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Using Rowhammer for Fault Analysis of Block Ciphers and a Mitigation Technique thereof

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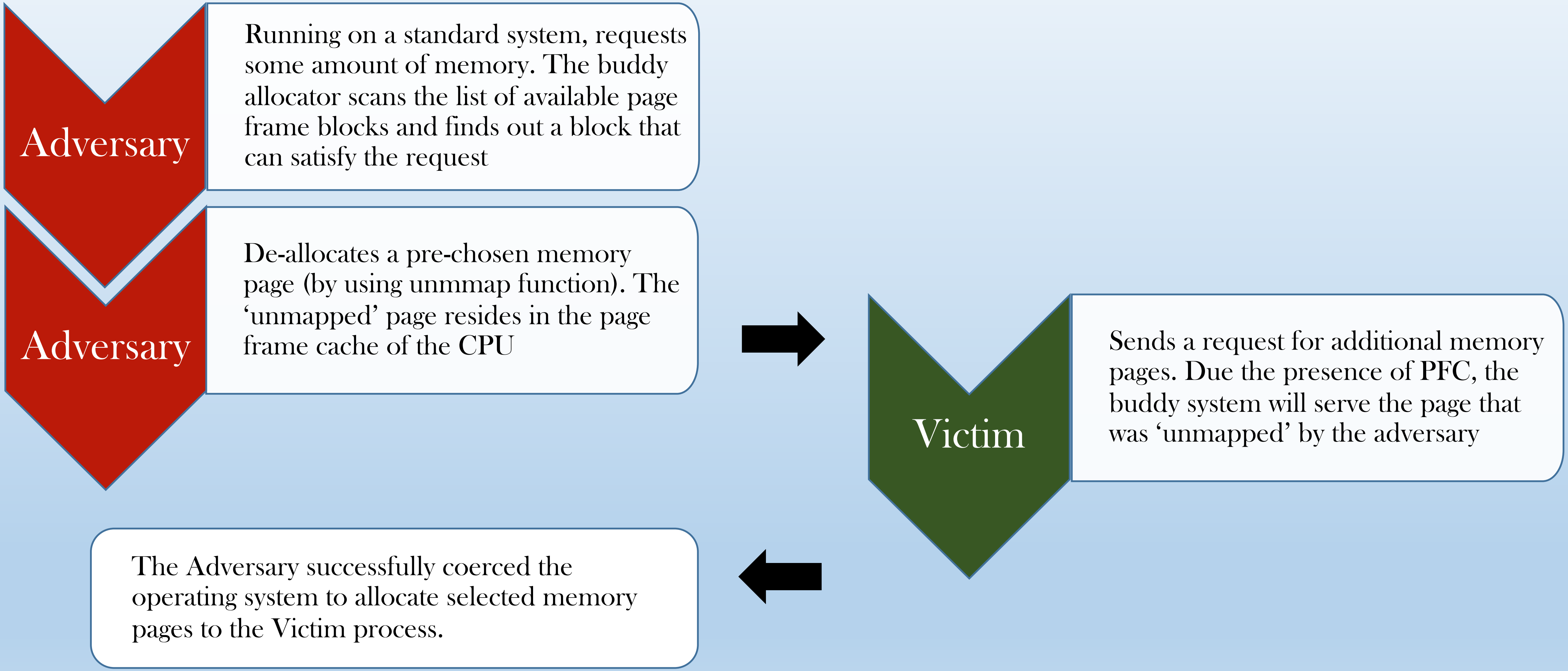
Exploiting Page Frame Cache



Adversary

Running on a standard system, requests some amount of memory. The buddy allocator scans the list of available page frame blocks and finds out a block that can satisfy the request

