Spectre Attacks: Exploiting Speculative Execution

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40th IEEE Symposium on Security and Privacy

Outline

- Attack description
- Background
- Spectre attack
- Spectre variations
- Mitigation options
- Strengths
- Weaknesses
- Discussion

Attack description

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- Works on Intel, AMD and ARM
- How?

Background

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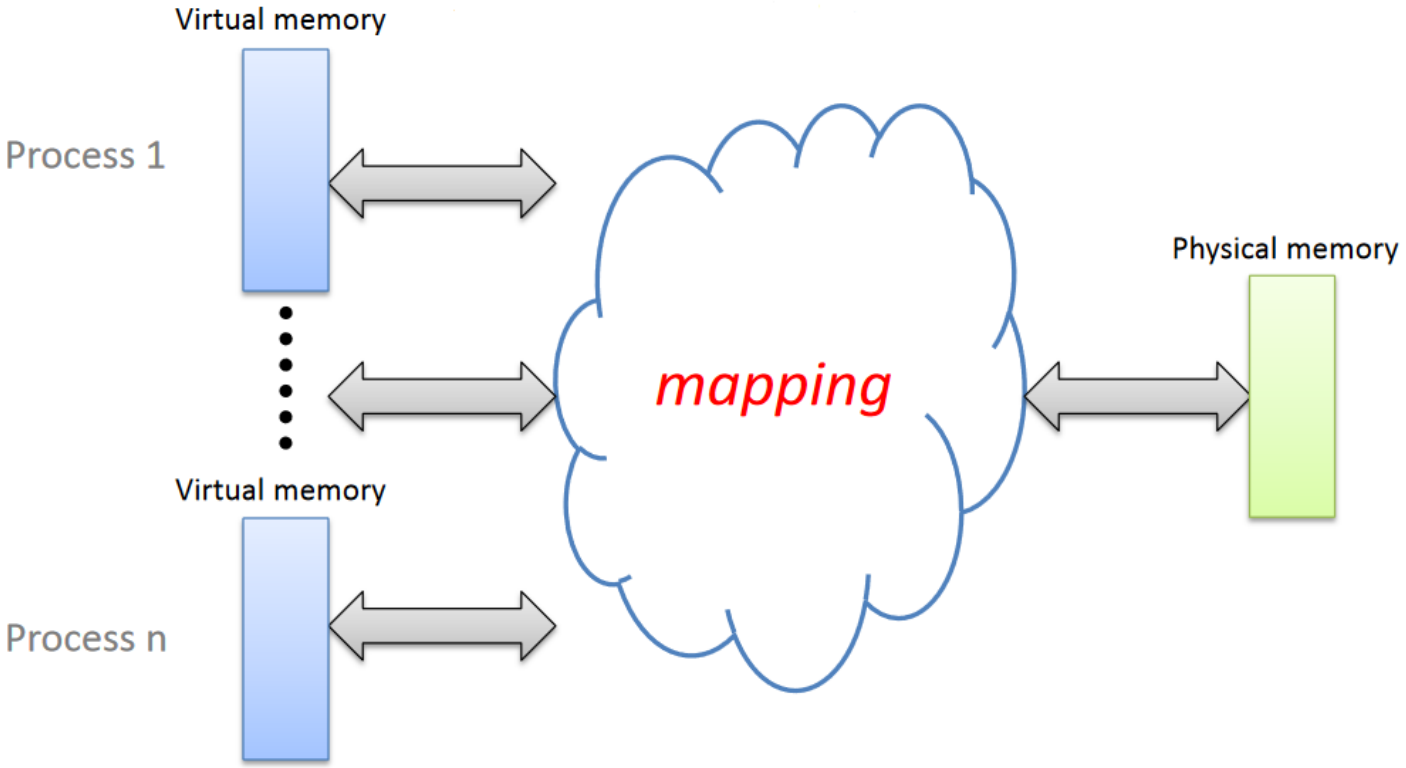

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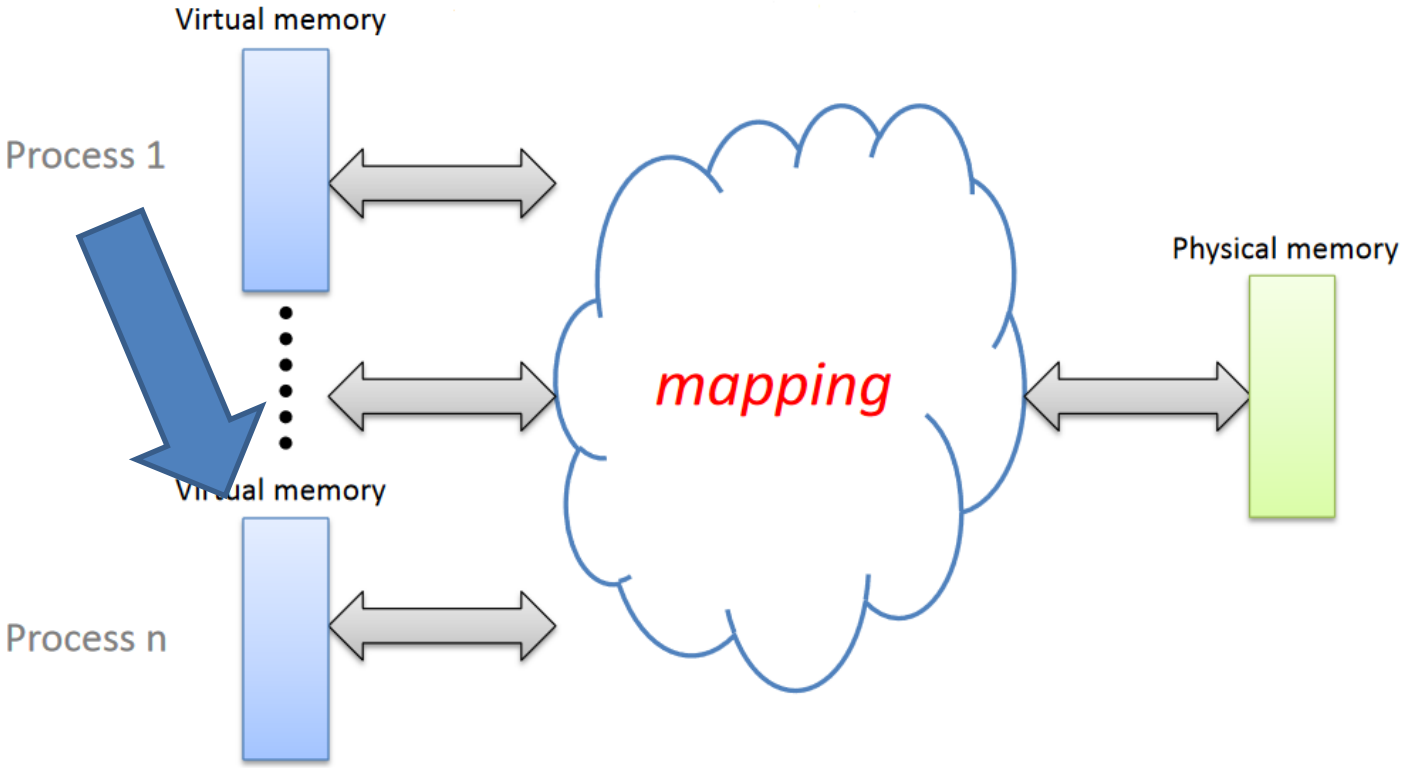

