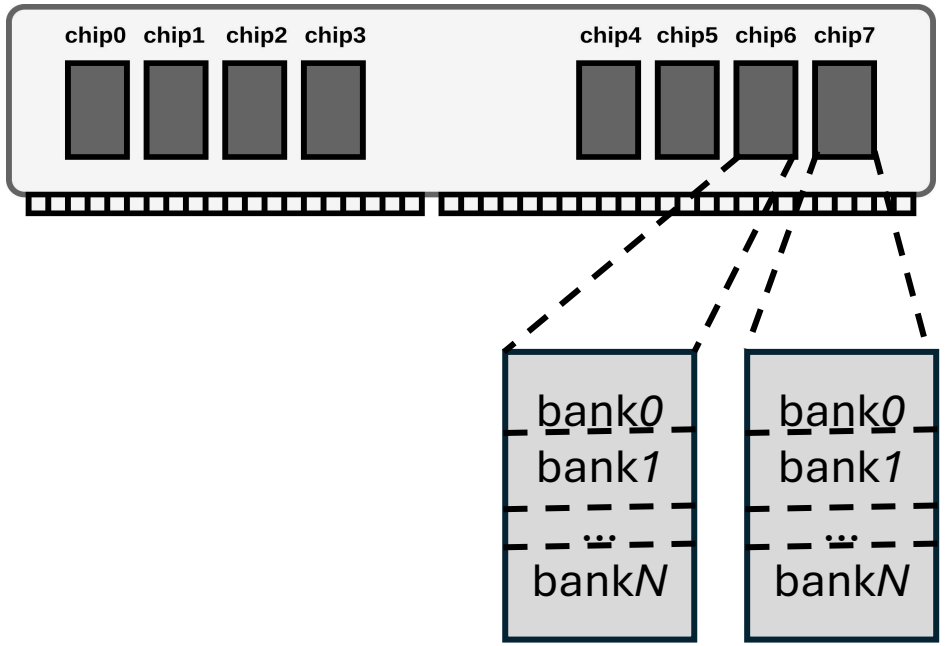

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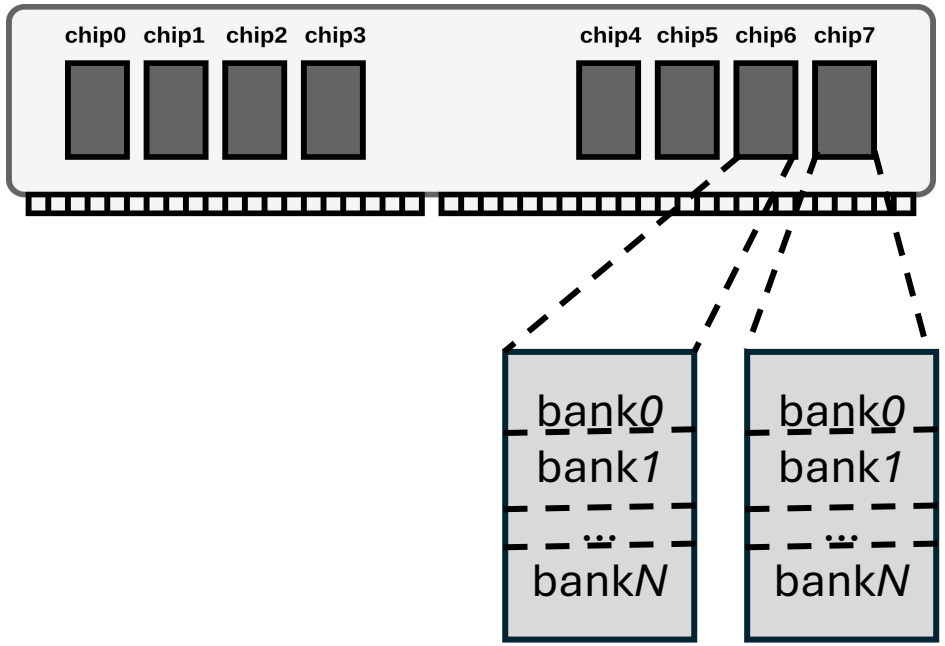

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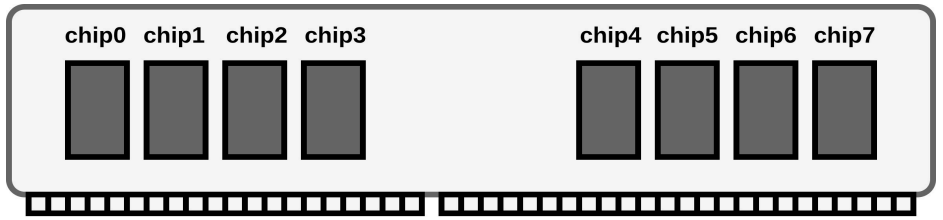

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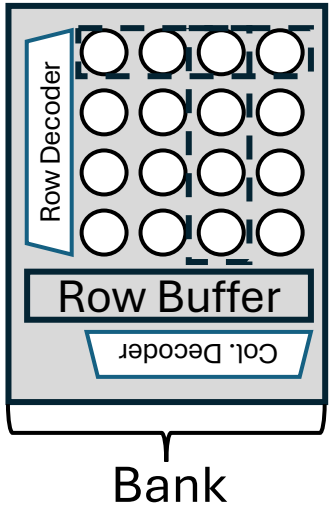

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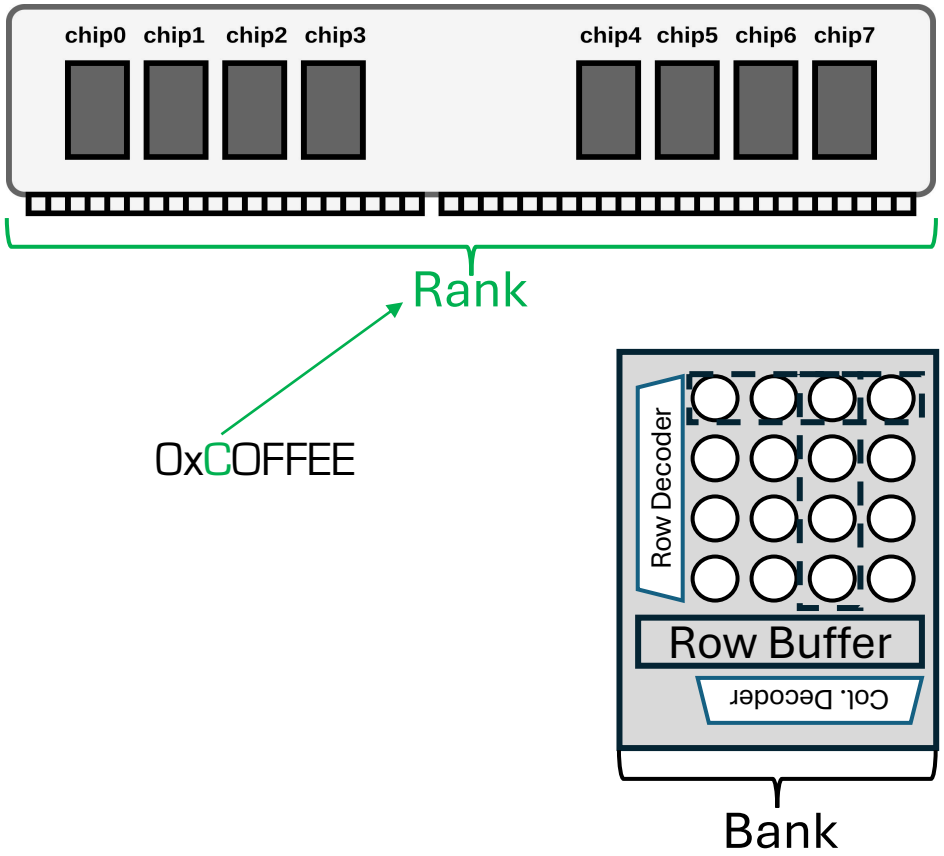