Adversary

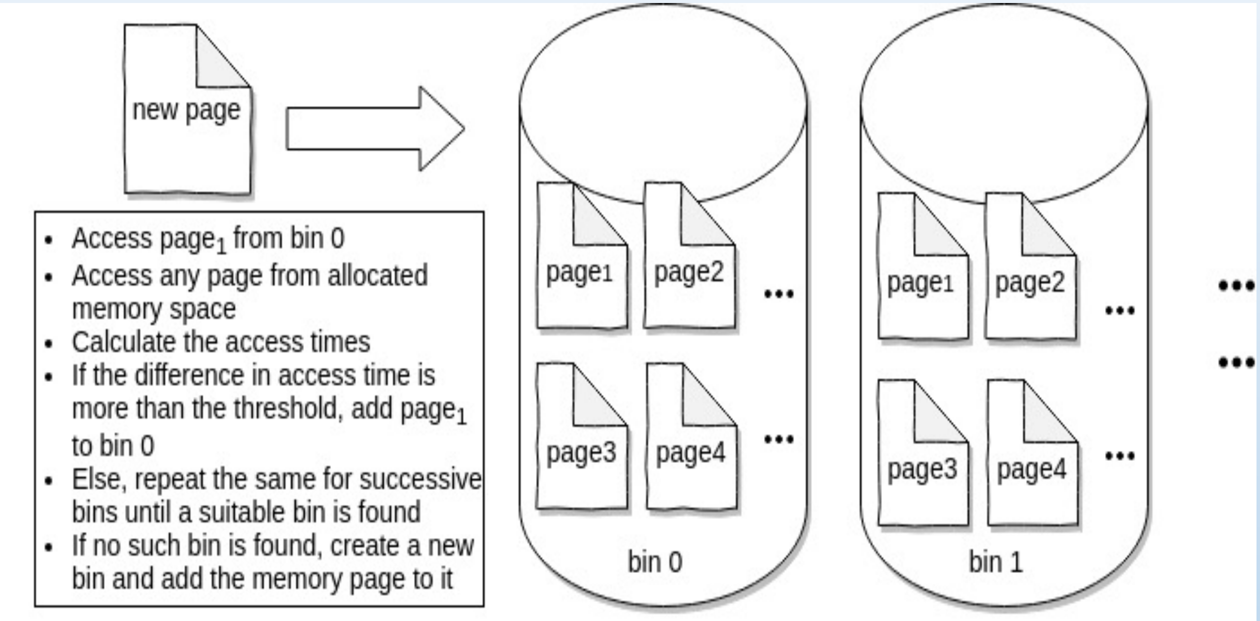
De-allocates a pre-chosen memory page (by using unmmap function). The 'unmapped' page resides in the page frame cache of the CPU

Victim

Sends a request for additional memory pages. Due the presence of PFC, the buddy system will serve the page that was 'unmapped' by the adversary

The Adversary successfully coerced the operating system to allocate selected memory pages to the Victim process.