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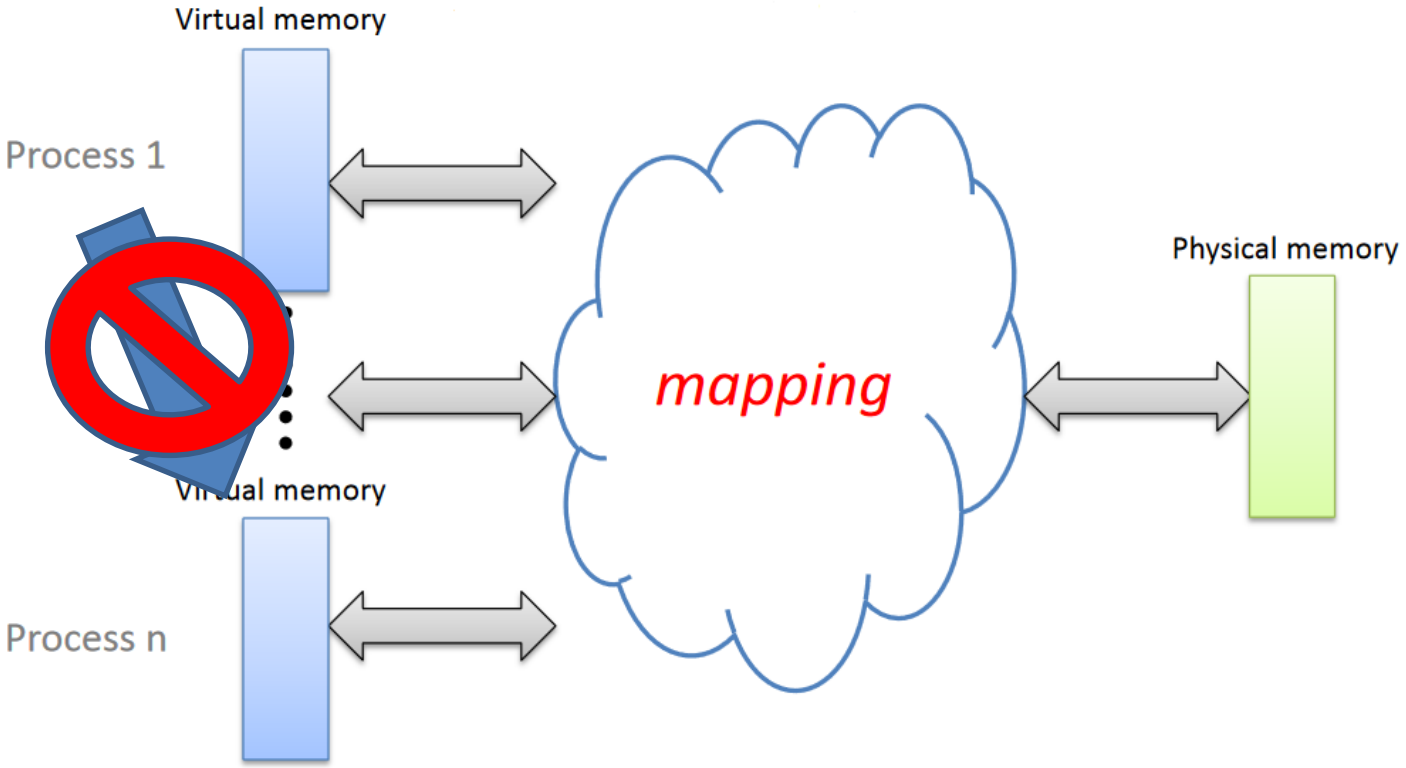

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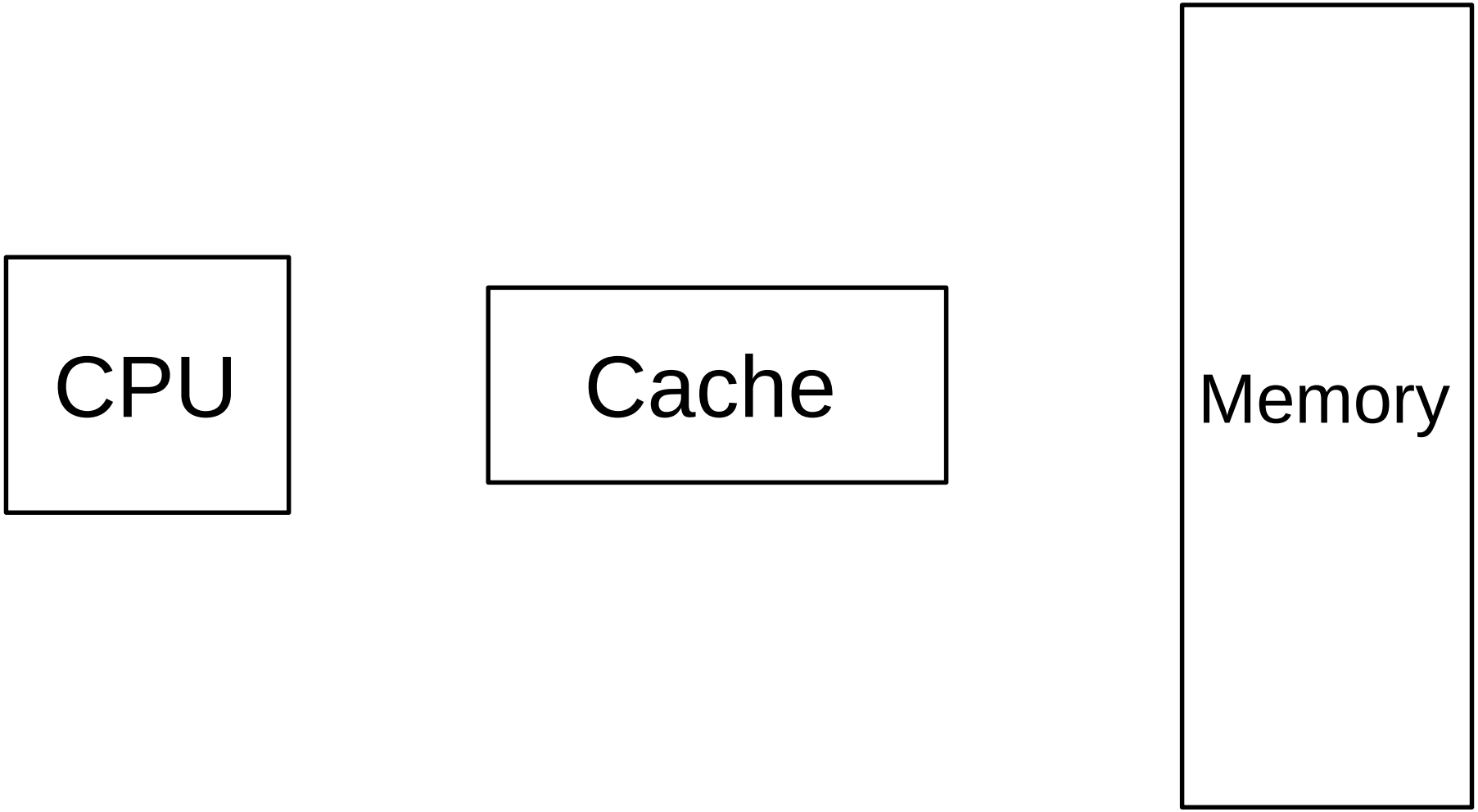