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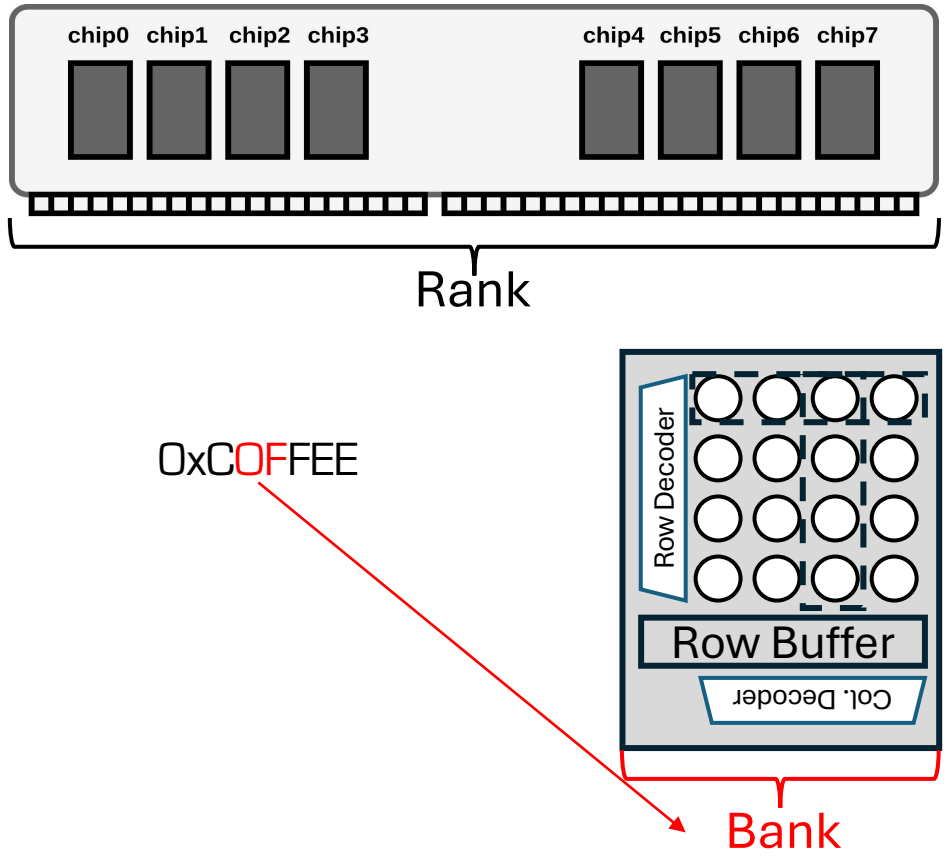

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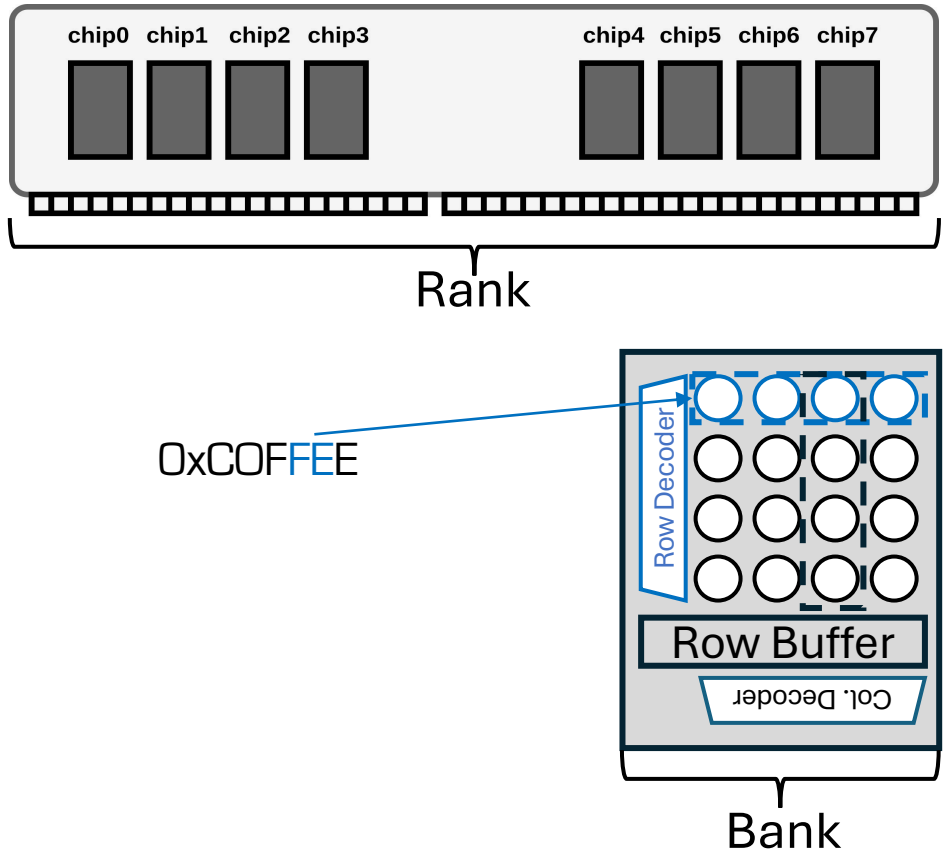

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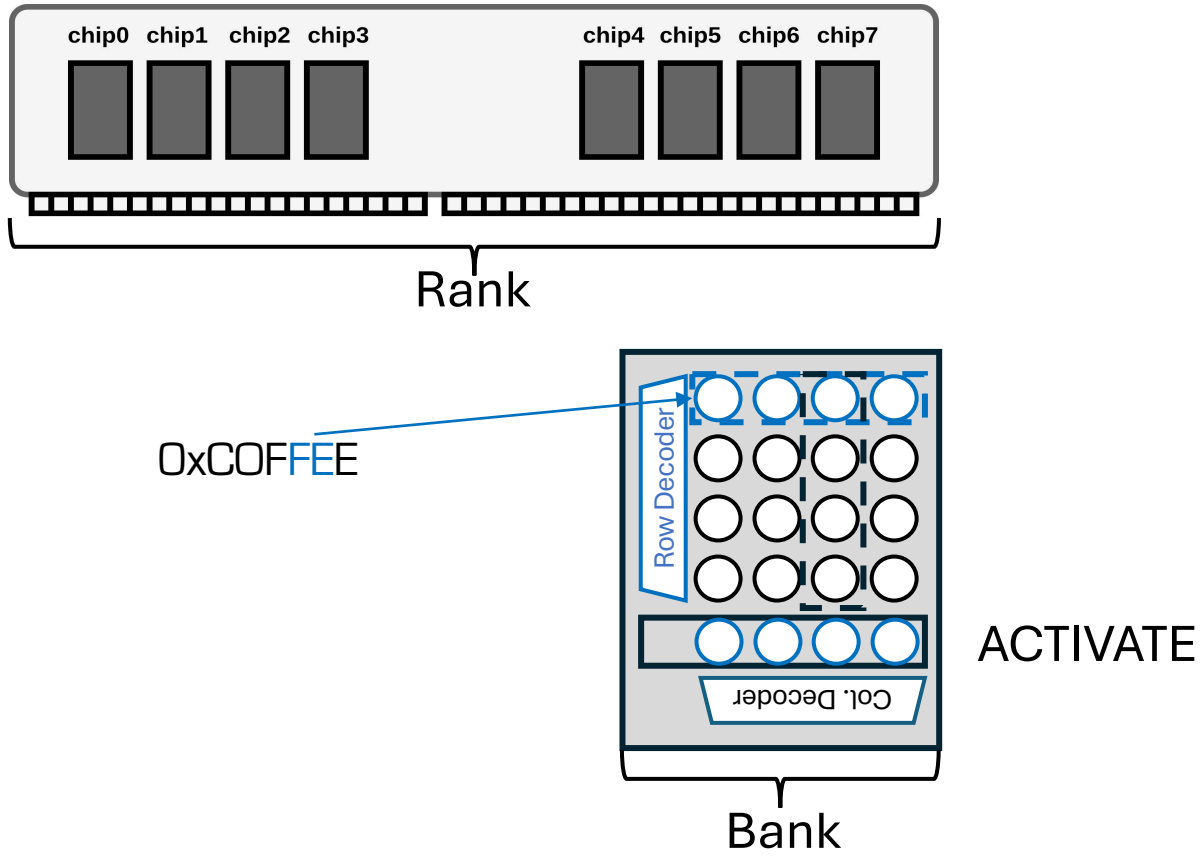

