# Fantastic Timers and Where to Find Them: High-Resolution Microarchitectural Attacks in JavaScript

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**Graz University of Technology**

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# Outline

- Building a covert channel from a virtual machine without network access to the browser
- Reviving cache attacks in the browser
- No high-resolution timers in JavaScript
- How can we build our own timers?
- How to get a higher resolution than the native timers?

# Covert channel

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  - either because there is no communication channel...
  - ...or the channels are monitored and programs are stopped on communication attempts
- Use side channels to communicate

# DRAM organization

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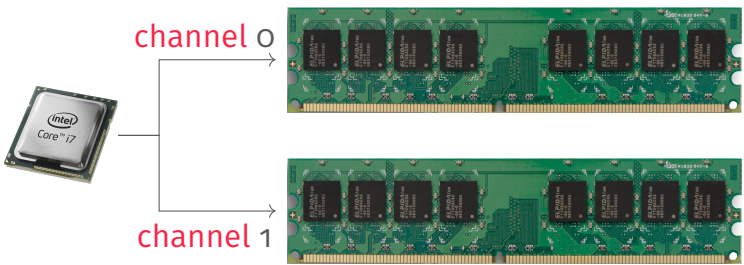

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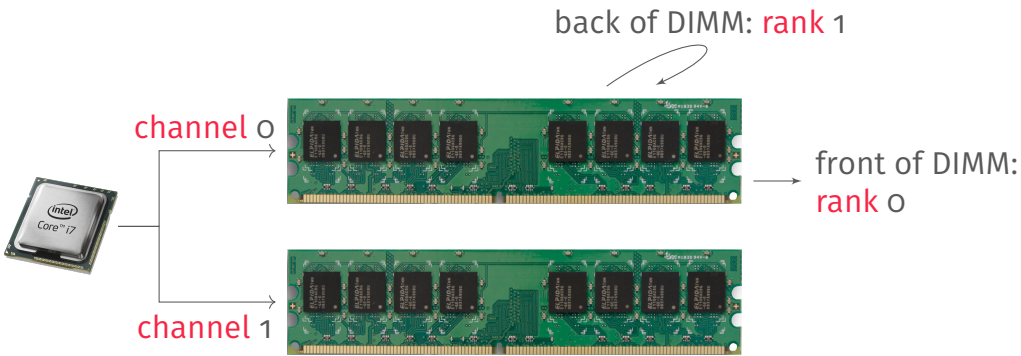

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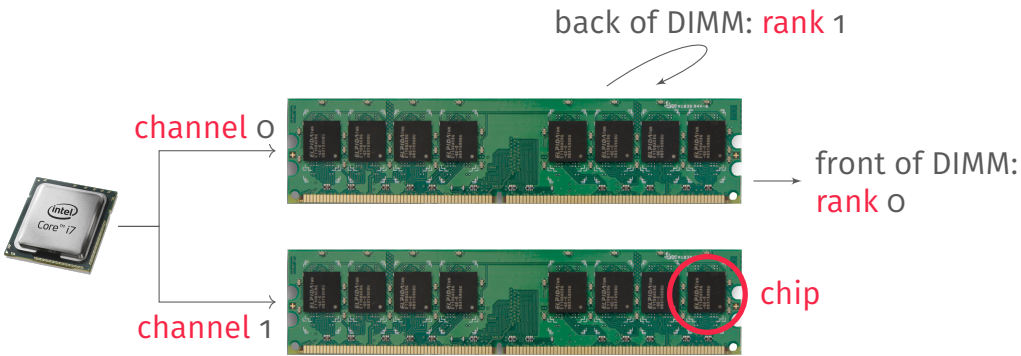
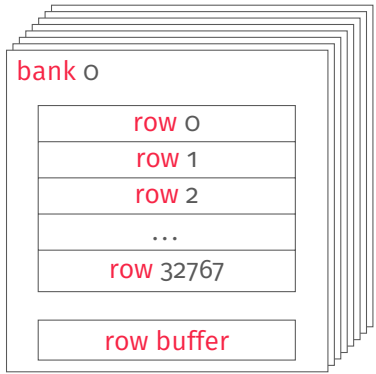