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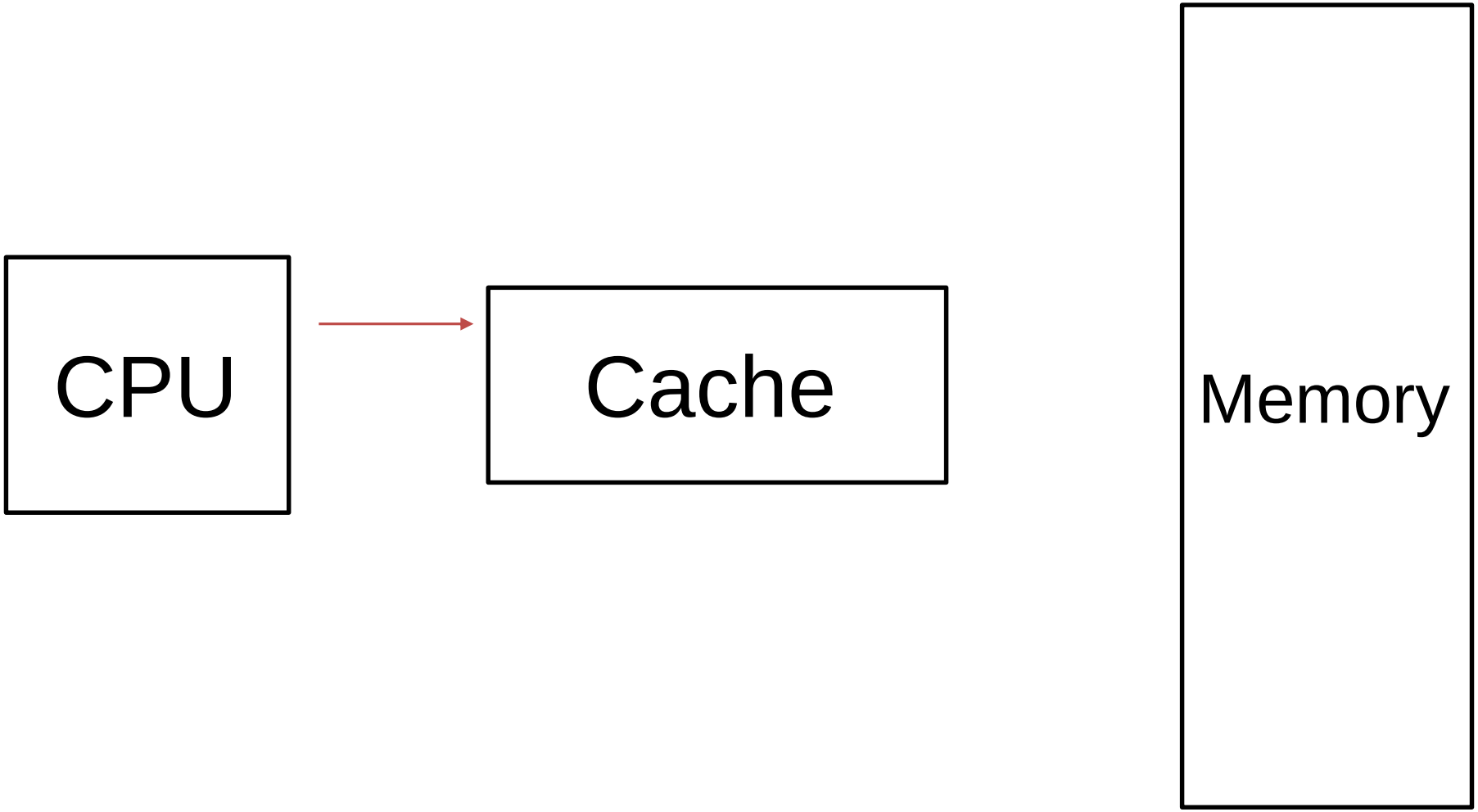

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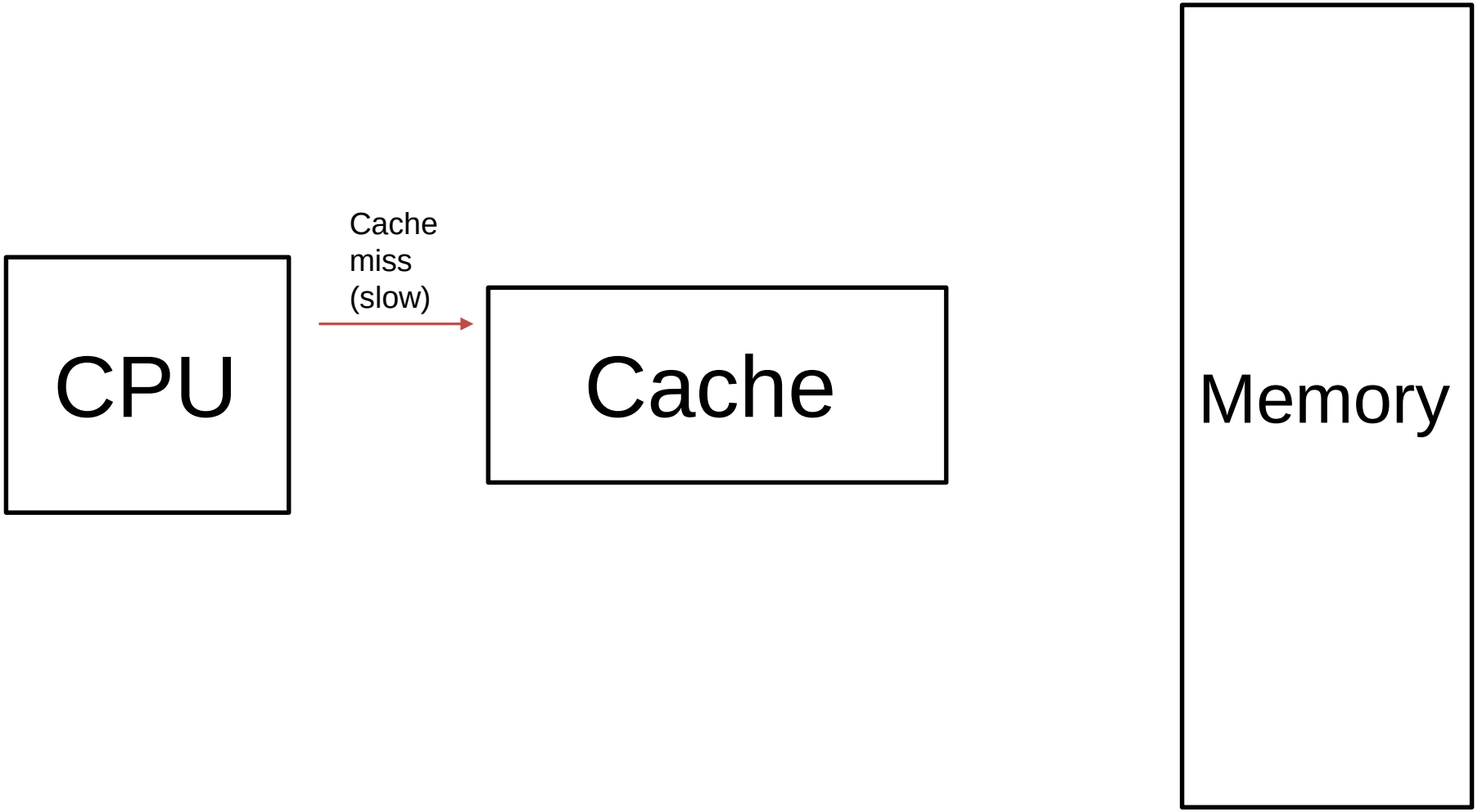

