CSI:Rowhammer

Cryptographic Security and Integrity against Rowhammer

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CSI:Rowhammer

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CSI:Rowhammer – Cryptographic Security and Integrity against Rowhammer

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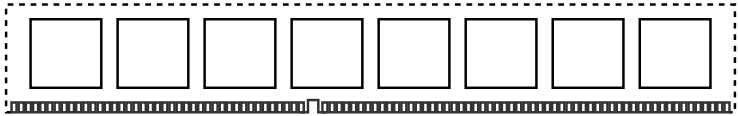
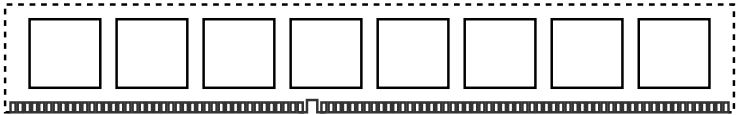
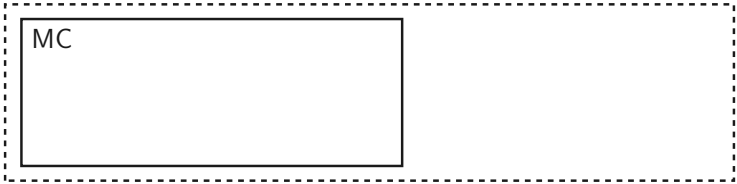
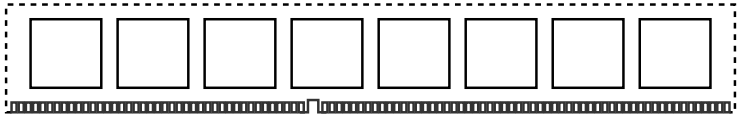
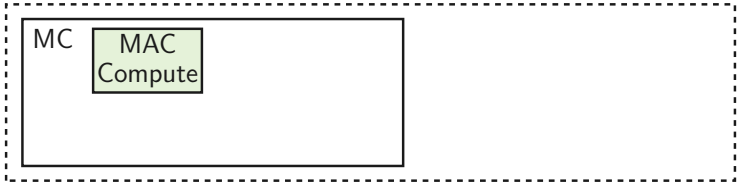
- All Rowhammer attacks are DoS in the **worst case**