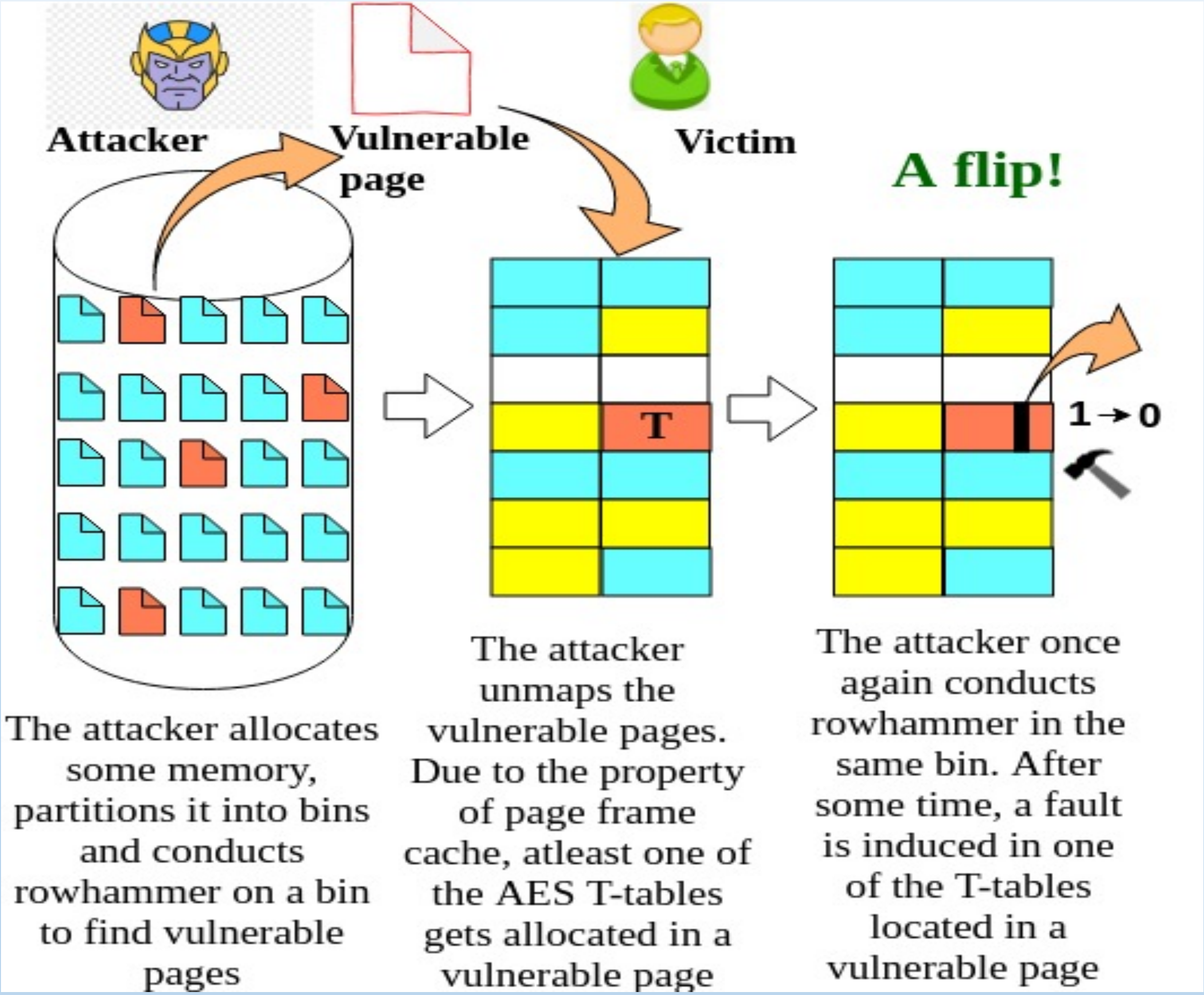
The bin-partitioning



- Access page$_1$ from bin 0
- Access any page from allocated memory space
- Calculate the access times
- If the difference in access time is more than the threshold, add page$_1$ to bin 0
- Else, repeat the same for successive bins until a suitable bin is found
- If no such bin is found, create a new bin and add the memory page to it

- Access the first page and put it in bin_0
- Next, access the next page and the first page simultaneously and check their access times
- If access time for next page is more than a pre-defined threshold, it signifies a row conflict
- The pair of pages must be located in the same bank but different rows.
- In that case, put the new page in bin_0
- If the access time is less than threshold, put it in the next bin, i.e, bin_1

ExplFrame on OpenSSL AES T-tables



The attacker allocates some memory, partitions it into bins and conducts rowhammer on a bin to find vulnerable pages

The attacker unmaps the vulnerable pages. Due to the property of page frame cache, atleast one of the AES T-tables gets allocated in a vulnerable page

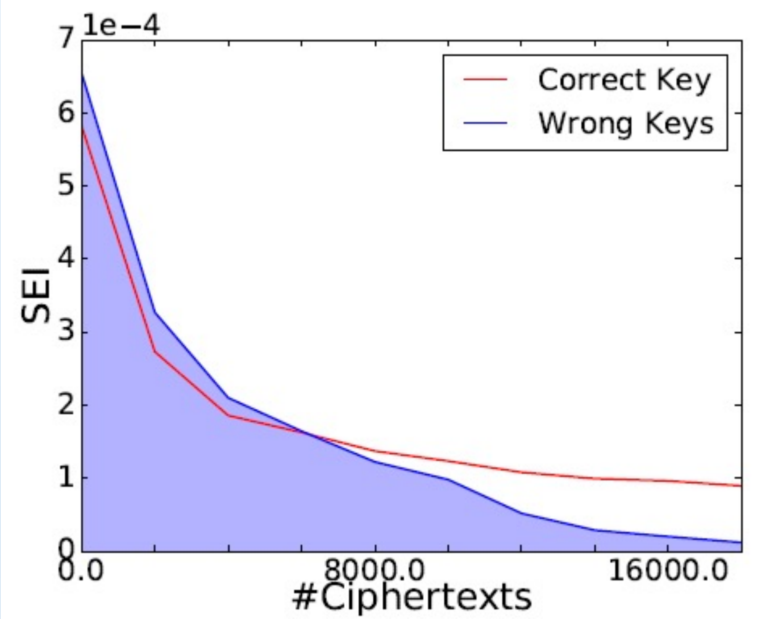
The attacker once again conducts rowhammer in the same bin. After some time, a fault is induced in one of the T-tables located in a vulnerable page

- OpenSSL v1.1.1 AES T-tables T0 – T3
- The adversary waits for the victim to load the T-tables into memory
- Due to the presence of PFC, the T-tables will be allocated in the same vulnerable page
- Once one of the T-tables is placed in a freed page, the adversary again starts Rowhammer-ing on the same bin.