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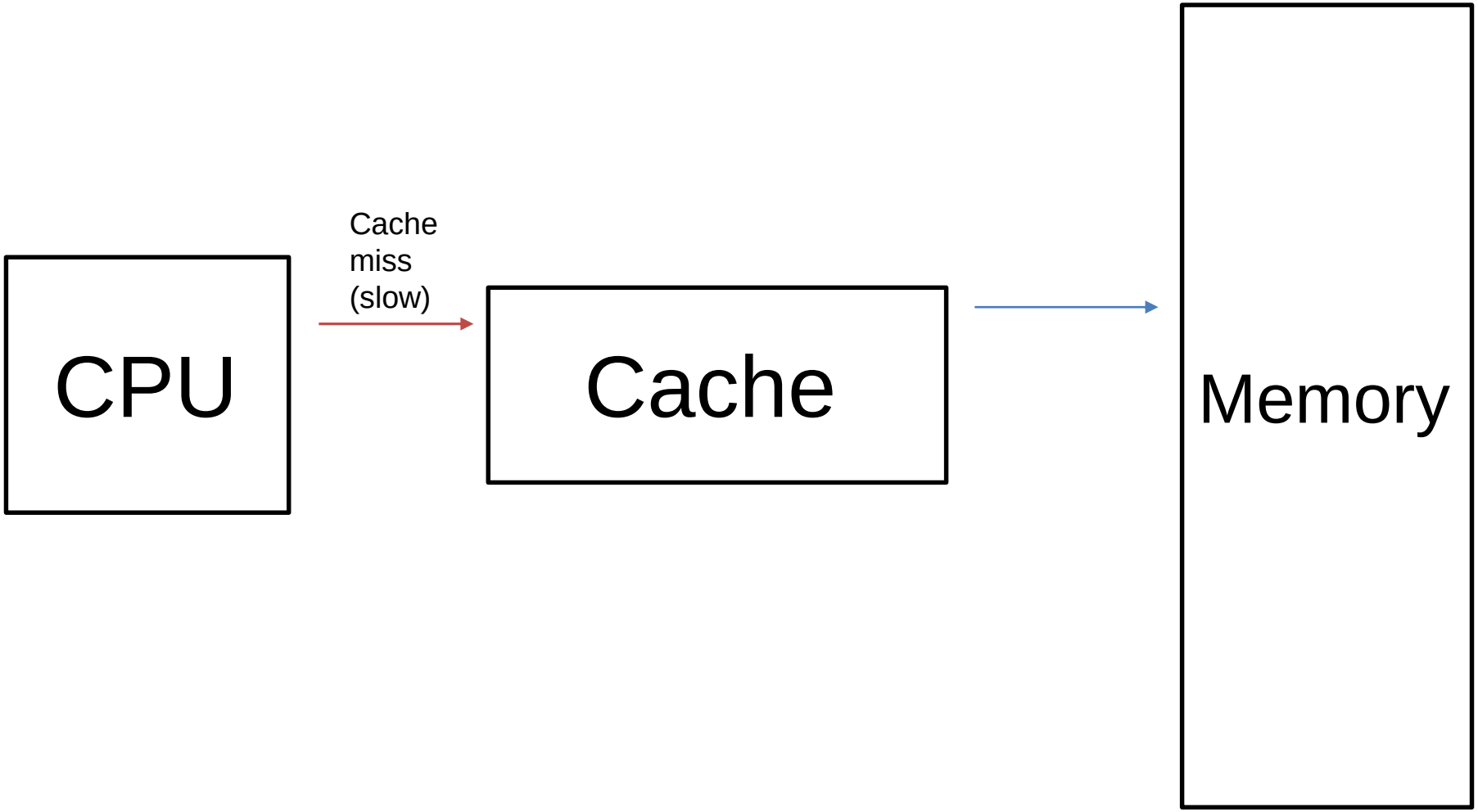

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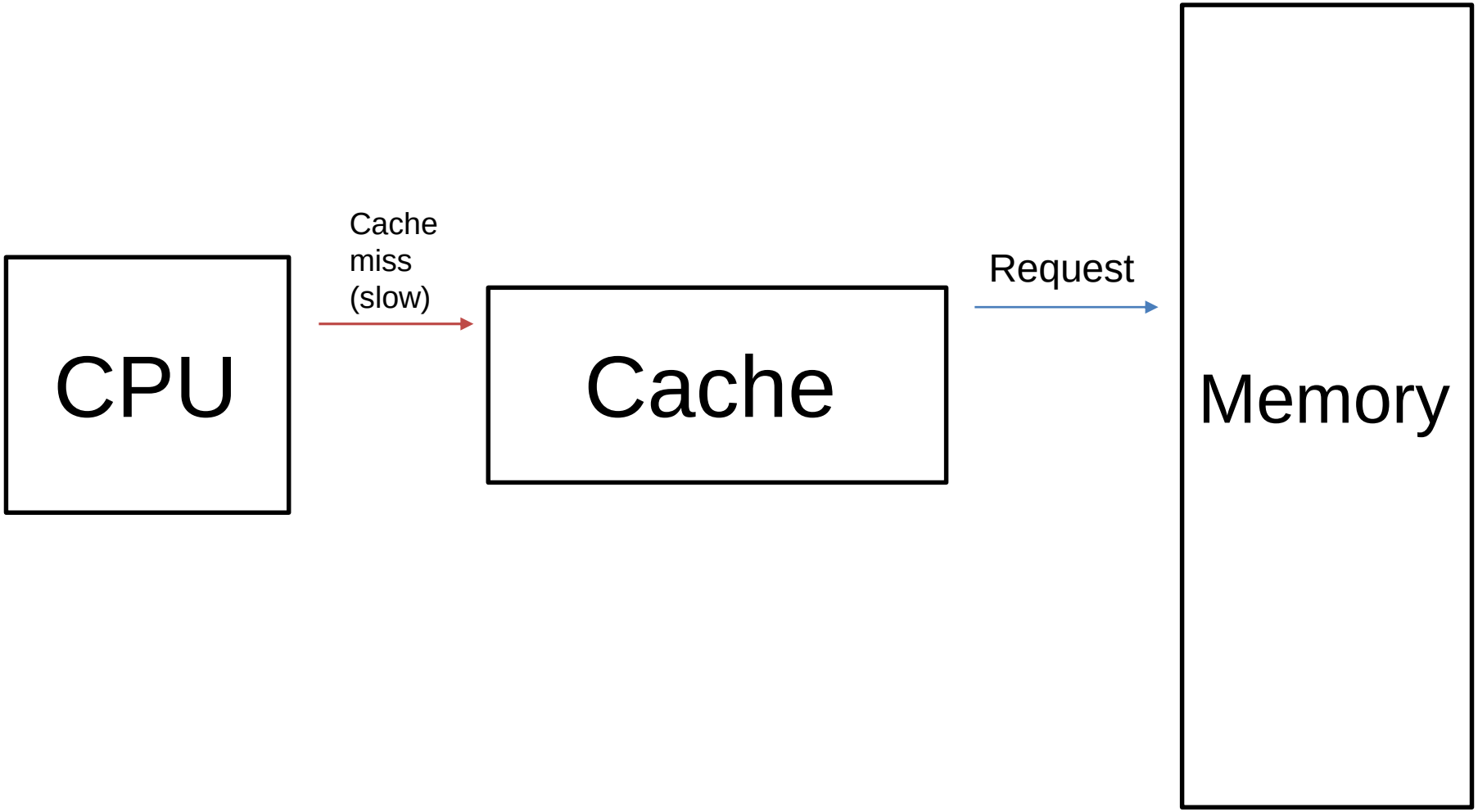