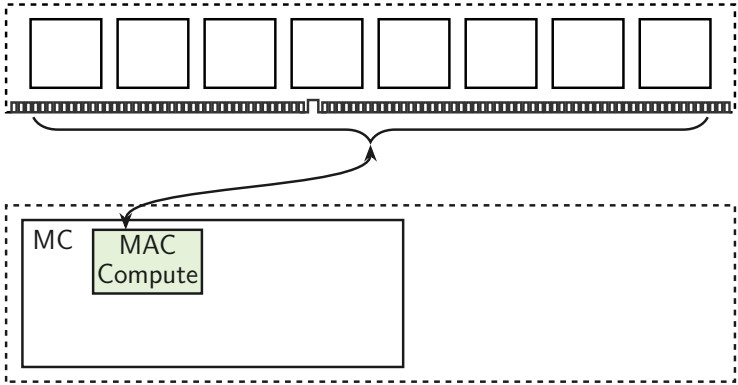


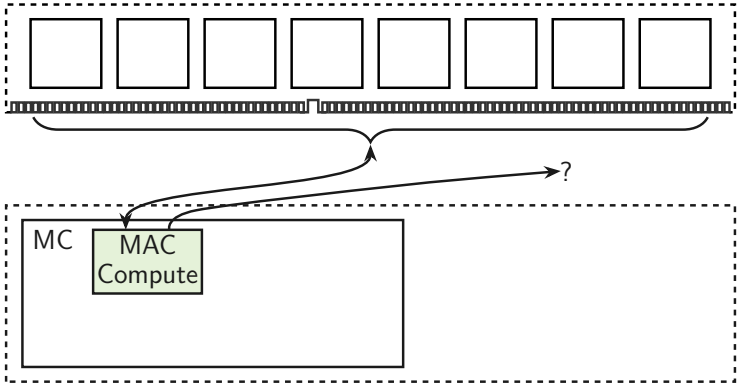


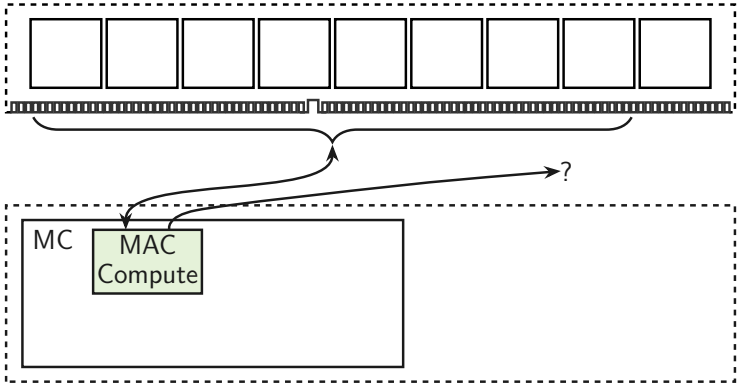

MC

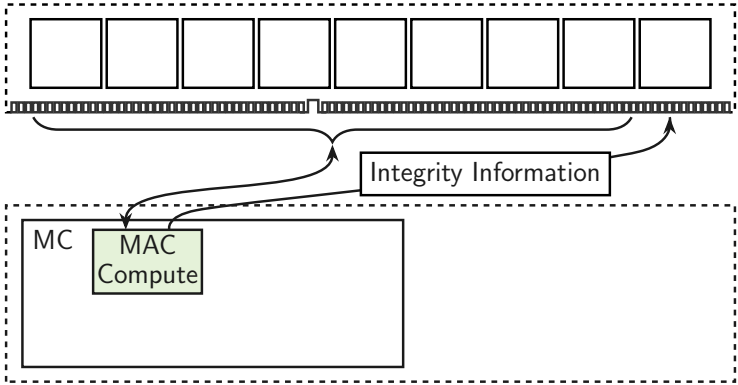


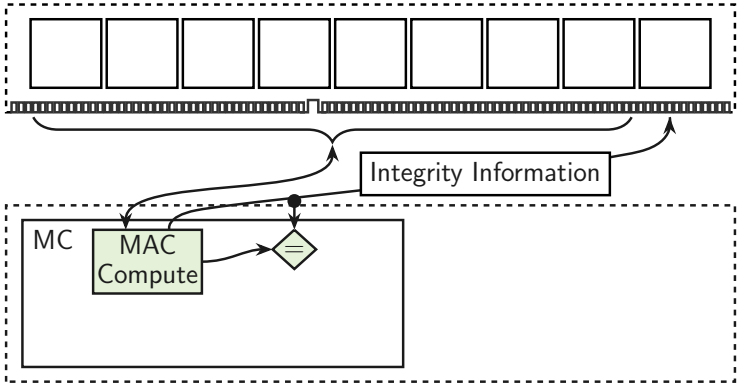

MC
MAC
Compute

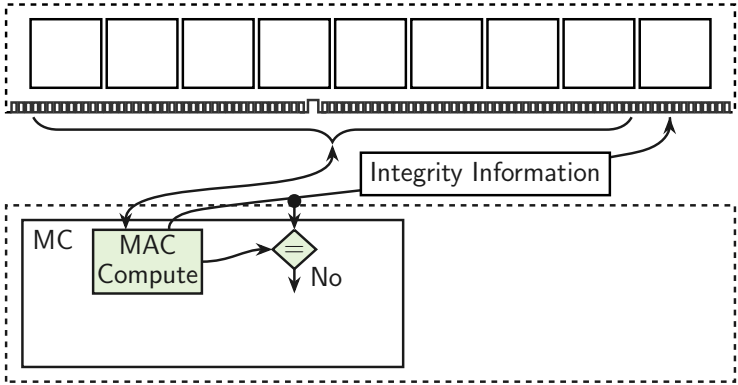

MC
MAC
Compute

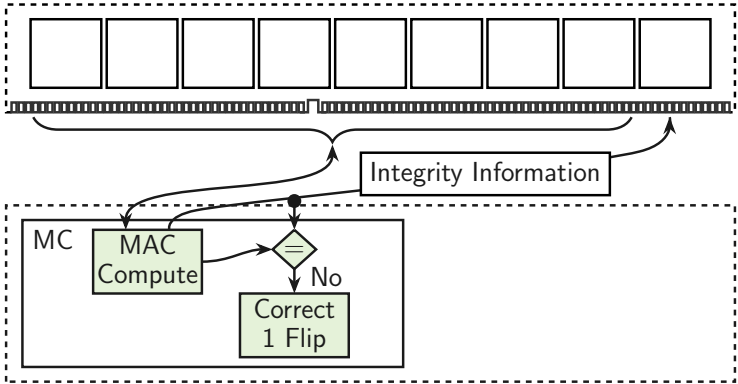

?
MC
MAC
Compute

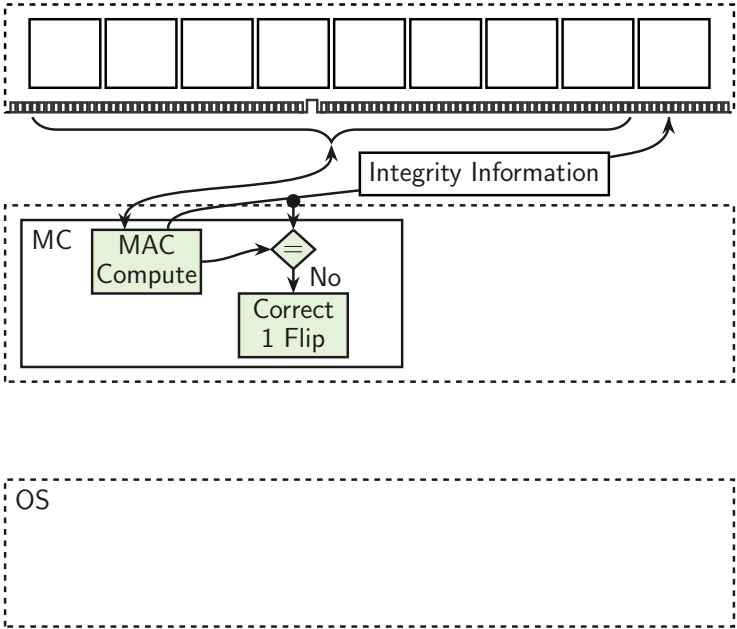

?
MC
MAC