# DRAM organization

chip

# DRAM organization

chip


bank 0

row 0
row 1
row 2
…
row 32767

row buffer

64k cells
1 capacitor,
1 transitor each

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- $\rightarrow$ Row buffer

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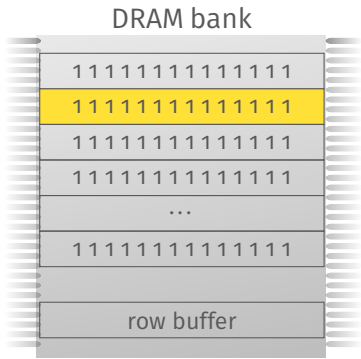


CPU reads row 1, row buffer empty!

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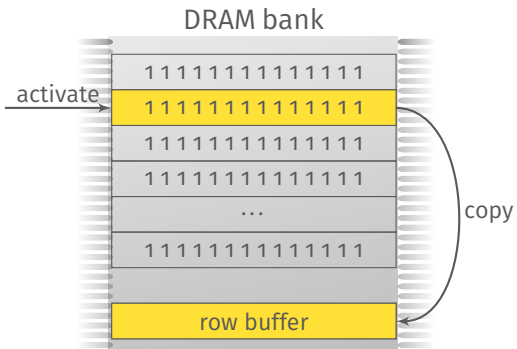

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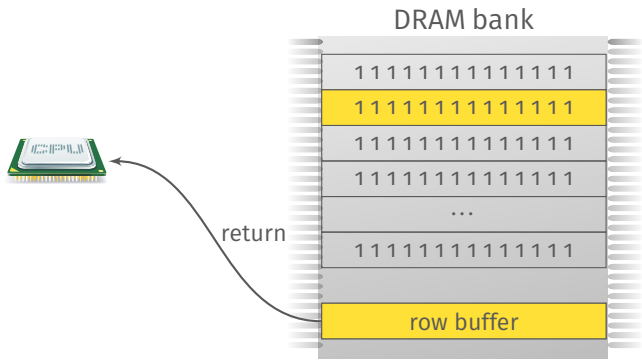

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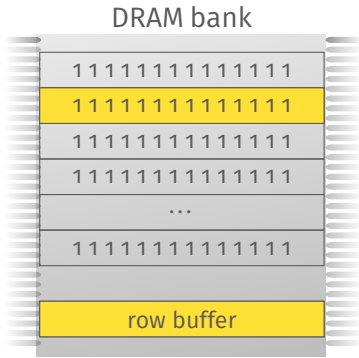


CPU reads row 1, row buffer now full!

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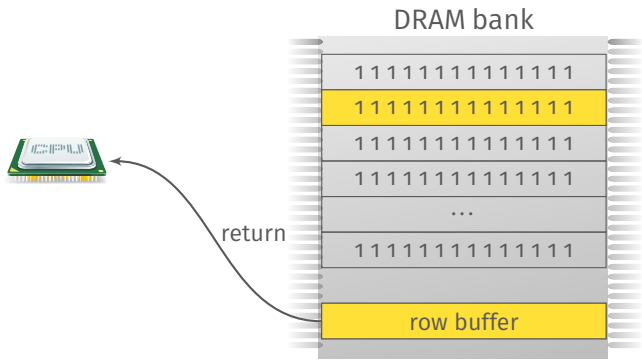
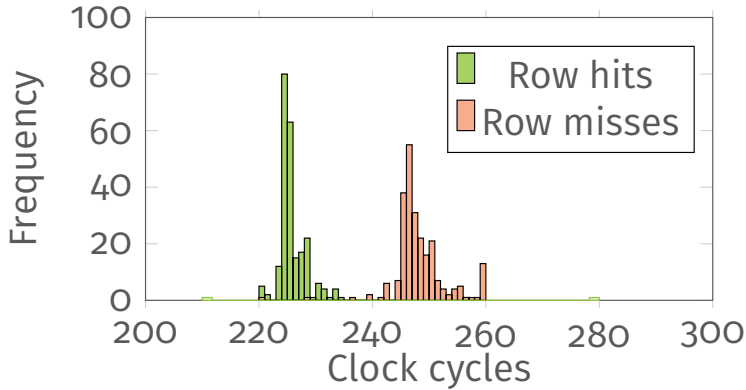



Less work!
Is it faster?