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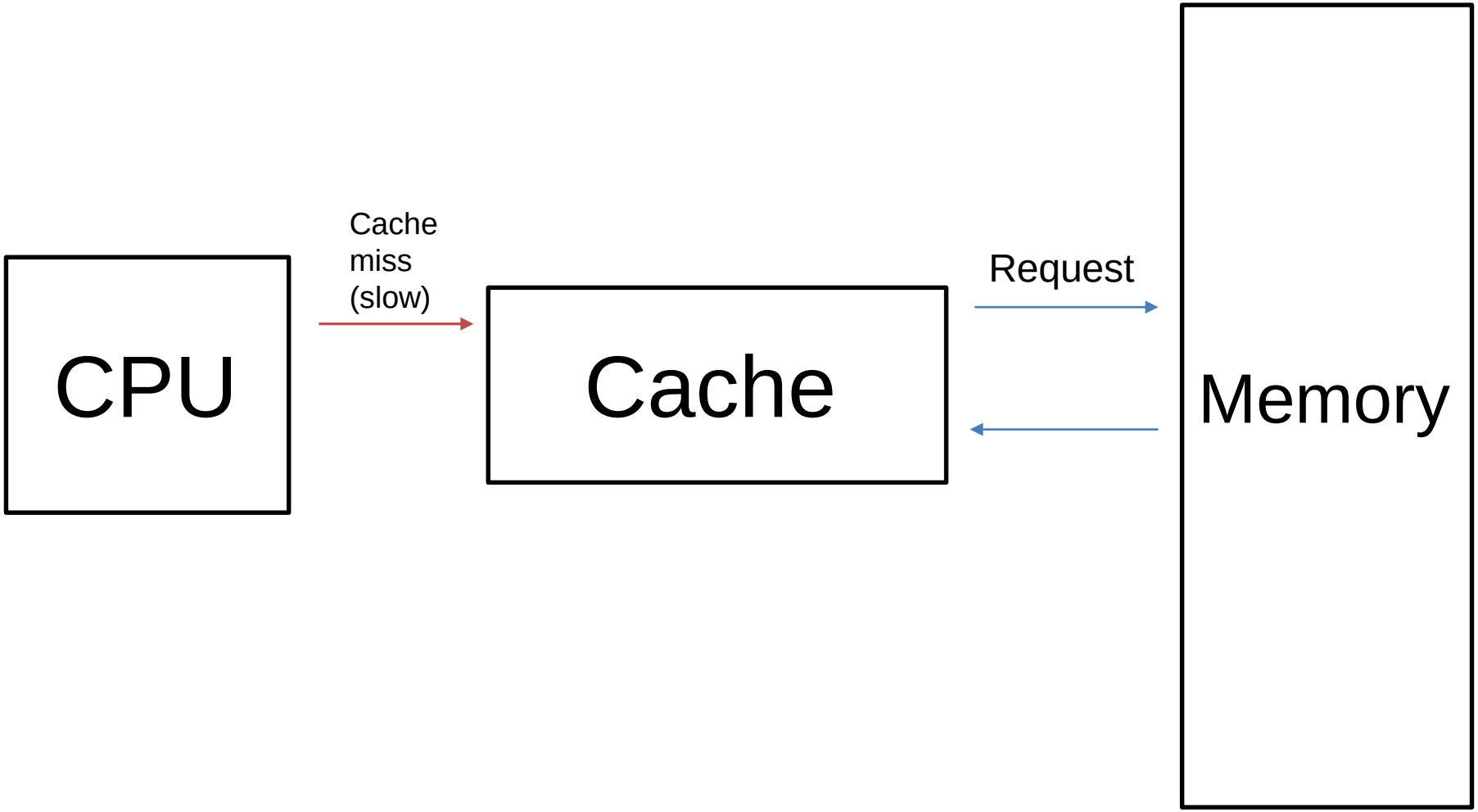

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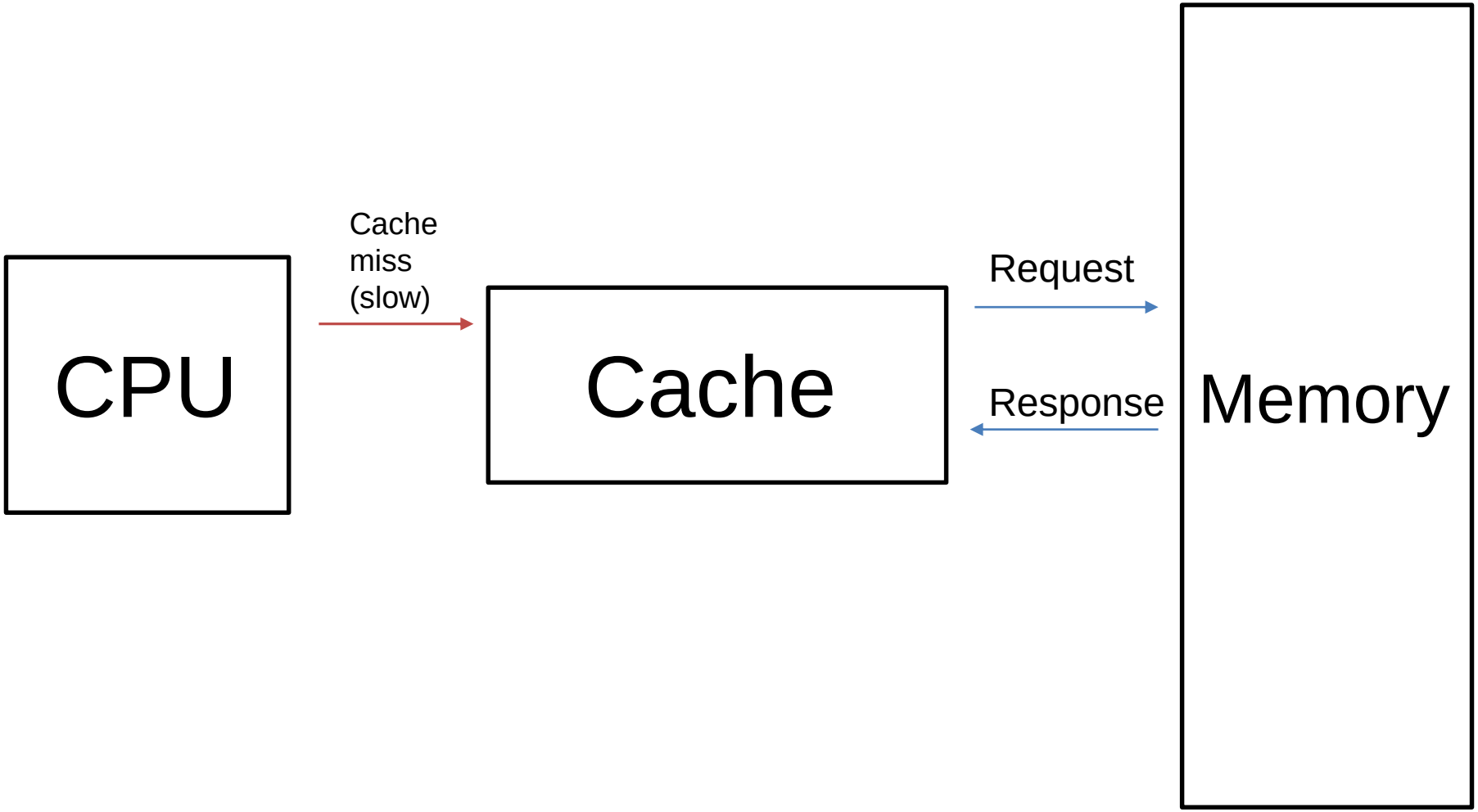