Compute

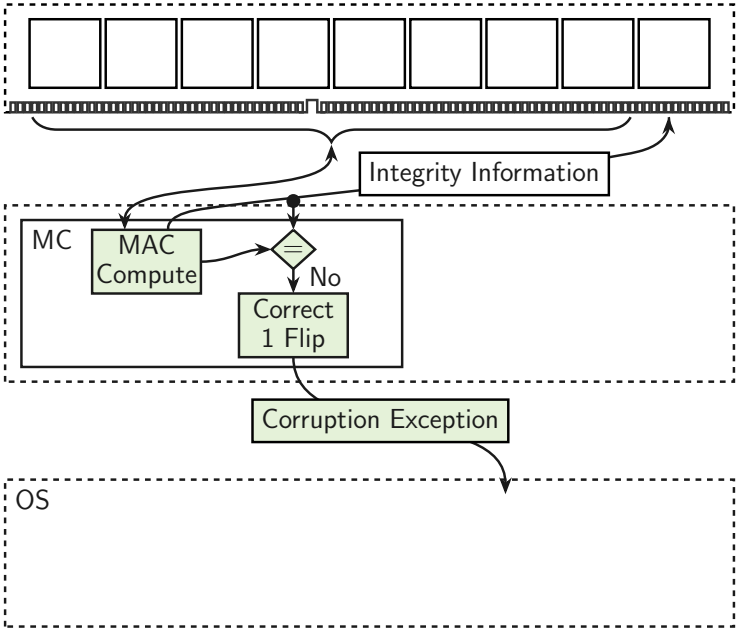

Integrity Information
MC
MAC
Compute

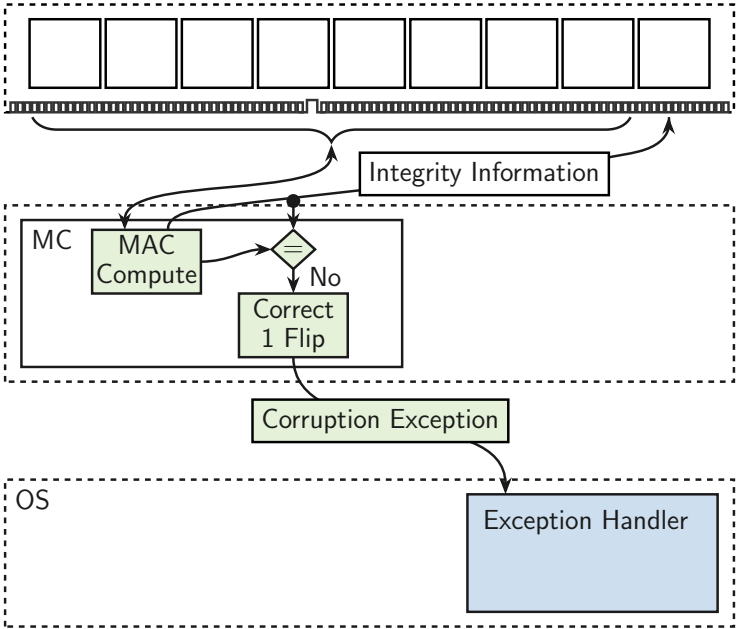

Integrity Information
MC
MAC
Compute

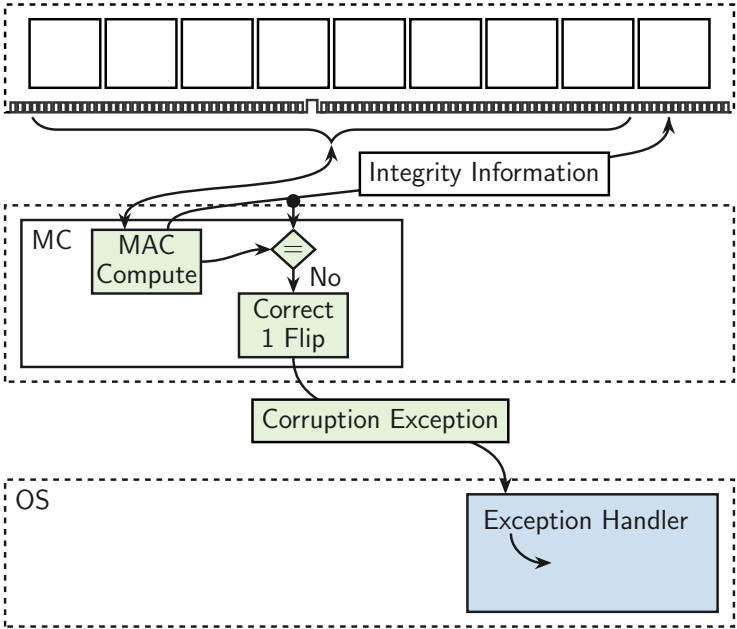

Integrity Information
MC
MAC
Compute
=
No


Integrity Information
MC
MAC
Compute
=
No
Correct
1 Flip


Integrity Information
MC
MAC
Compute
=
No
Correct
1 Flip
OS


Integrity Information
MC
MAC