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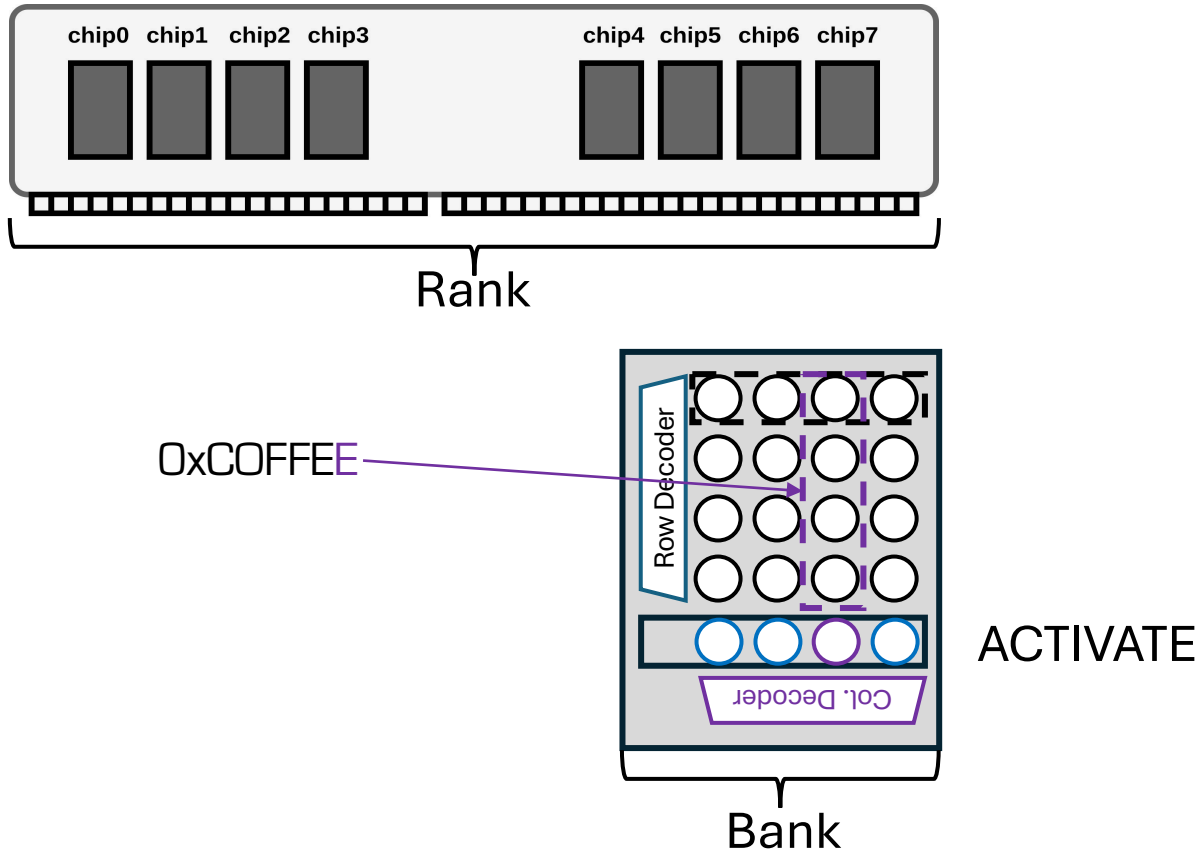

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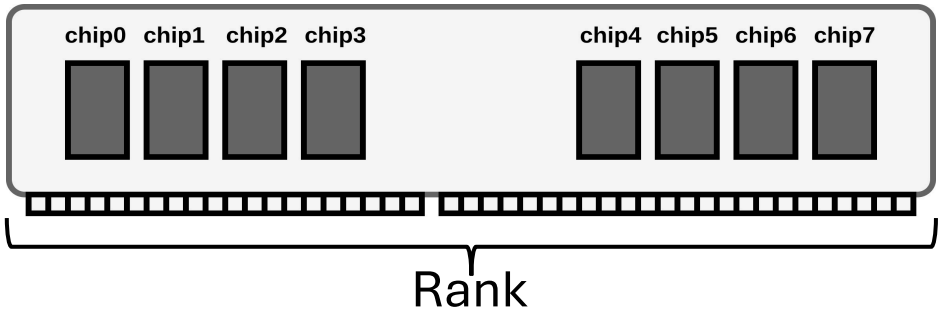

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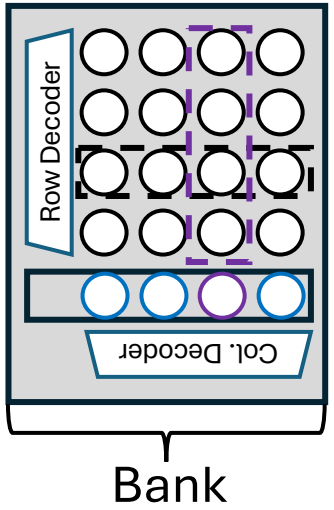

ACTIVATE

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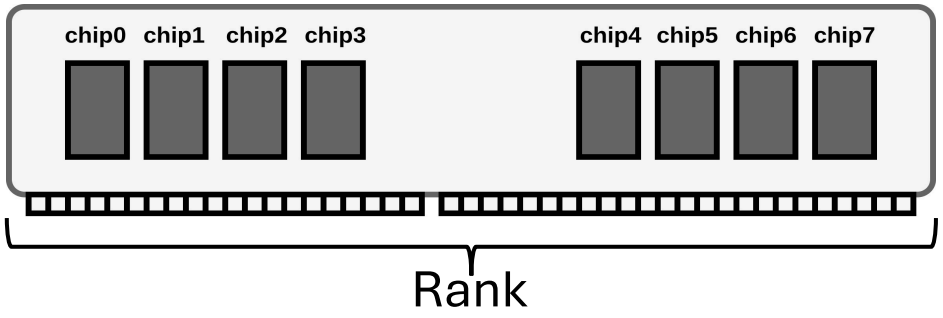

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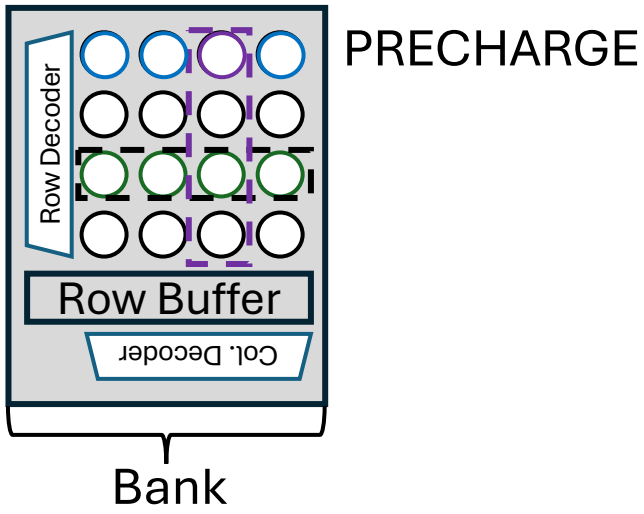