# Timing difference




Row hits ($\approx$ 225 cycles) and row conflicts ($\approx$ 247 cycles)

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## performance.now()

[...] represent times as floating-point numbers with up to microsecond precision.

— Mozilla Developer Network

# ...up to microsecond precision?

| | |
|---|---|
| Firefox $\leq 36$ | $1 \cdot 10^{-3}$ |

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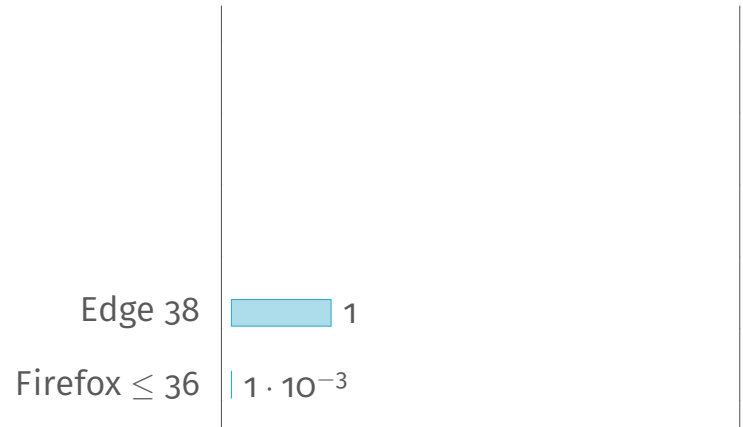

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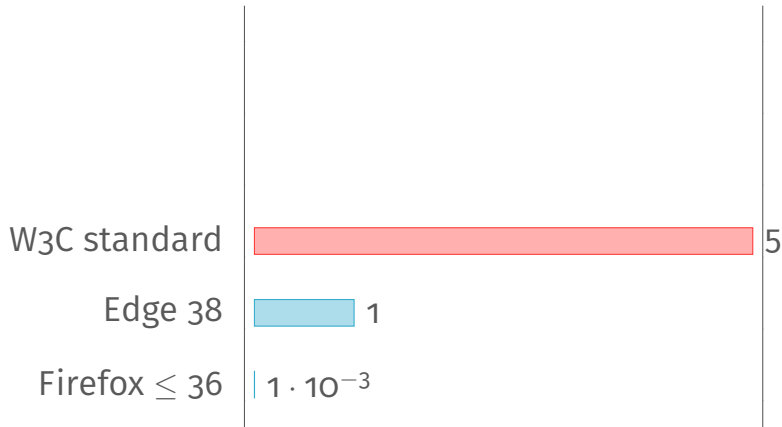

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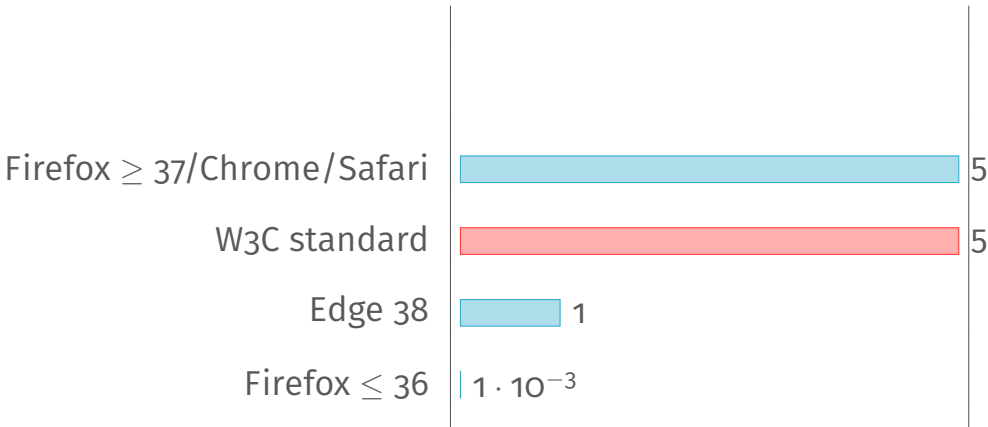