Compute
=
No
Correct
1 Flip
Corruption Exception
OS


Integrity Information
MC
MAC
Compute
=
No
Correct
1 Flip
Corruption Exception
OS
Exception Handler


Integrity Information
MC
MAC
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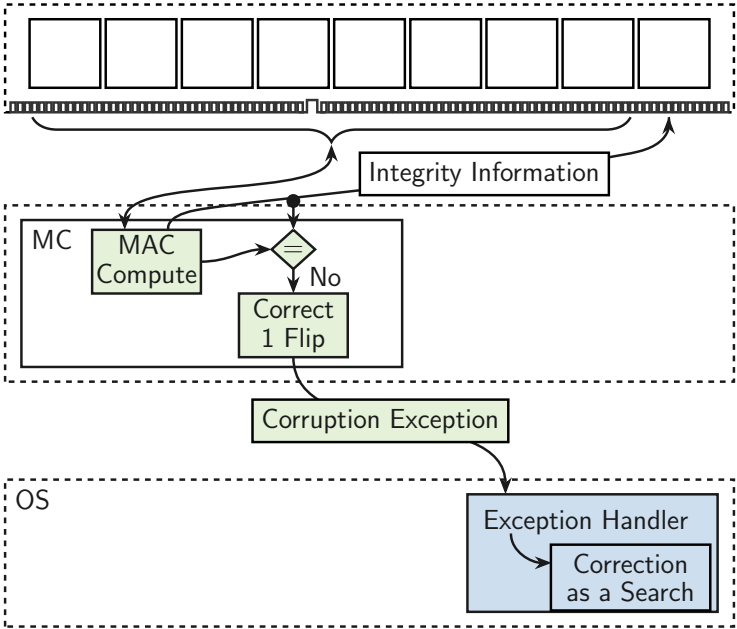
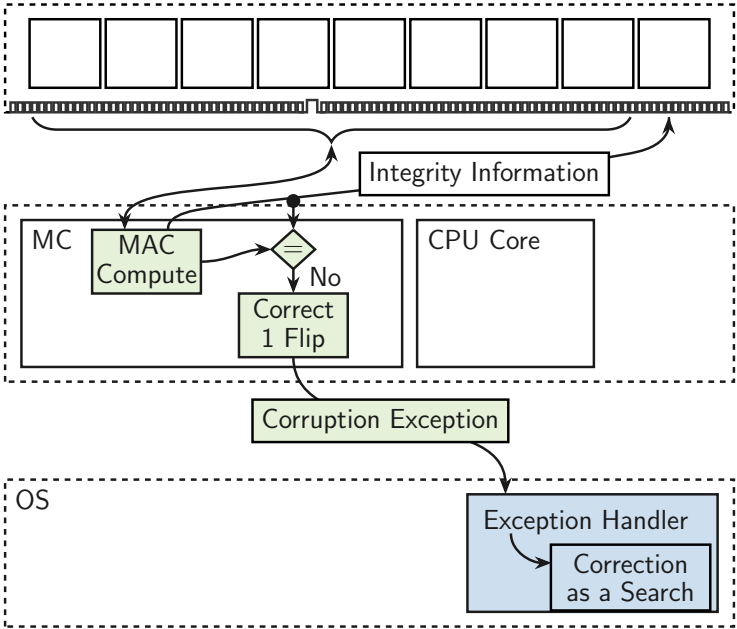
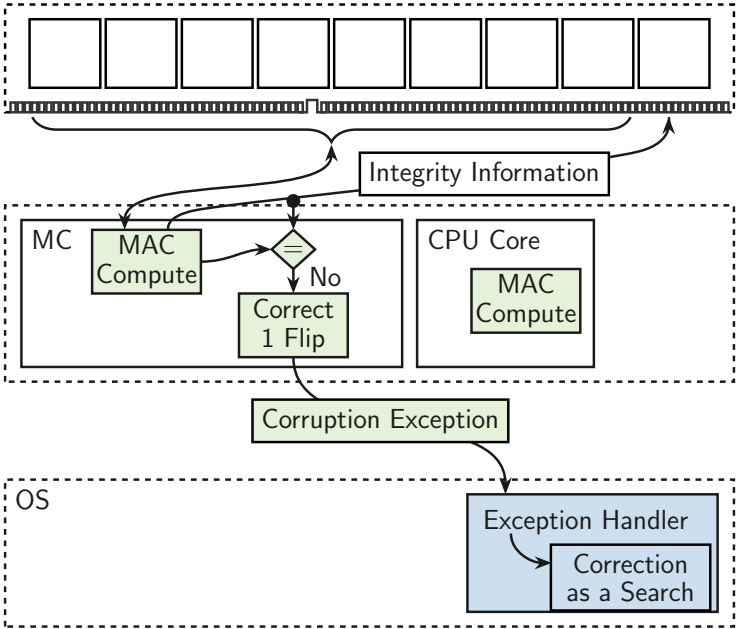
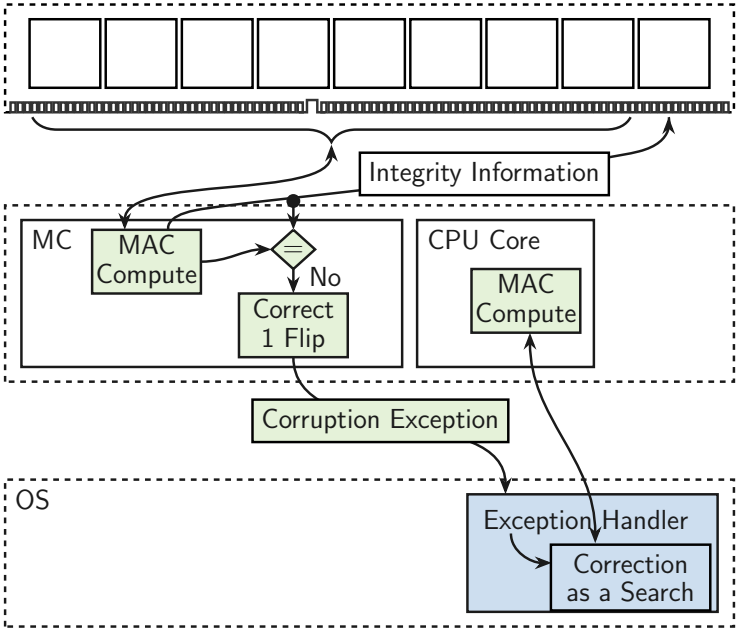