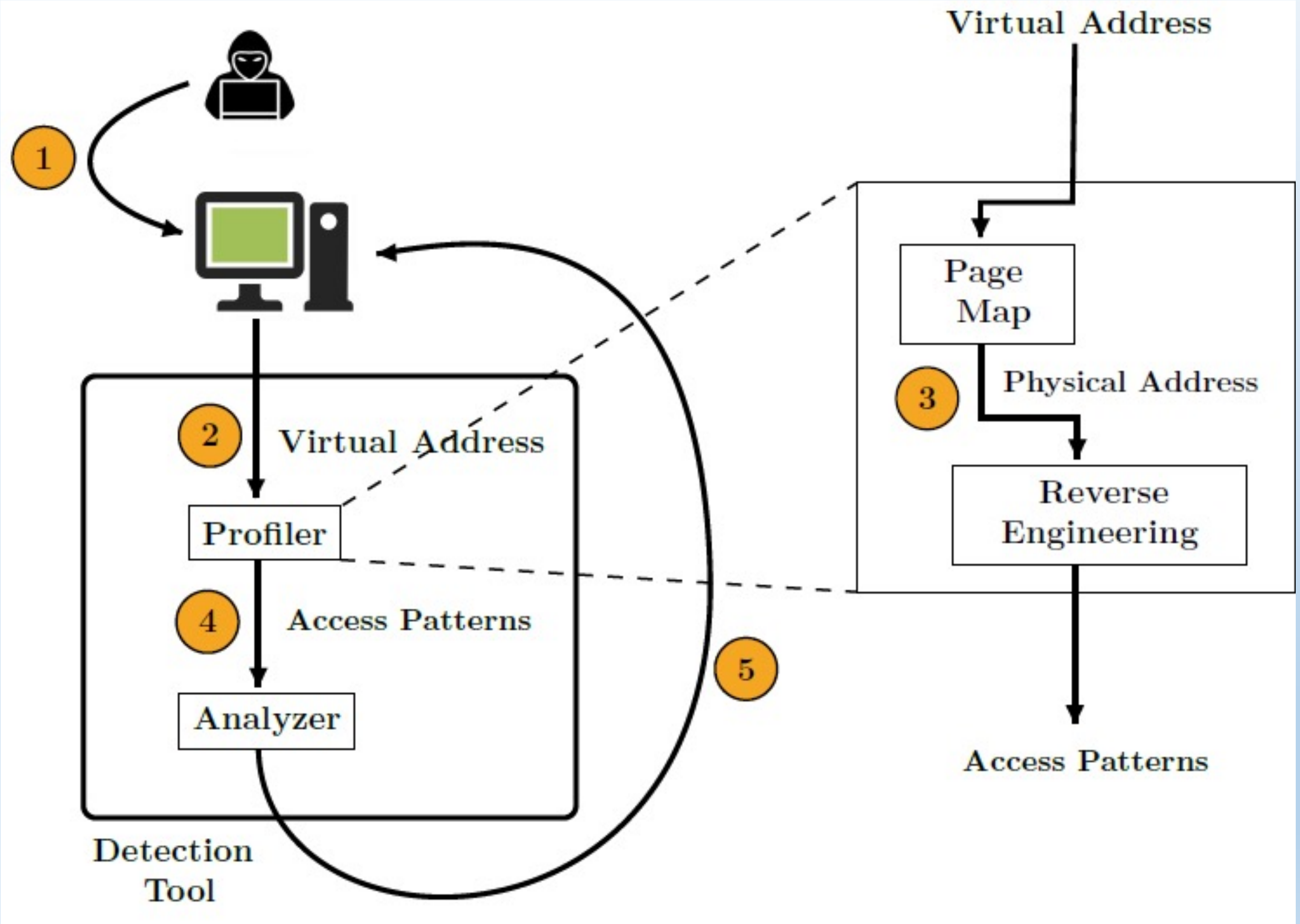
Deep Round PFA

- Central Idea – Guess a part of the key and partially decrypt upto the round where bias is observed
- Identify the bias using Squared Euclidean Imbalance (SEI) test