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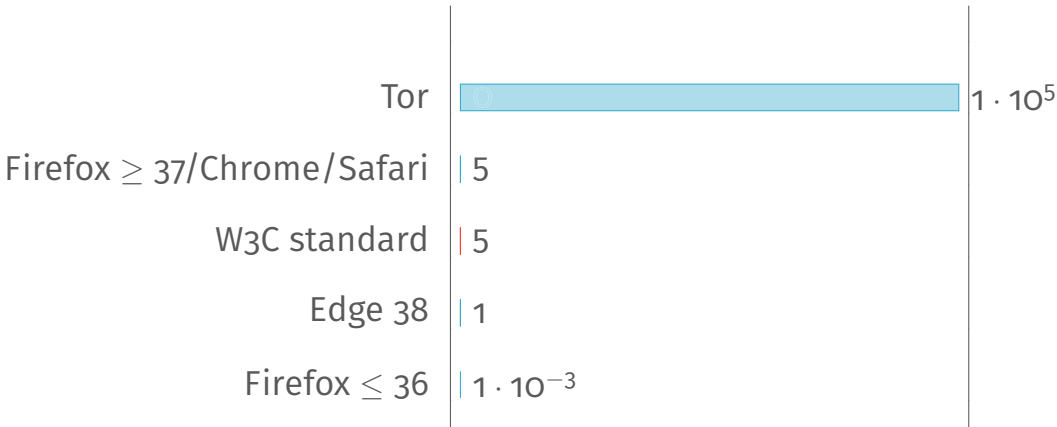

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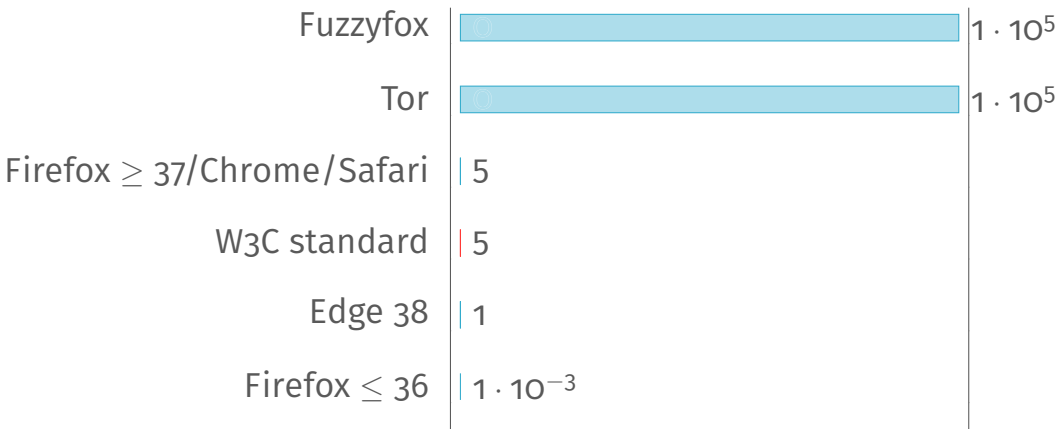

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- Highly accurate: 500 ns (Firefox/Chrome), 15 µs (Tor)

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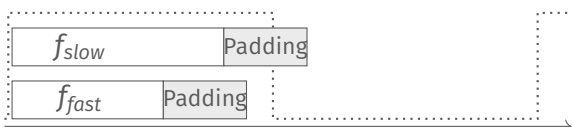


- Edge thresholding: apply padding such that the slow function crosses one more clock edge than the fast function.

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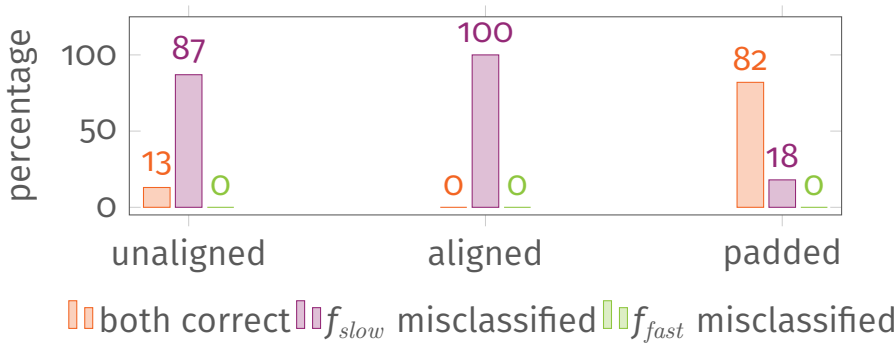