PRECHARGE

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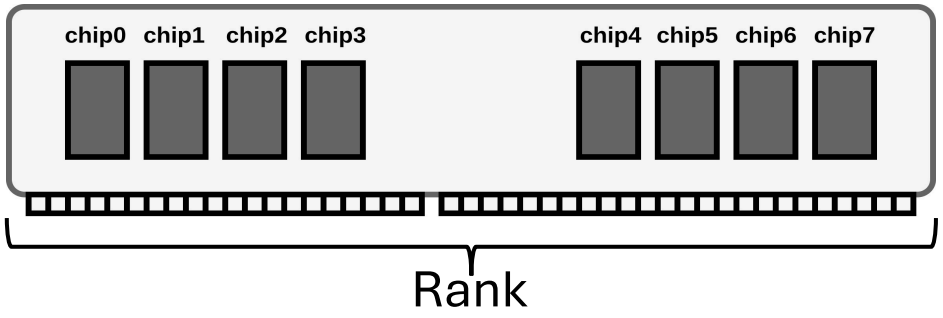

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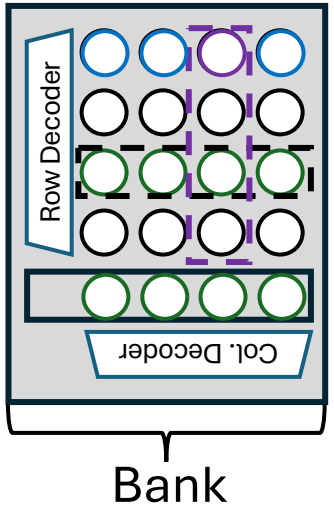

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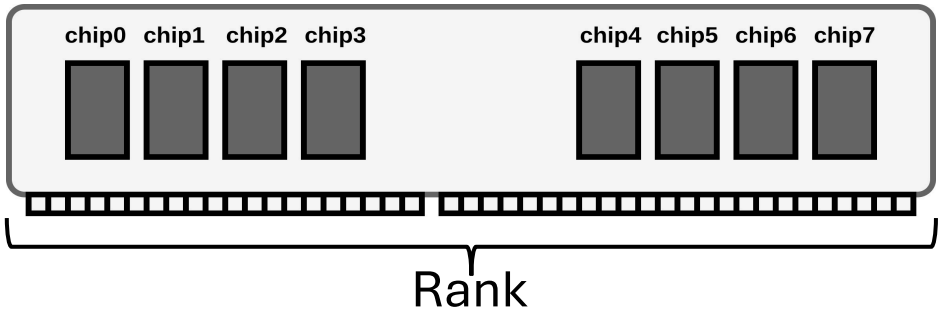
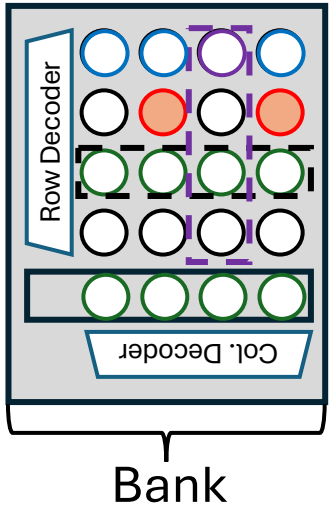


Bitflips!

0xCOFFEE
0xCOFFFE
0xCOF00E



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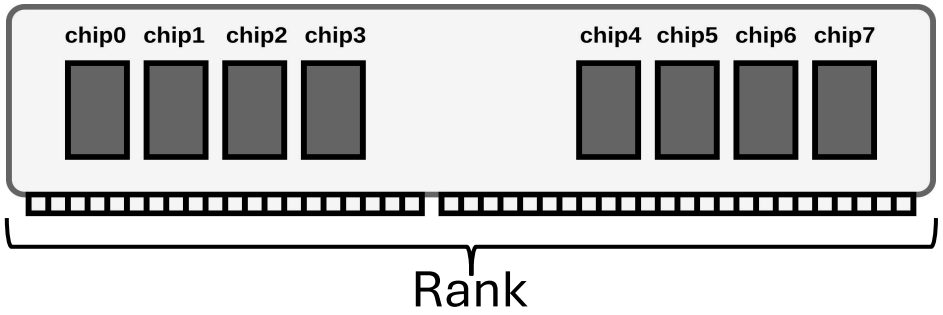

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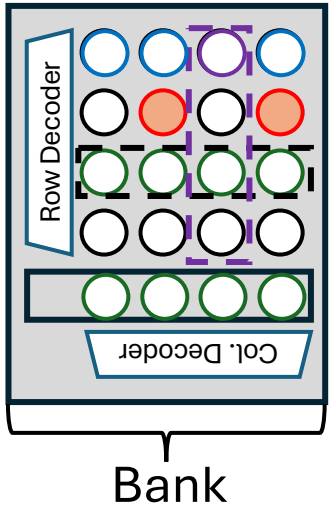

RowHammer

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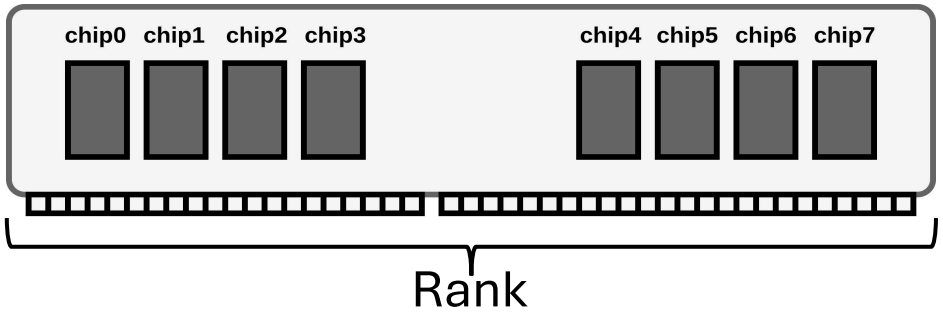

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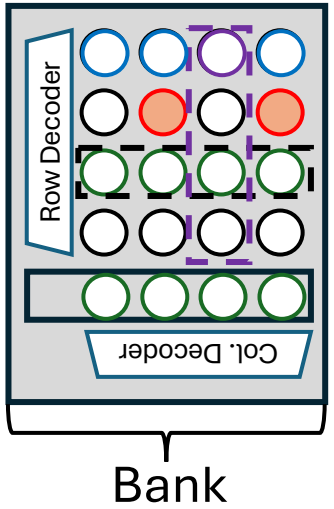