Integrity Information
MC
MAC
Compute
=
No
Correct
1 Flip
Corruption Exception
OS
Exception Handler
Correction
as a Search


Integrity Information
MC
MAC
Compute
=
No
Correct
1 Flip
CPU Core
Corruption Exception
OS
Exception Handler
Correction
as a Search


Integrity Information
MC
MAC Compute
=
No
Correct 1 Flip
CPU Core
MAC Compute
Corruption Exception
OS
Exception Handler
Correction as a Search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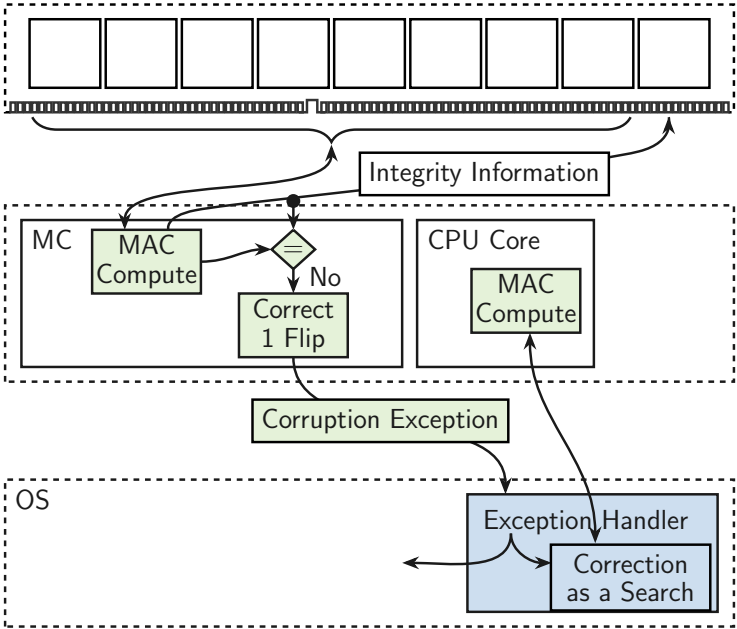
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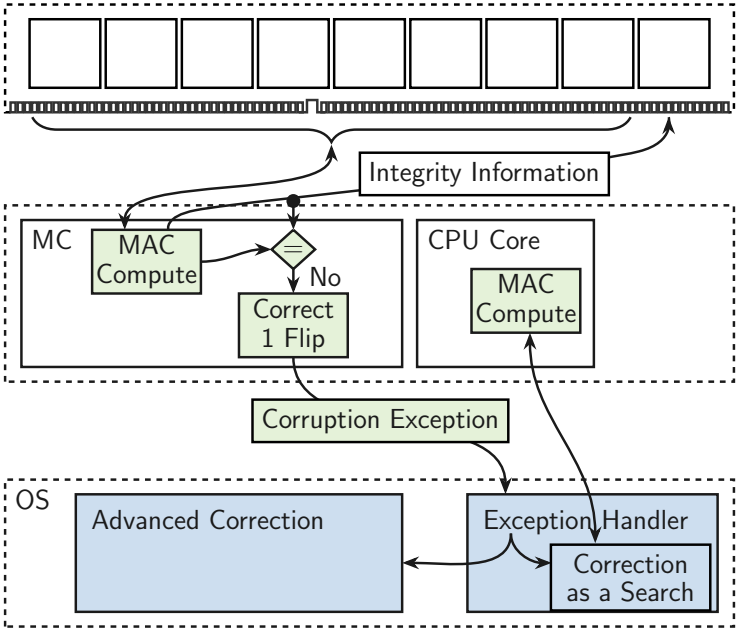
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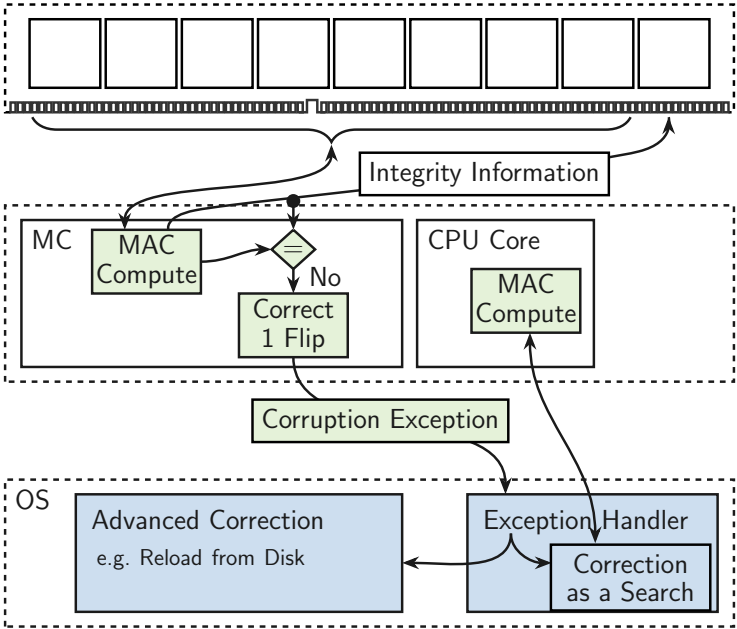
Integrity Information
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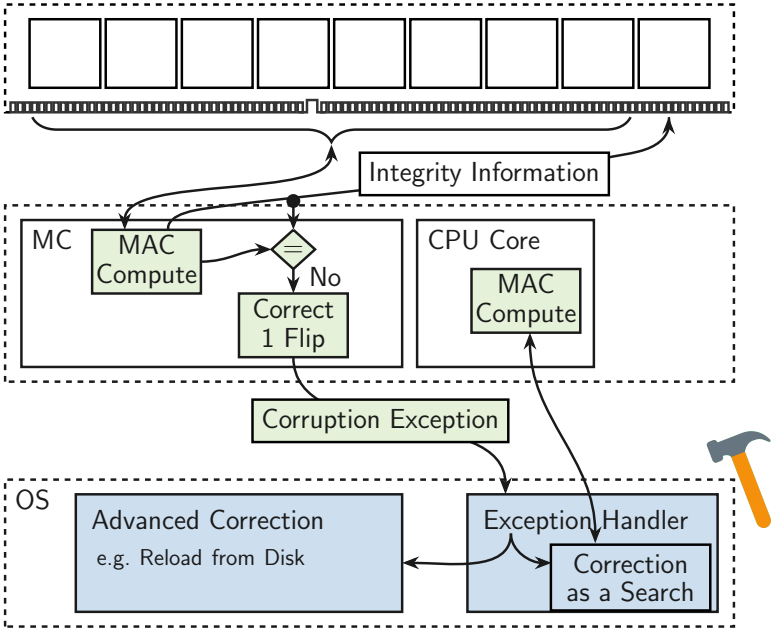