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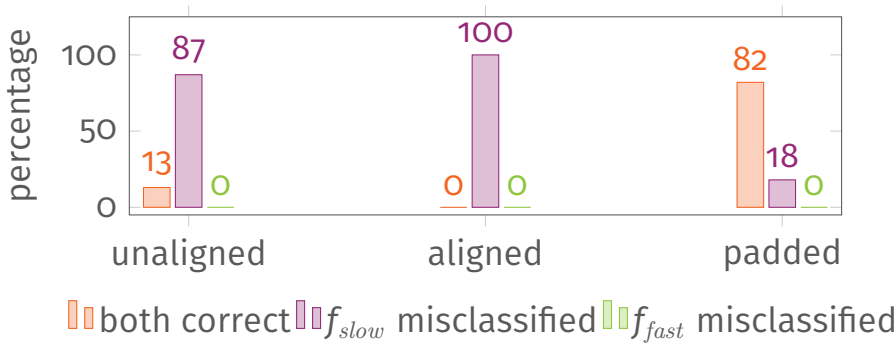


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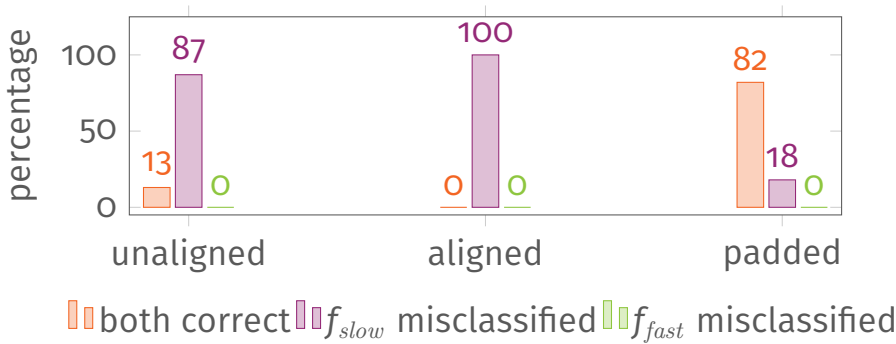


- Yields nanosecond resolution
- Firefox/Tor (2 ns), Edge (10 ns), Chrome (15 ns)

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- However, animation is limited to 60 fps $\rightarrow$ 16 ms

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- Multiple possibilities: `postMessage`, `MessageChannel` or `BroadcastChannel`
- Yields microsecond resolution (even on Tor and Fuzzyfox)

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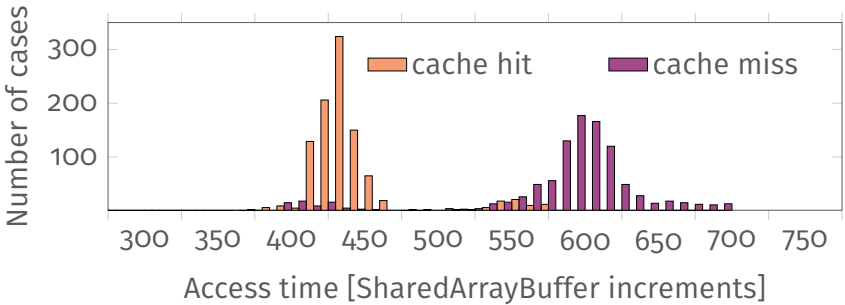
- Sufficient for microarchitectural attacks

# Measuring cache timing



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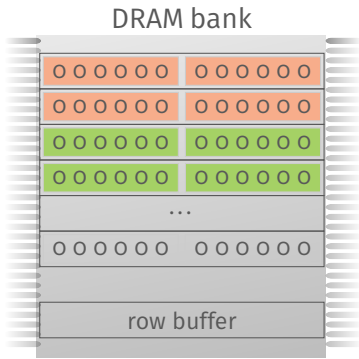
- If measured timing was “fast” sender transmitted 0.