- We target the 9th round of AES computation
- Fault is induced in table T0 and we encrypt 20,000 plaintexts with the faulty T-tables
- The blue region in the convergence plot represents SEI values for wrong key
- The red line refer to SEI for correct key



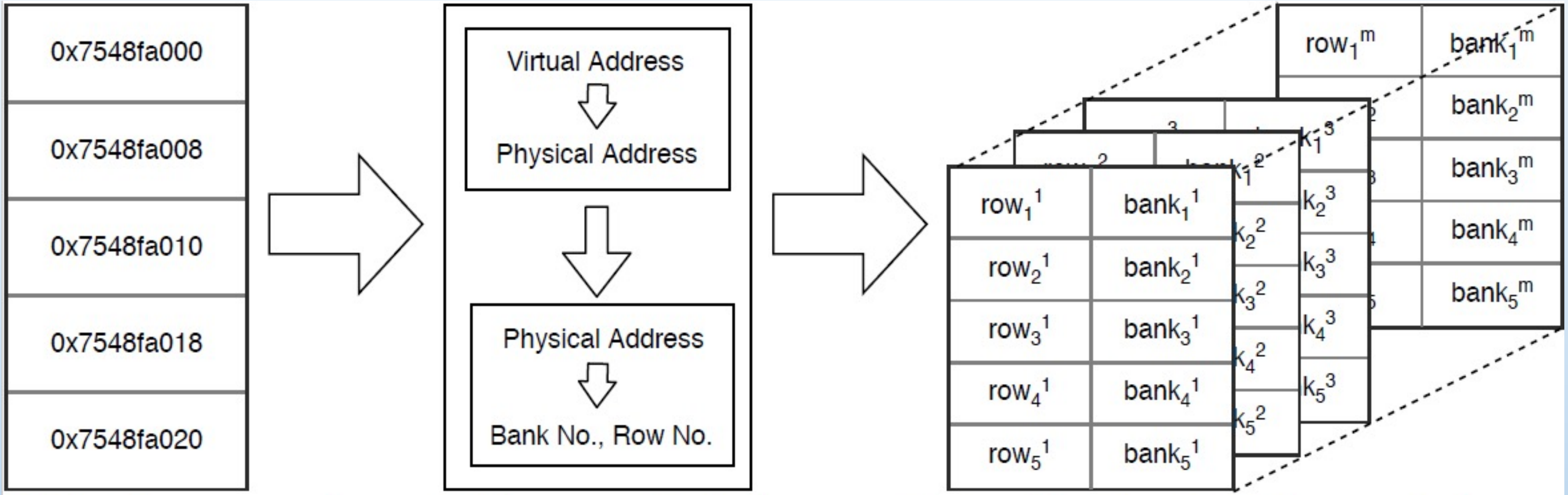
Overview of our Diagnostic tool



Five Step Approach

1. Access
2. Address Map
3. Access Map
4. Data Preparation
5. Authorization

Profiler: Generating Access Patterns



0x7548fa000

0x7548fa008

0x7548fa010

0x7548fa018

0x7548fa020

Virtual Address → Physical Address

Physical Address → Bank No., Row No.

row_1^1	bank_1^1
row_2^1	bank_2^1
row_3^1	bank_3^1
row_4^1	bank_4^1
row_5^1	bank_5^1

row_1^m	bank_1^m
	bank_2^m
	bank_3^m
	bank_4^m
	bank_5^m

Virtual addresses accessed by a process

Profiler - maps each virtual address to a corresponding bank and row number

Creates a 3D matrix containing the row and bank number for all the accessed address in each iteration

- Identification of a probable Adversary
- Generation of Access Patterns

Analyzer: Determining Rowhammer Process

Offline Phase

- Obtains data for both benign and malicious patterns
- Trains a CNN to differentiate patterns that induce bit flips

Online Phase

- Obtains access pattern for unknown process
- Uses the already trained CNN to classify the process

Future Works

- Explore the ExplFrame attack on ECC protected memory
- Can we replace supervised learning used in the diagnostic tool with an unsupervised one?

Thank You!