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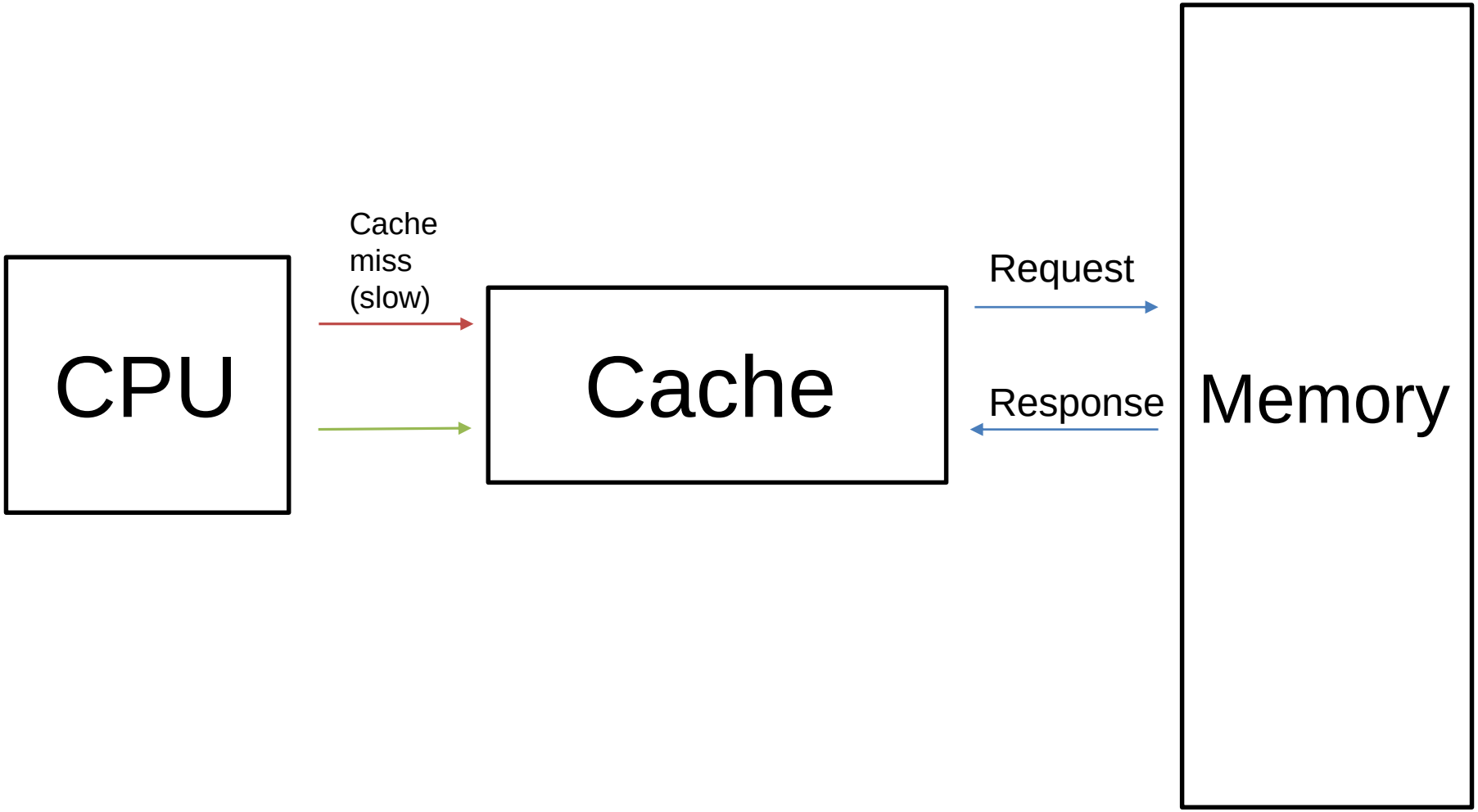

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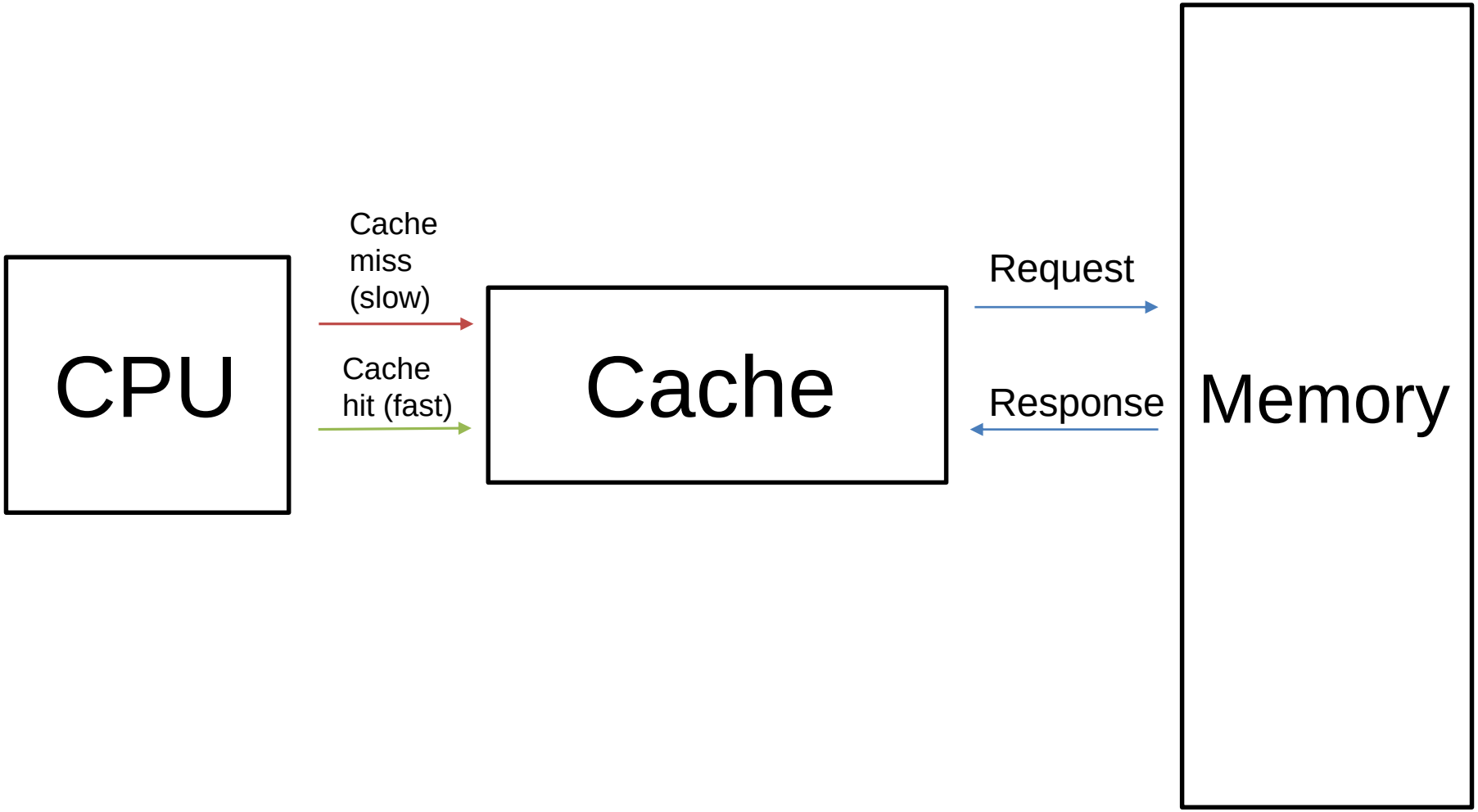

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  - Sender process has a value it wants to transmit to the receiver process
  - Sender changes the cache (loading, evicting) in a value-dependent way
  - Receiver can’t see the value in the cache directly but can time the cache and thus infer the value

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  - Branch Predictor (Speculate if direct branch taken or not)
  - Branch Target Buffer/BTB (Speculate what a value will be)
- Leads to improved Instruction Level Parallelism
- Otherwise CPU would have to sit idle while waiting for results

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- Branch predictor

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if (slow condition){
    //do something
} else {
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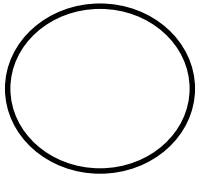

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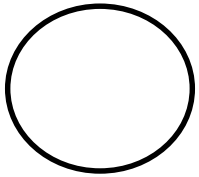

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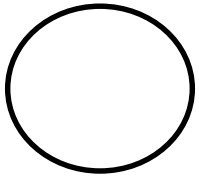

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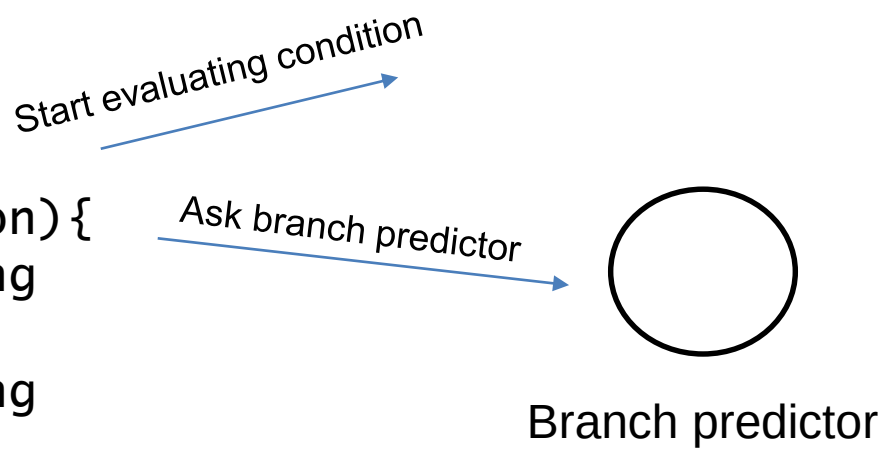