# Transmitting data




Sender and receiver decide on one bank

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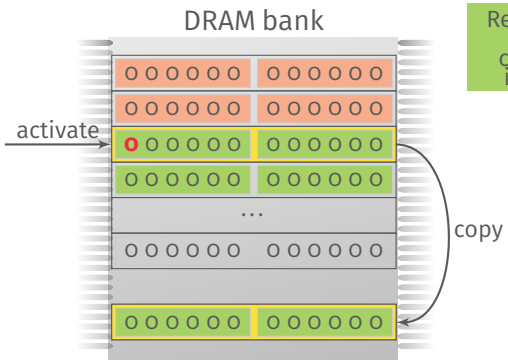


Receiver measures access time to its address

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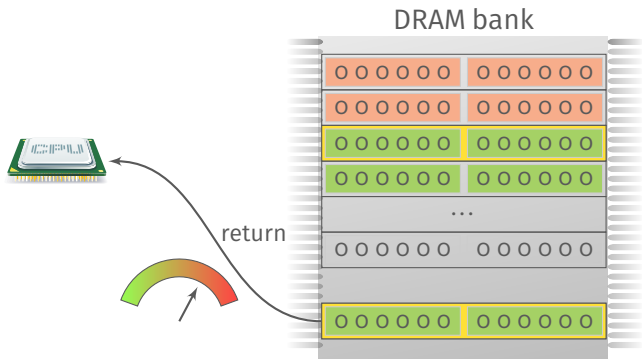

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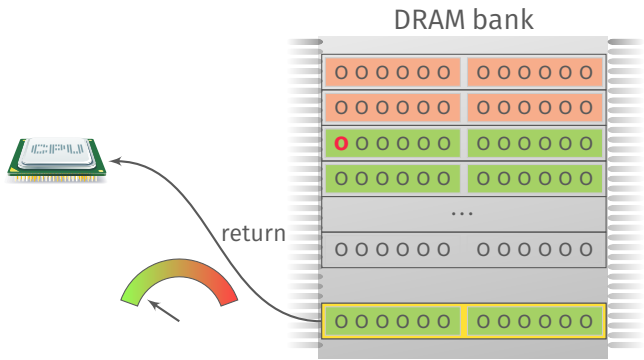


Repeated access always has low access times

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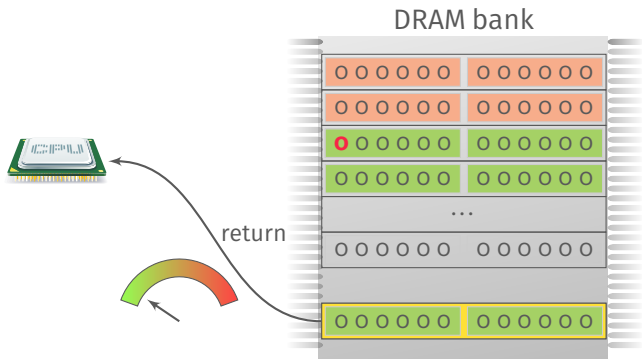

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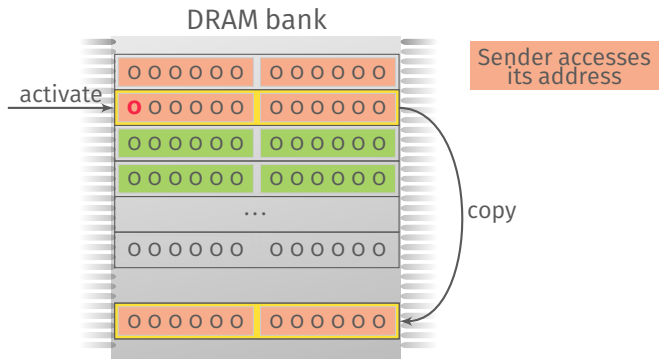