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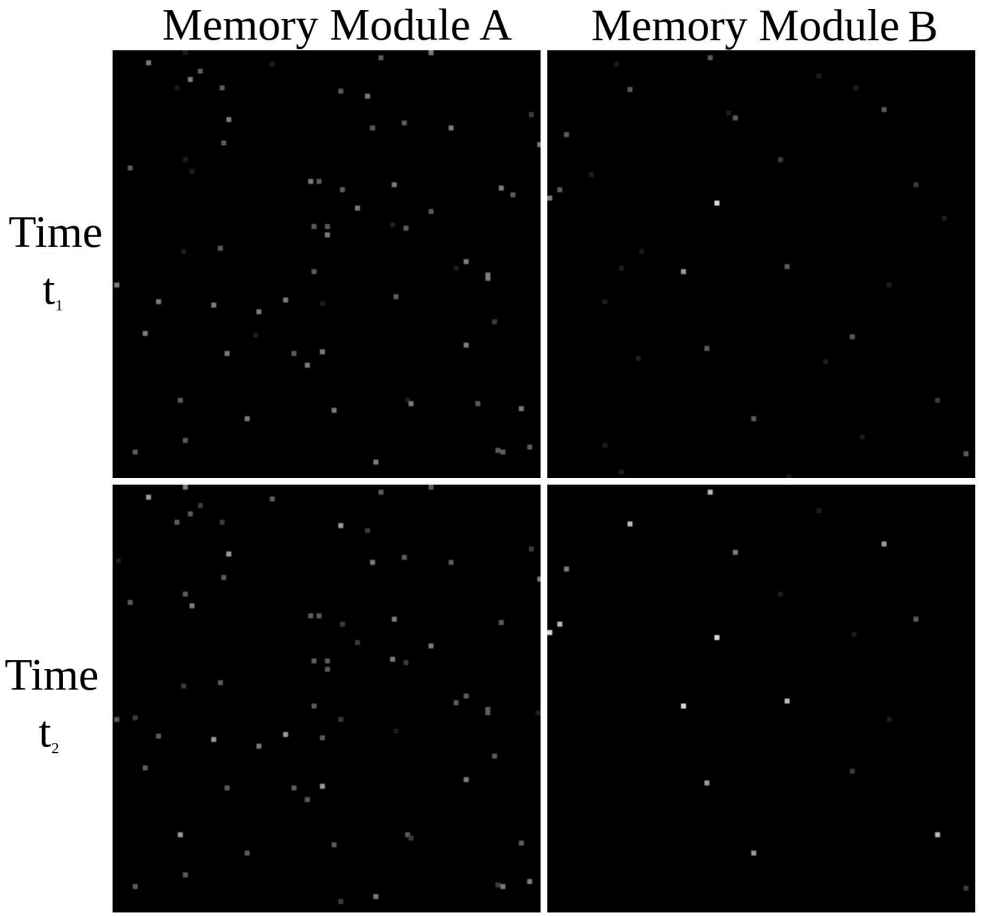

Threat Model

- We consider a host-based fingerprinting model
  - Authentication
  - Cross-application tracking
  - Targeted attacks
  - Anti-cheat techniques
- Assumptions
  - Unprivileged attacks
- Challenges
  - Bitflip non-determinism
  - Overcome OS memory abstractions
  - RowHammer defenses

Test bed

We used 98 DIMMs from two DRAM manufacturers.

Dimension	Manufacturer A	Manufacturer B
1Rx8	35	10
1Rx16	11	2
2Rx8	36	4
Total	**82**	**16**

We used 8 Intel Kaby Lakes, 2 Sky Lakes and 1 Coffee Lake machines.

Getting around non-determinism

- Bitflips are **arbitrary**.
- We used JS divergence to match fingerprints on a 2 MiB page.
- We used the birthday paradox to quickly find the same region.

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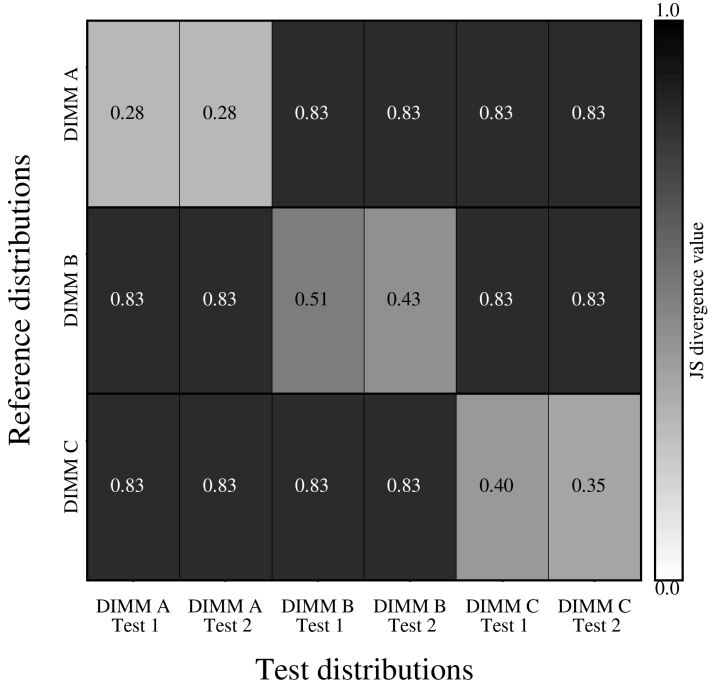