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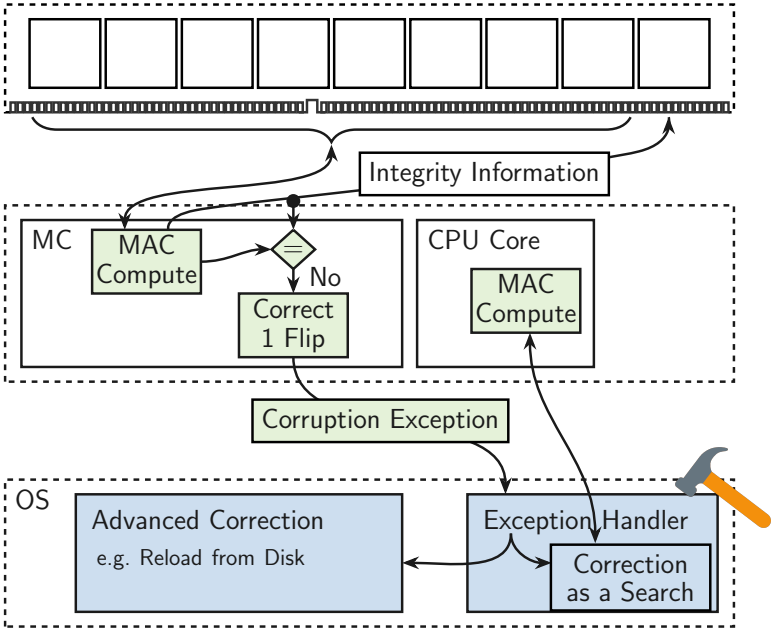
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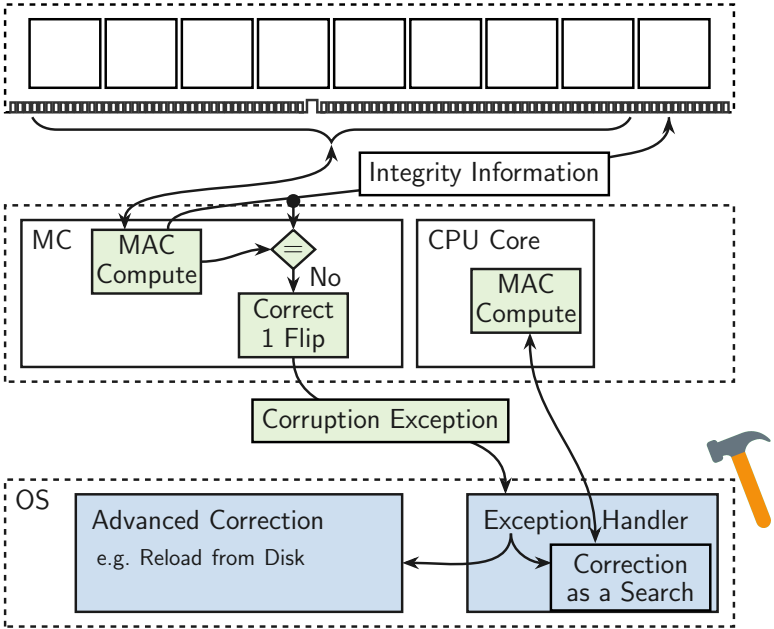
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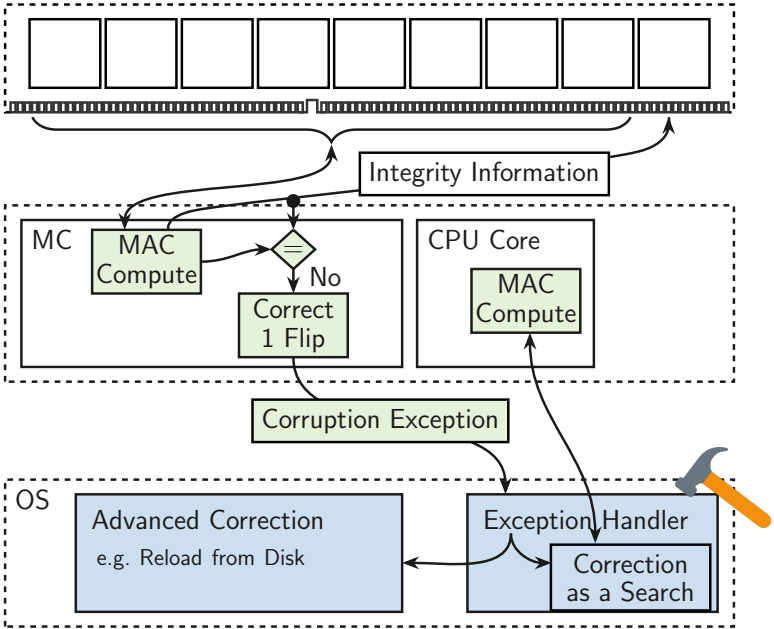
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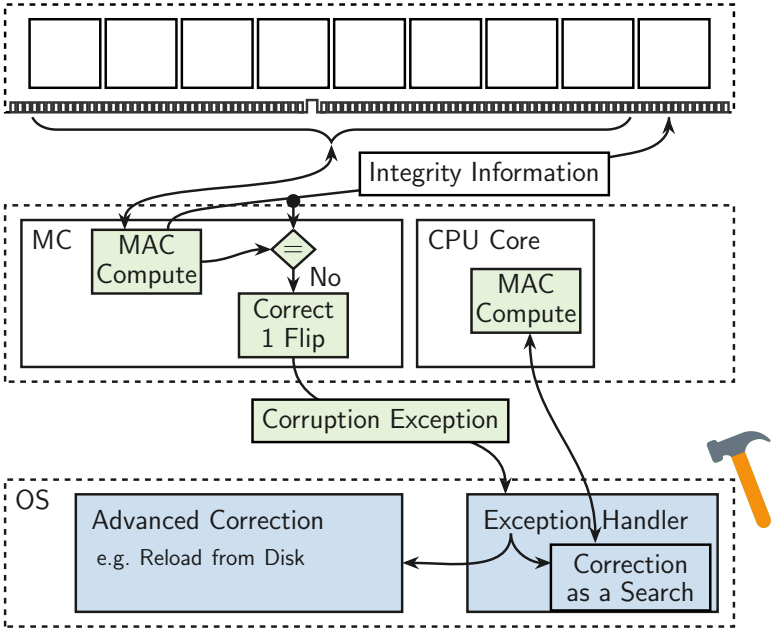
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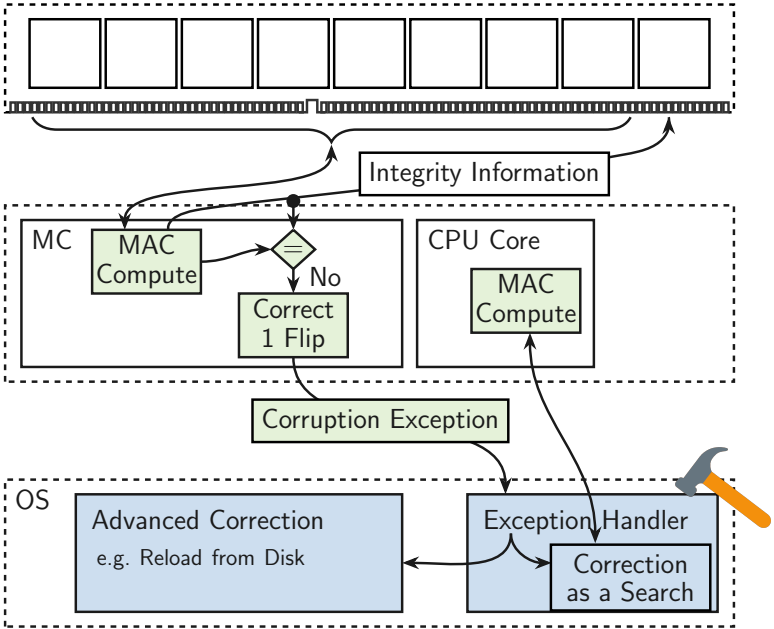
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MAC Compute
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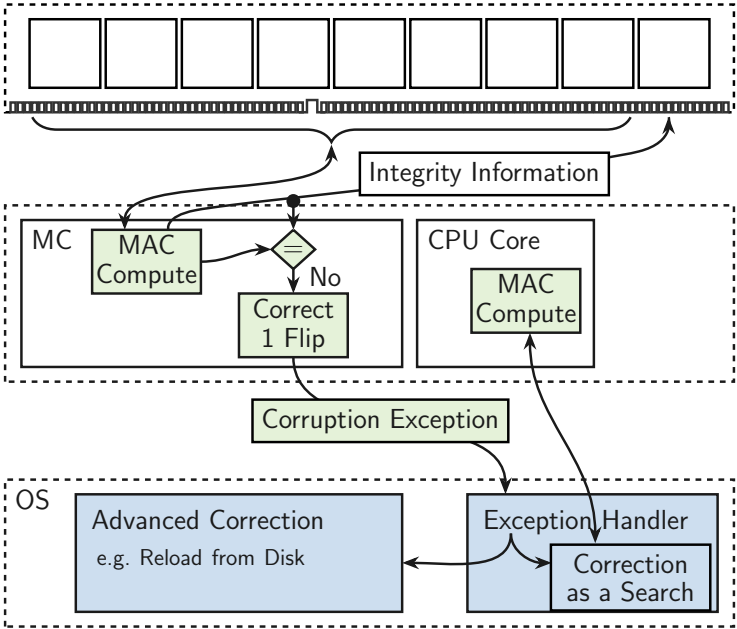
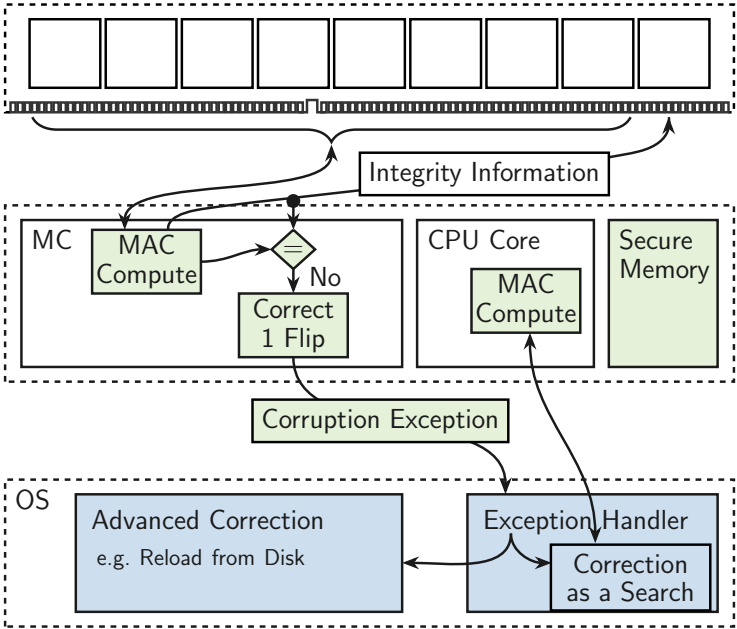
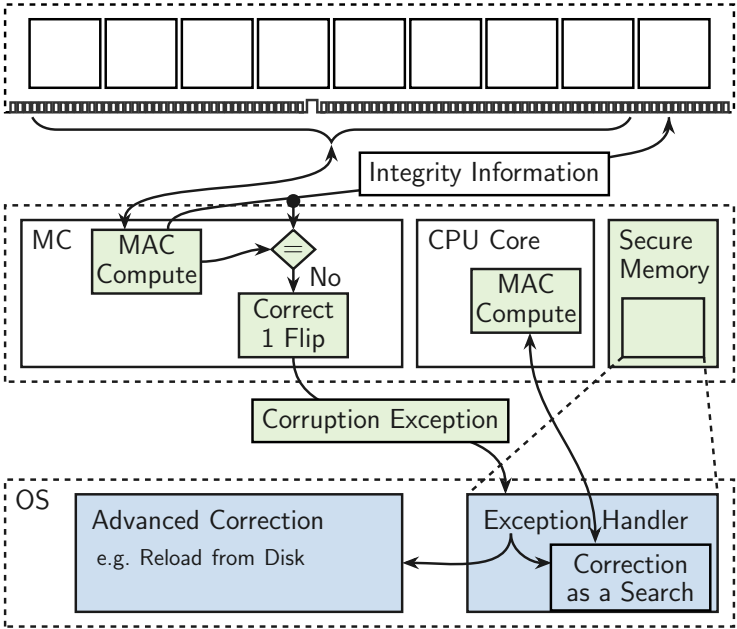