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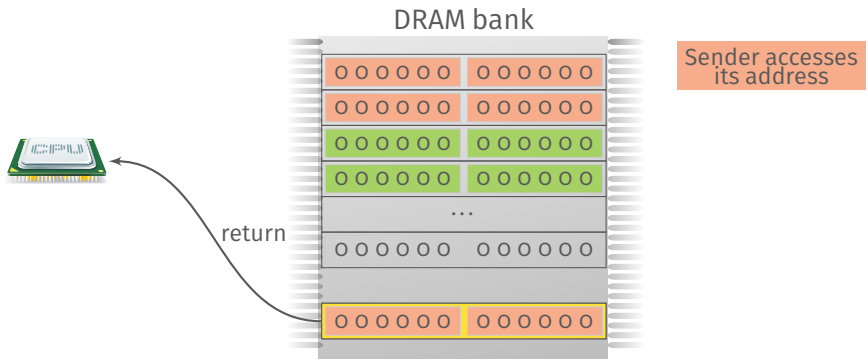

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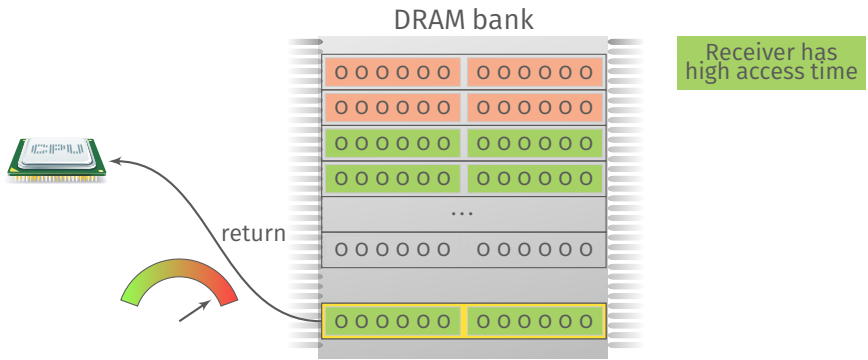
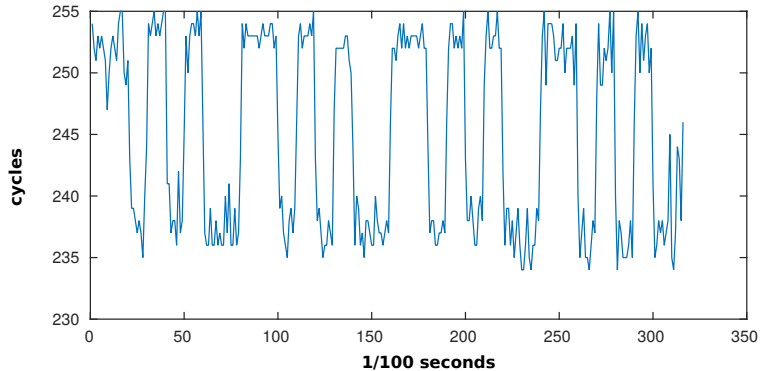


# Measurement

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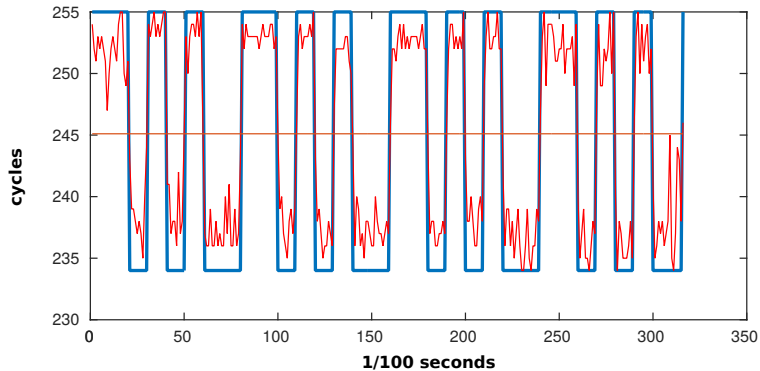


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- Sequence bit indicates whether it is a re-transmission or a new packet

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  - What is possible in native code? 596 kbit/s cross CPU and cross VM

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- Mozilla → Discussing about clock randomization and not shipping `SharedArrayBuffer`
- Tor → Working on fuzzy time

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- It allows to build timers with nanosecond resolution
- Microarchitectural attacks in the browser are possible again

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# FANTASTIC TIMERS AND WHERE TO FIND THEM

## HIGH-RESOLUTION MICROARCHITECTURAL ATTACKS IN JAVASCRIPT