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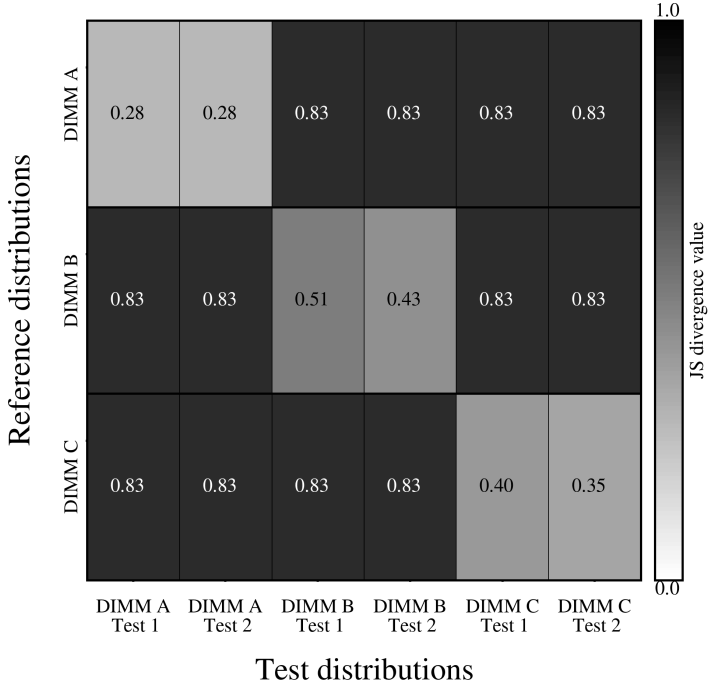
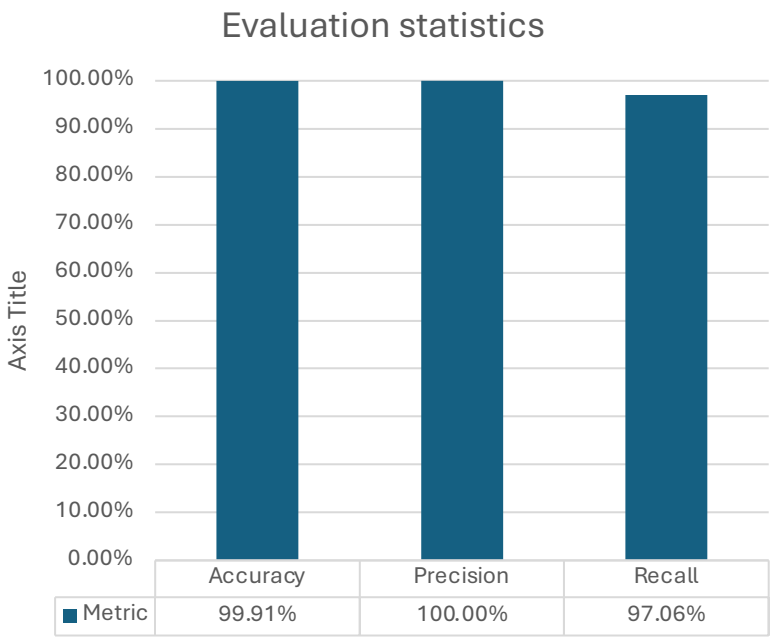
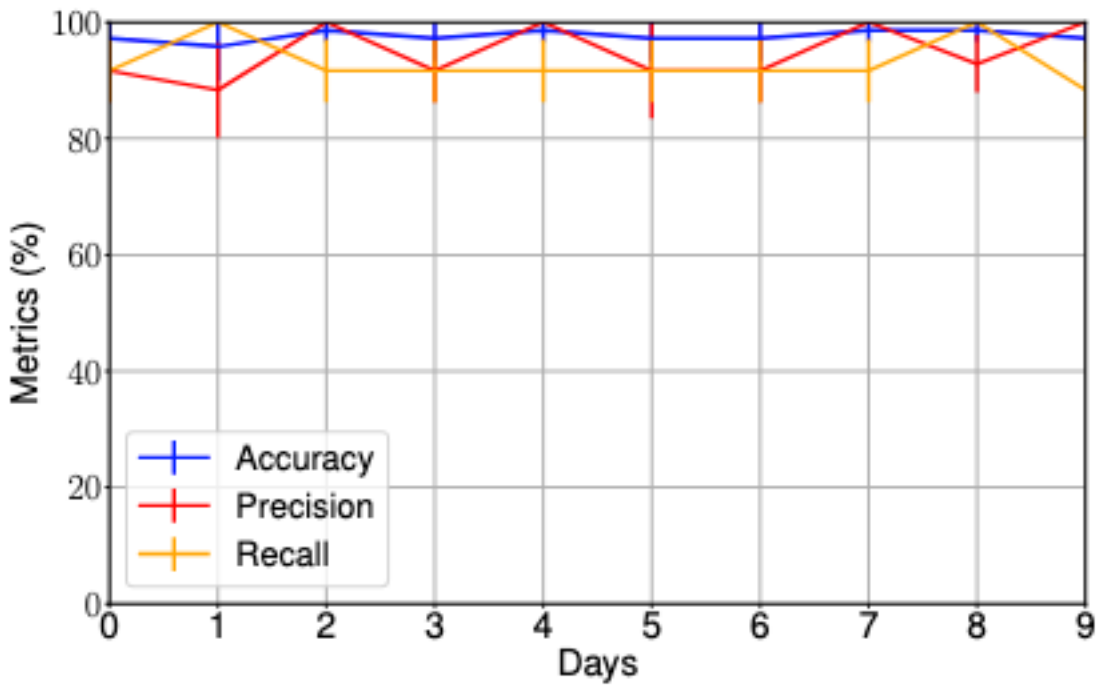
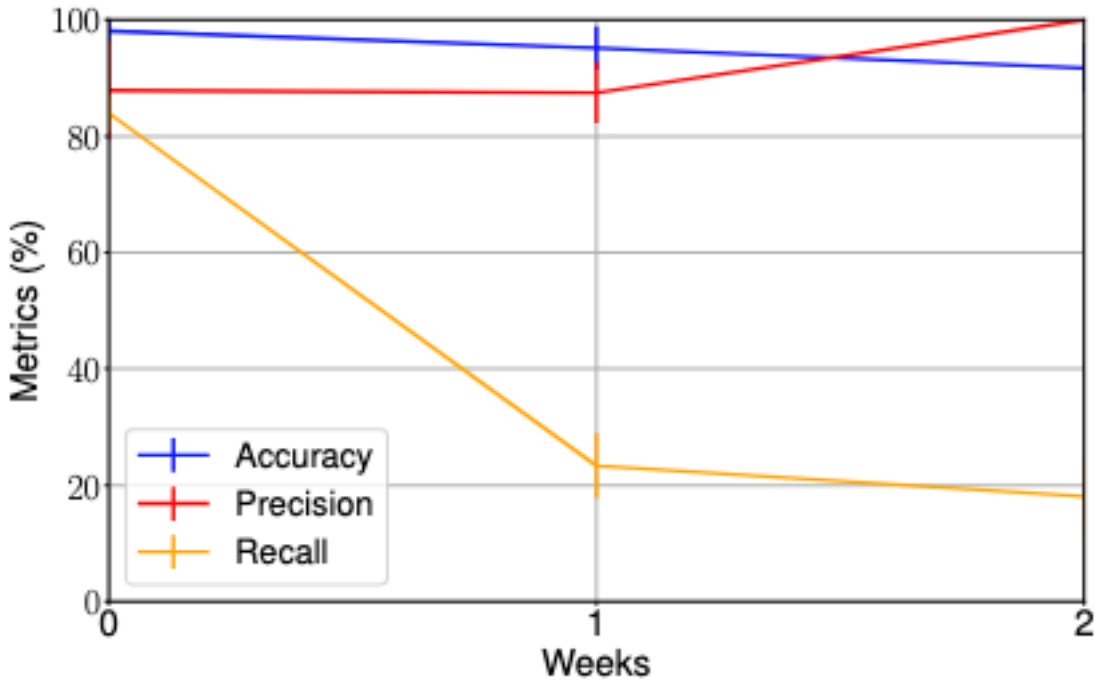




Stability

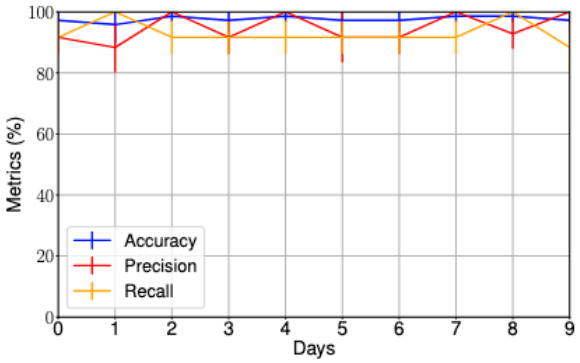


Fingerprint metrics across **days**



Fingerprint metrics across **weeks**

Stability



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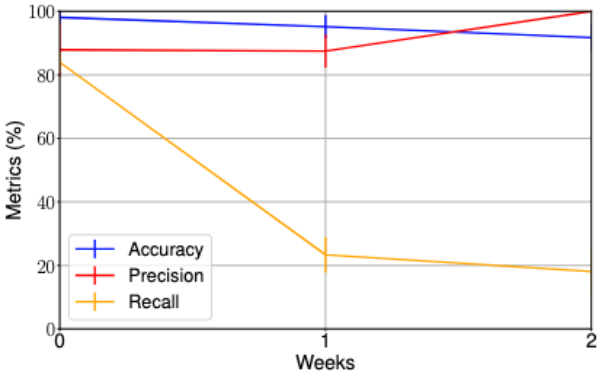
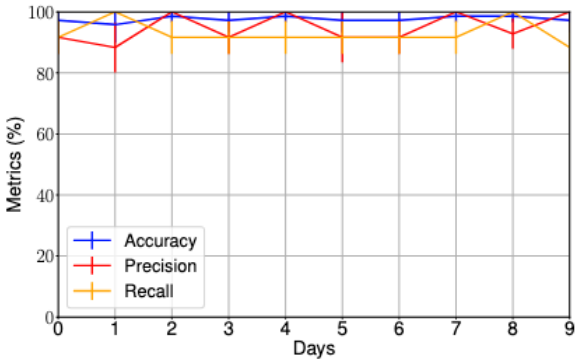


Fingerprint metrics across **weeks**

Why is there a drop in performance?

Stability



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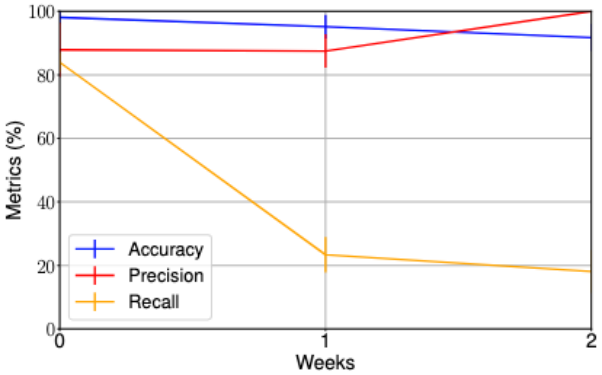

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Why is there a drop in performance?