Integrity Information
MC
MAC Compute
=
No
Correct 1 Flip
CPU Core
MAC Compute
Corruption Exception
OS
Advanced Correction
e.g. Reload from Disk
Exception Handler
Correction as a Search


Integrity Information
MC
MAC Compute
=
No
Correct 1 Flip
CPU Core
MAC Compute
Secure Memory
Corruption Exception
OS
Advanced Correction
e.g. Reload from Disk
Exception Handler
Correction as a Search


Integrity Information
MC
MAC Compute
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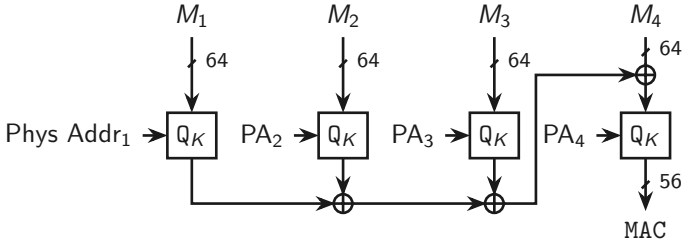
No
Correct 1 Flip
CPU Core
MAC Compute
Secure Memory
Corruption Exception
OS
Advanced Correction
e.g. Reload from Disk
Exception Handler
Correction as a Search

CSI:Rowhammer – MAC Design



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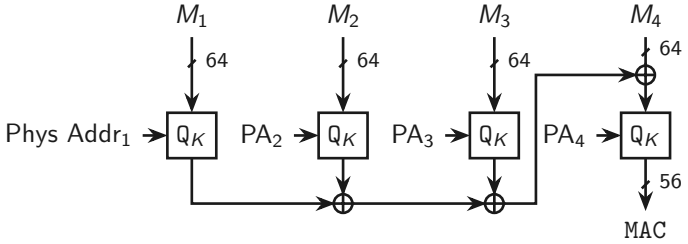
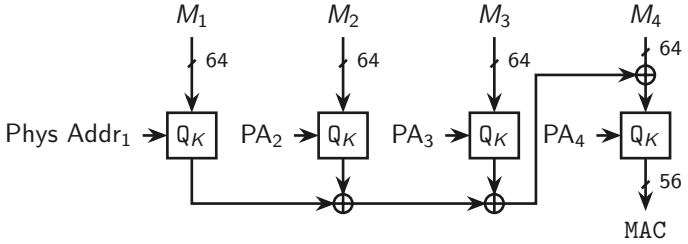


- PMAC construction

CSI:Rowhammer – MAC Design



- PMAC construction
- QARMA$_5$-64-σ_0 block cipher [Ava17]

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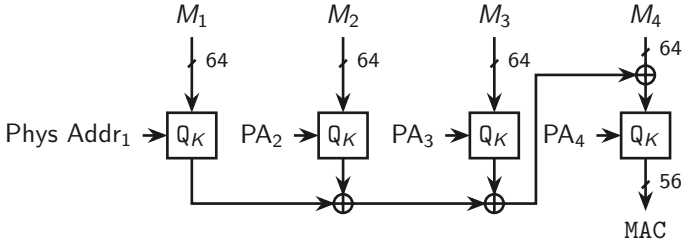

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- Physical address as tag

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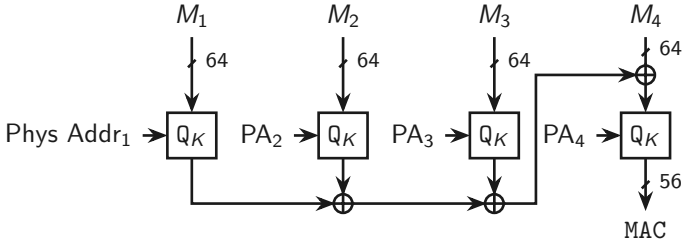

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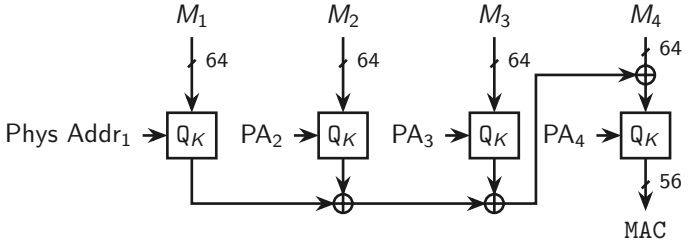
- 5.13 ns 256-bit