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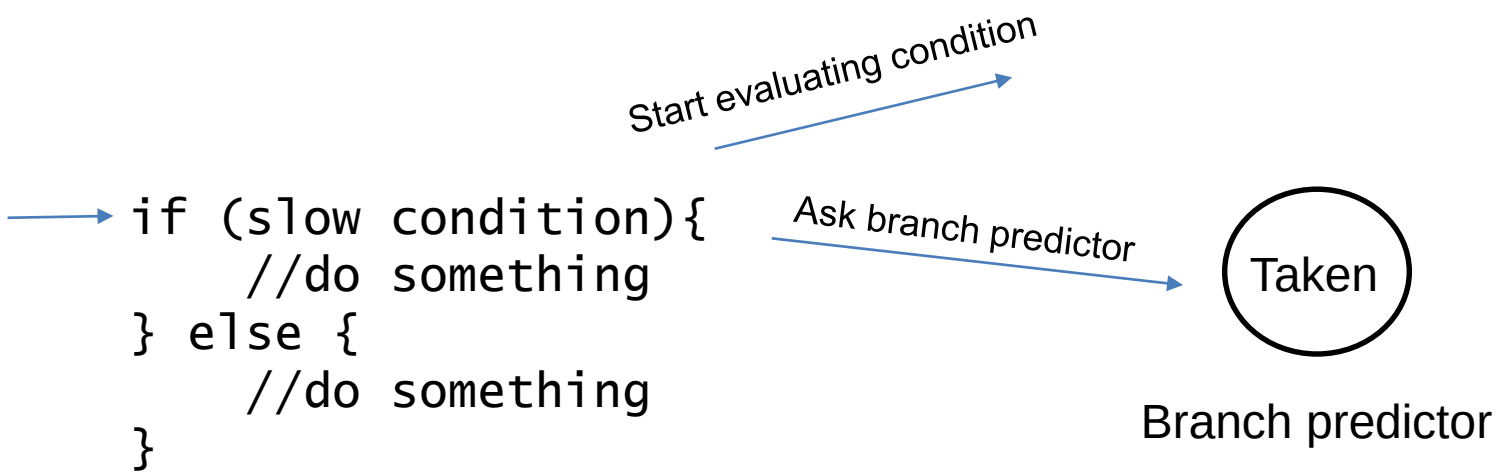

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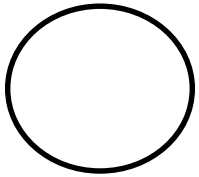

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  - => No correctness issues?
- But speculative execution has measurable side effects

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- Setup phase: Mistrain CPU into speculatively executing these instructions

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  - Misexecute own code (e.g. sandbox, interpreter, JIT)

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  - Other microarchitectural state

Spectre Variants

Variant 1: Exploiting Conditional Branch Misprediction

Address	Value
000	4
001	13
010	9
011	2
100	12
101	75
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k

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- We want to find out what a certain byte in the virtual address of the victim is

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- Let's call this secret byte k

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- Second phase: Choose x out-of-bounds such that *array1[x]* resolves to secret byte

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  - Works even though no high res. timer available
  - Able to read out browser's address space

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  - mov R3, [R2]

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- Branch Target Buffer

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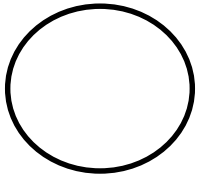

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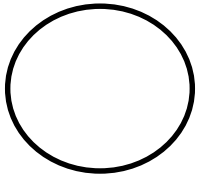

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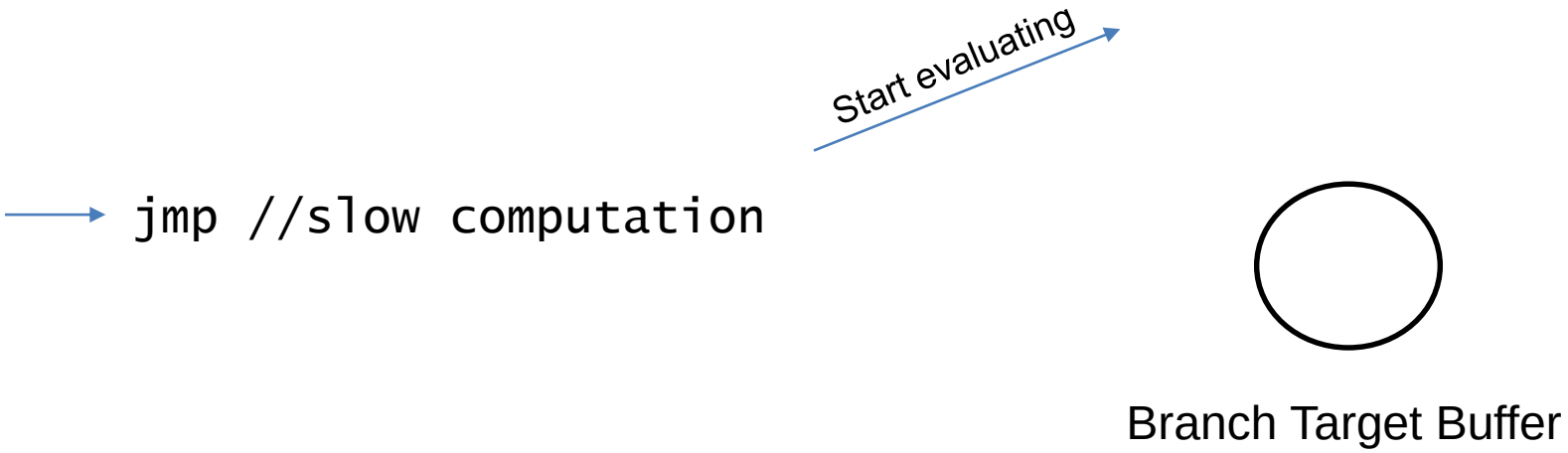

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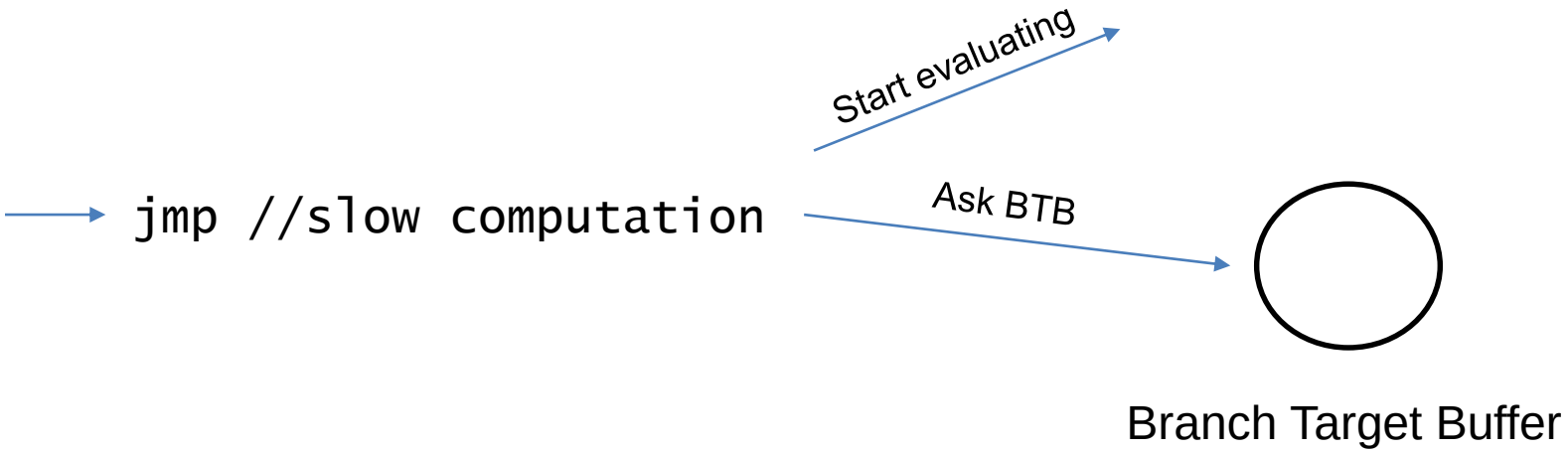