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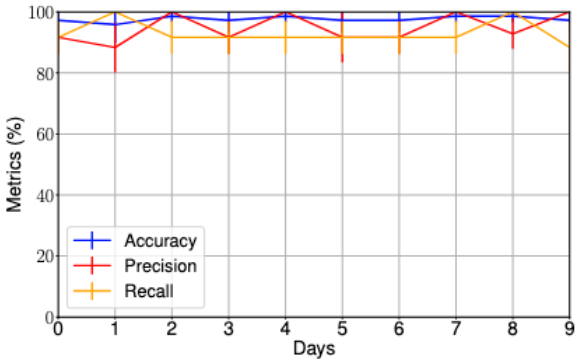

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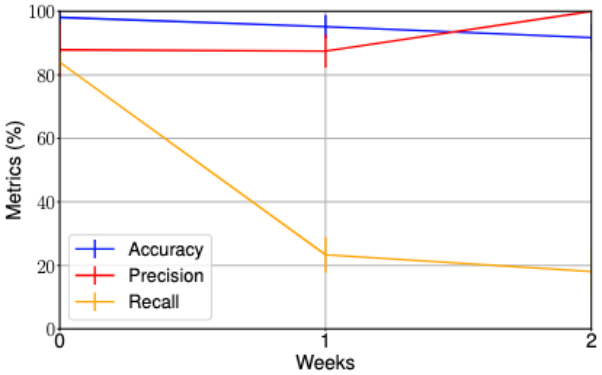

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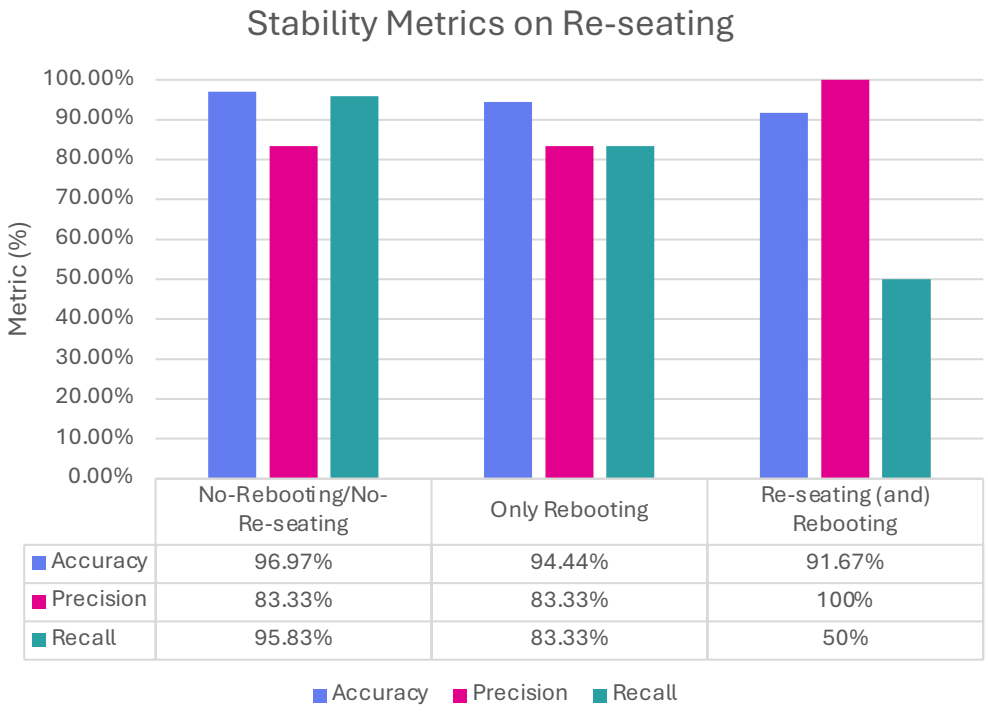


	No-Rebooting/No-Re-seating	Only Rebooting	Re-seating (and) Rebooting
Accuracy	96.97%	94.44%	91.67%
Precision	83.33%	83.33%	100%
Recall	95.83%	83.33%	50%

Why is there a drop in performance?

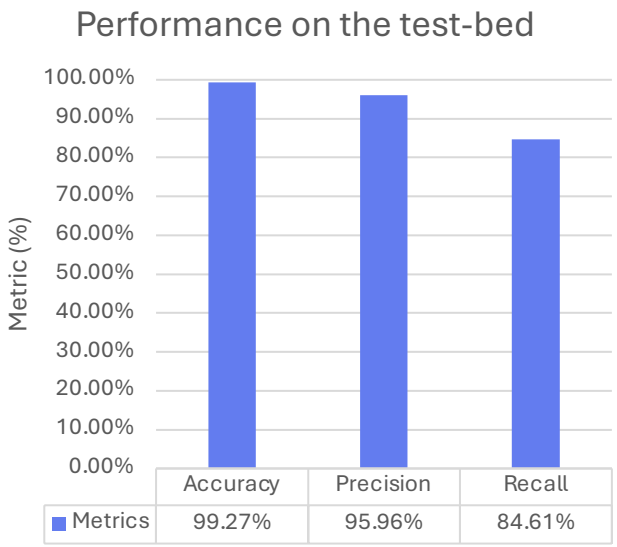
Re-seating

Performance and Robustness

100,000 accesses

Repeating twice

9.9 seconds



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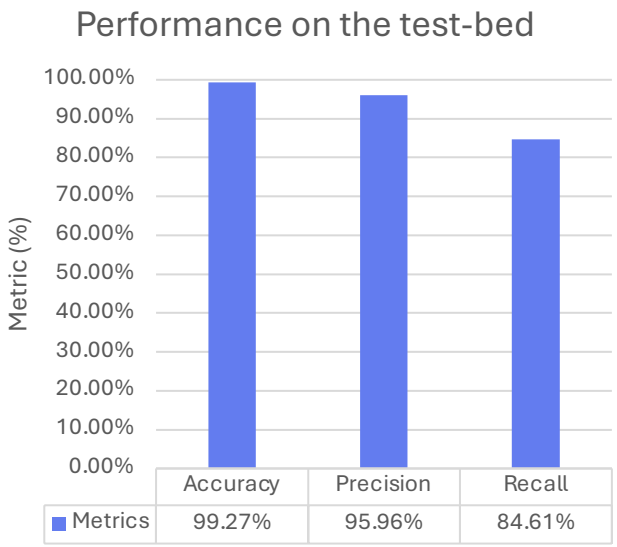
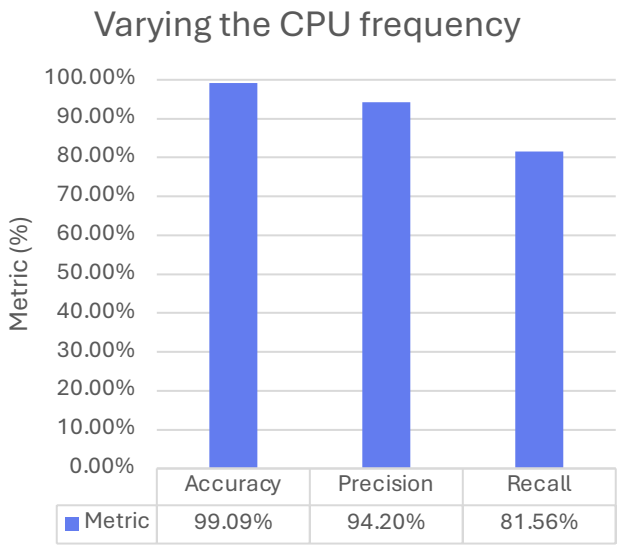
Running YouTube

No crashes.