CSI:Rowhammer – MAC Design



- PMAC construction
- QARMA$_5$-64-σ_0 block cipher [Ava17]
- Physical address as tag

- 5.13 ns 256-bit
- 6.60 ns 512-bit

Data Correction

CSI:Rowhammer – Correction as a Search

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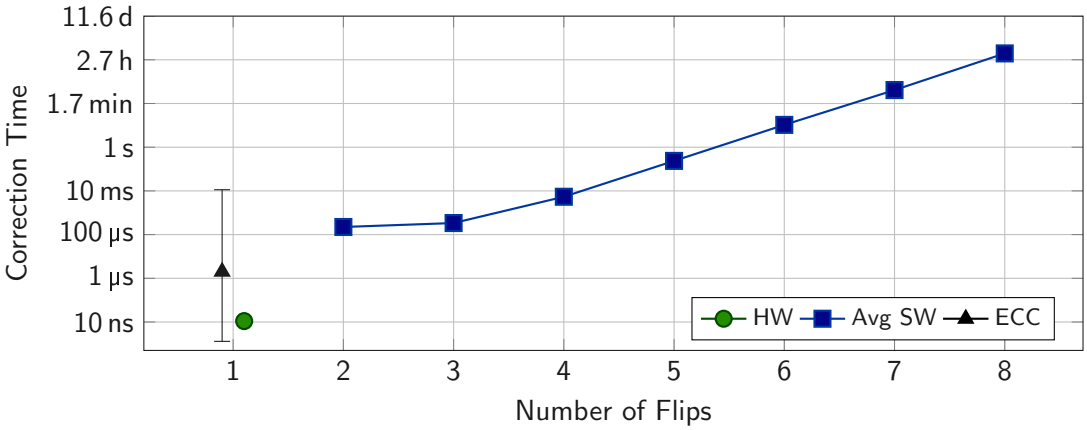
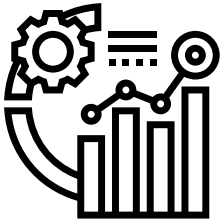
$$\texttt{MAC from DRAM} \longrightarrow 01010010 \checkmark$$

- Parity bits to shrink search space

CSI:Rowhammer – Correction Time



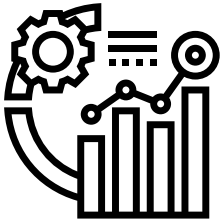
CSI:Rowhammer – Advanced Error Correction



CSI:Rowhammer – Advanced Error Correction

- OS has some **knowledge** about the corrupted data

CSI:Rowhammer – Advanced Error Correction



- OS has some **knowledge** about the corrupted data
- Reload disk backed data instead of correcting

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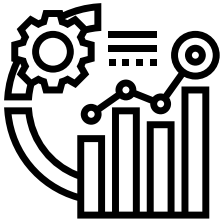
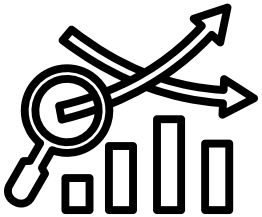


- OS has some **knowledge** about the corrupted data
- Reload disk backed data instead of correcting
- Recompute data (page tables)

Evaluation

CSI:Rowhammer – Evaluation



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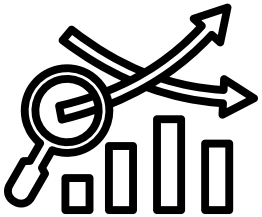

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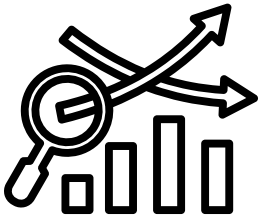
CSI:Rowhammer – Evaluation



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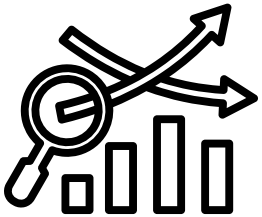

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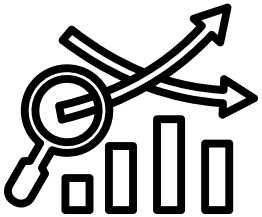
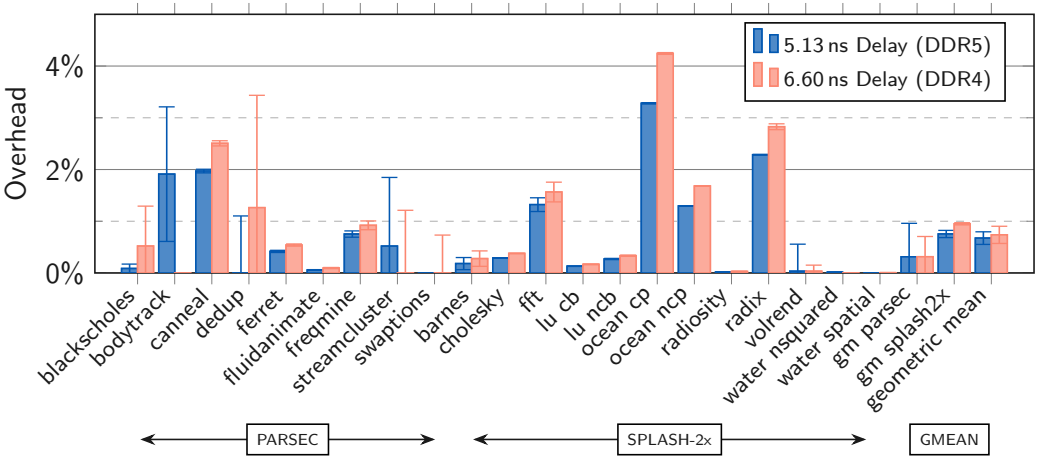


- Implemented CSI:Rowhammer in **gem5**
- Modified **Linux** kernel
- Evaluated correct functionality
- Evaluated performance overhead

CSI:Rowhammer – Performance Overhead



CSI:Rowhammer – Security Evaluation

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6	31.5	2	45.4
7	38.8	1	50.2
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- **Approximate Equality**
- Silent Data Corruption rate less than once per 10^9 billion years.
- Rowhammer second preimage after one year: $9.75 \cdot 10^{-5}\,\%$

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CSI:Rowhammer

Cryptographic Security and Integrity against Rowhammer

Jonas Juffinger, Lukas Lamster, Andreas Kogler, Moritz Lipp, Maria Eichlseder, Daniel Gruss

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PoC: github.com/CSIRowhammer/CSIRowhammerPoC

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