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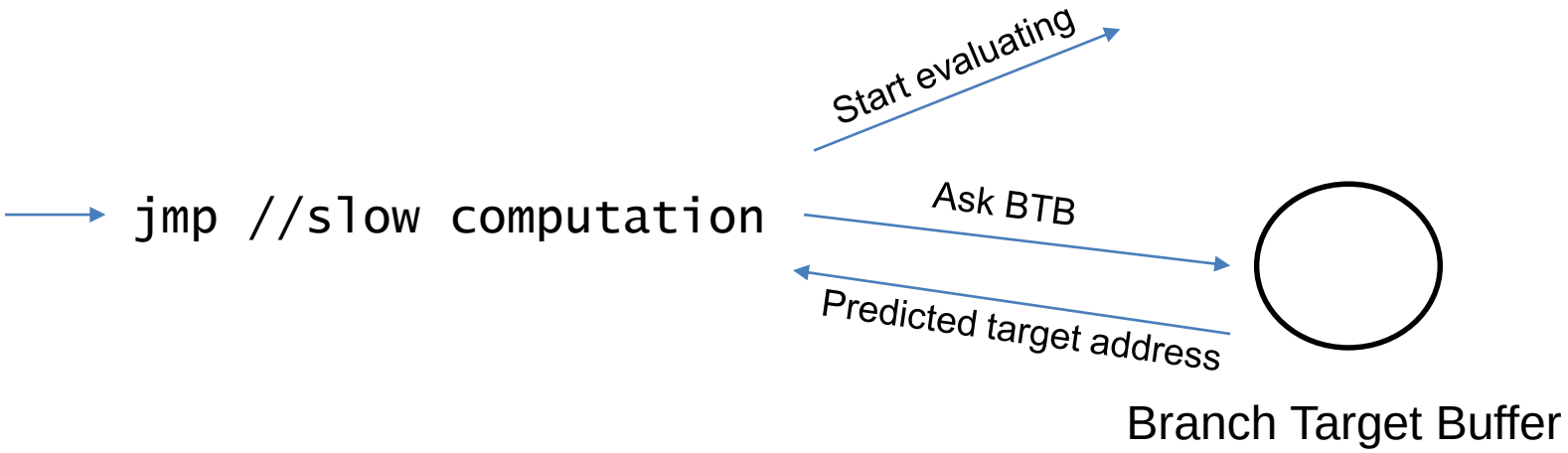

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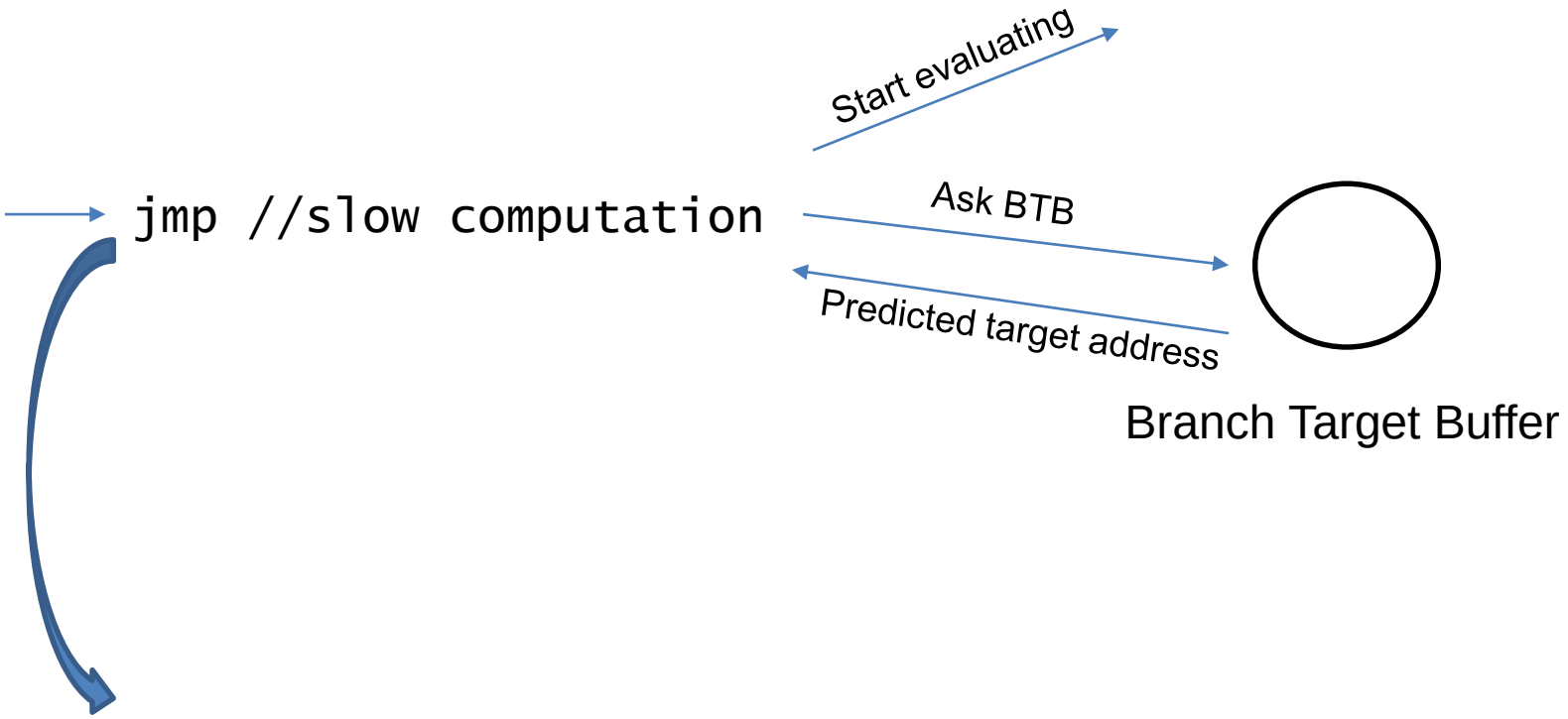

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- Final phase: Recover over covert channel

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Other Methods of achieving speculative execution

[1] Spectre Returns! Speculation Attacks using the Return Stack Buffer
By Esmaiel Mohammadian Koruyeh, Khaled Khasawneh,
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Other Methods of achieving speculative execution

- Mistraining return instructions [1]

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Mitigation Options

[1] https://support.google.com/faqs/answer/7625886

[2] https://developer.arm.com/support/arm-security-updates/speculative-processor-vulnerability/compiler-support-for-mitigations

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  - Addressing Spectre Variant 1 (CVE-2017-5753) in Software [2]

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Mitigation Options

[1] oo7: Low-overhead Defense against Spectre Attacks via Binary Analysis
Guanhua Wang, Sudipta Chattopadhyay, Ivan Gotovchits, Tulika Mitra, Abhik Roychoudhury

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  - => different microarchitectural state can be used to leak information

Novelty

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- Developers now need to know about microarchitecture to code non-vulnerable software!

Strengths

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  - => But one can search in shared libraries
- Doesn’t tell us the speed of the Javascript implementation

Related papers

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- A Systematic Evaluation of Transient Execution Attacks and Defenses by Claudio Canella, Jo Van Bulck, Michael Schwarz, Moritz Lipp, Benjamin von Berg, Philipp Ortner, Frank Piessens, Dmitry Evtyushkin, Daniel Gruss

Discussion Starters

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