Performance and Robustness

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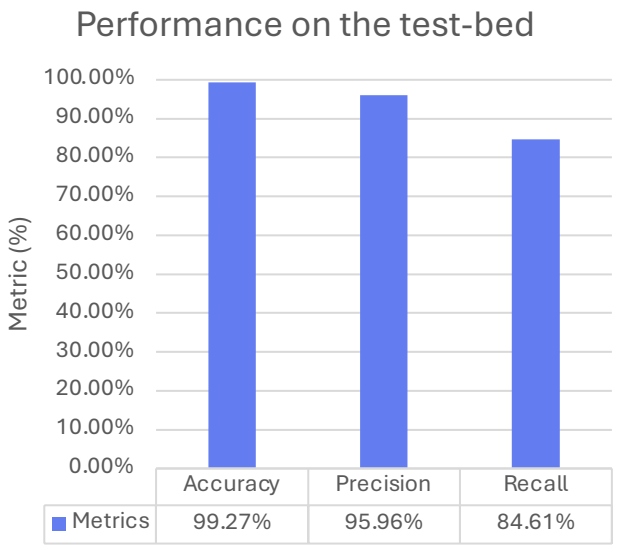
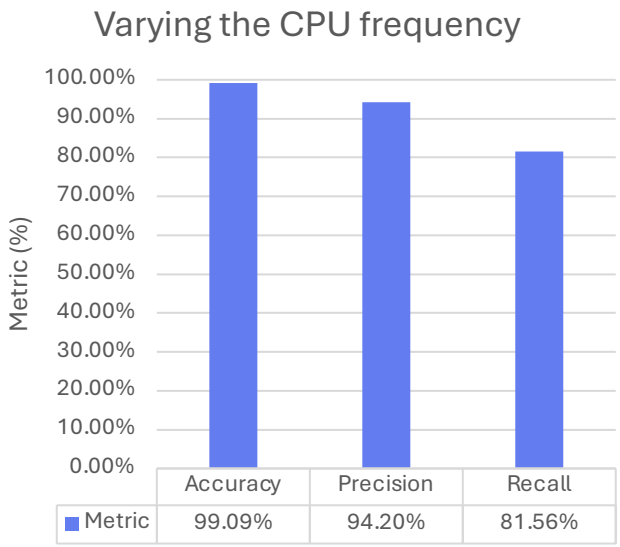
No crashes.

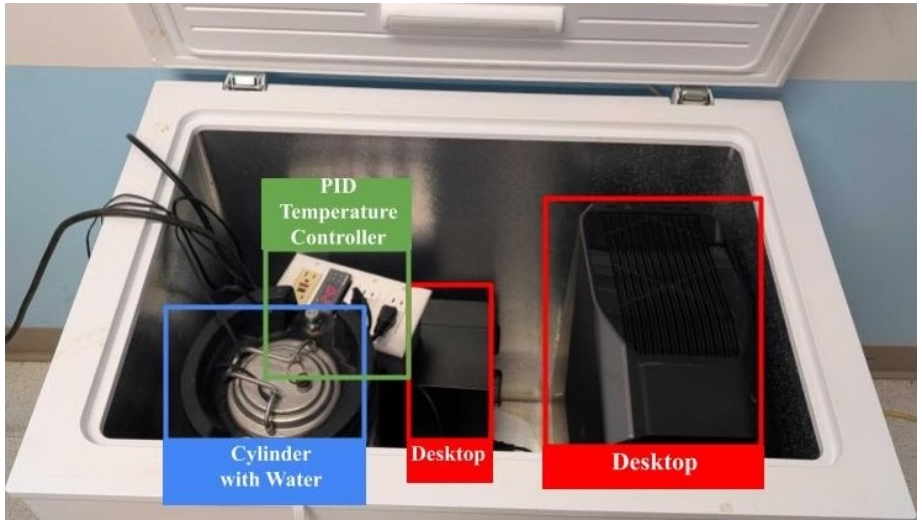
Varying the temperature.

Reference at 15° C

Testing at 40° C







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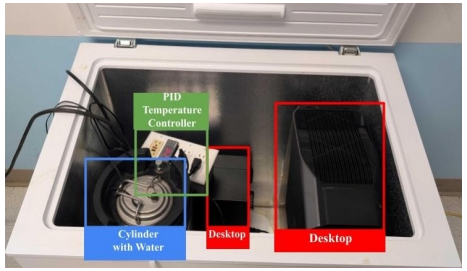

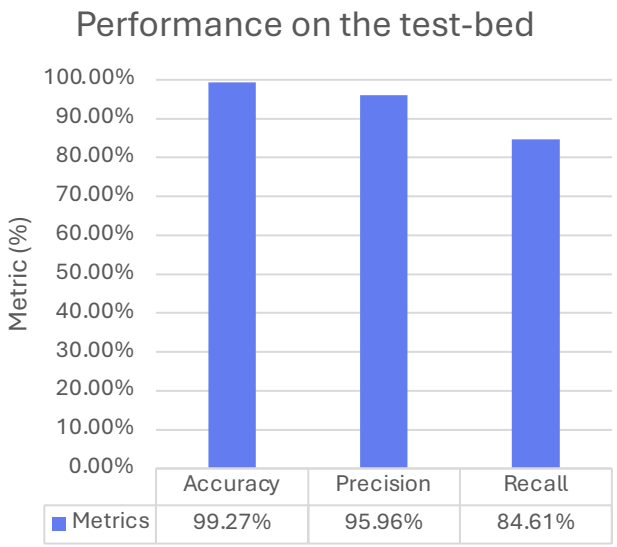

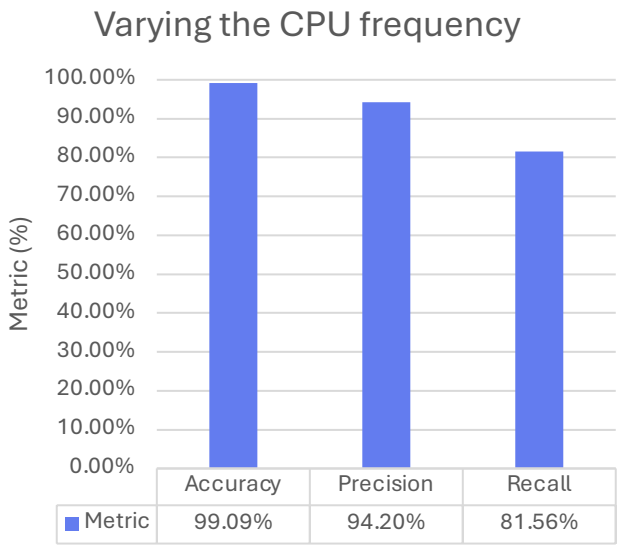

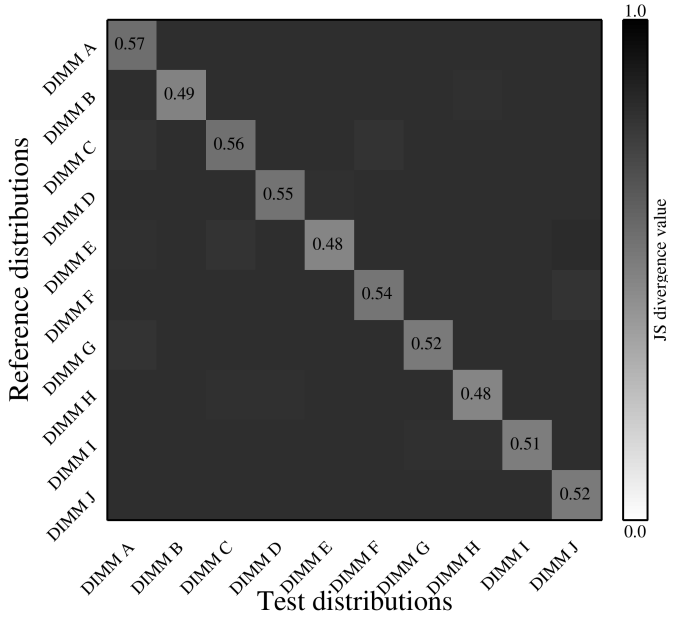

Conclusion

- In this work, we presented FP-RowHammer.
  - A RowHammer based fingerprinting technique.
  - First large-scale RowHammer fingerprinting technique on 98 DDR4 DIMMs
  - High uniqueness and stability
- Risky for apps to use FP-Rowhammer for authentication, but OS/hardware vendors can safely implement FP-Rowhammer.
- **FP-RowHammer cannot be trivially mitigated without fixing the RowHammer vulnerability.**
- Extend our findings to simulation models.

Thank You

Questions?

Read the full paper at: