Varys

Protecting SGX Enclaves From Practical Side-Channel Attacks

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TECHNION Israel Institute of Technology

Key issue of the cloud:

We cannot trust it

We cannot trust the cloud

- Thousands of employees
- Legal obligations
- Infrastructure vulnerabilities

GERALD SAUER OPINION 02.28.17 10:00 AM

A MURDER CASE TESTS ALEXA'S DEVOTION TO YOUR PRIVACY

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Urgent security triage needed

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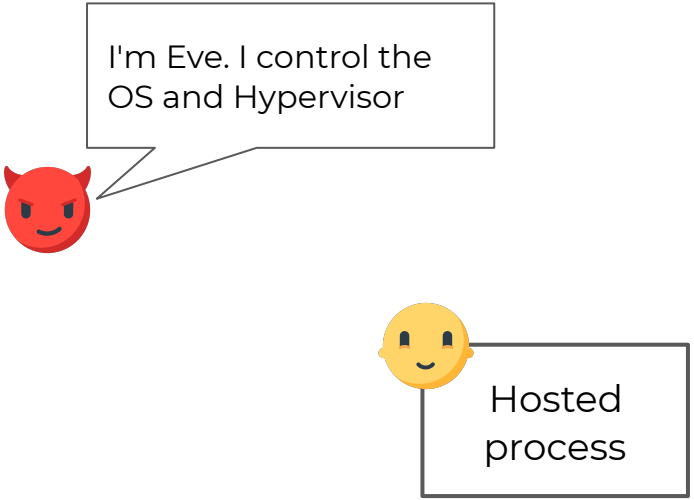
Privileged attack vectors



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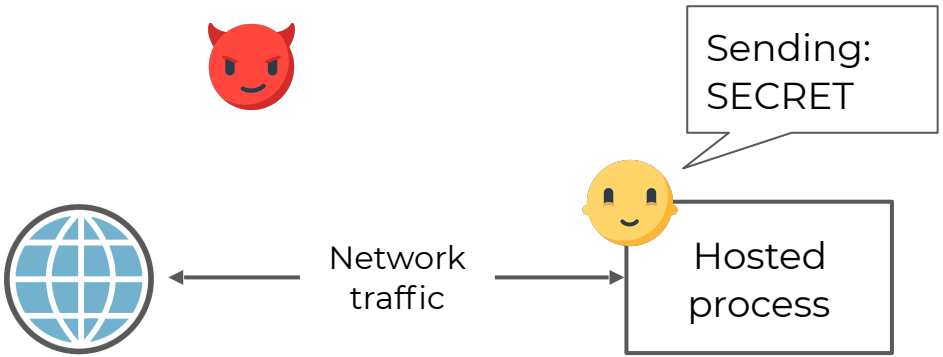

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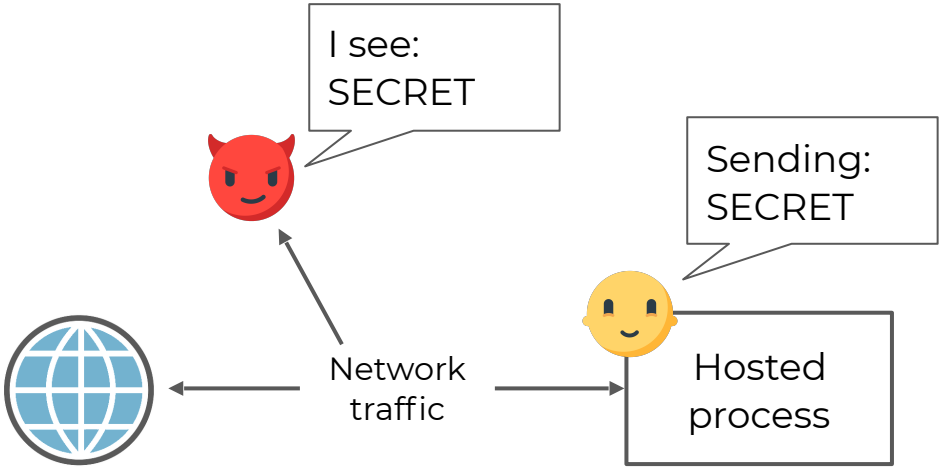

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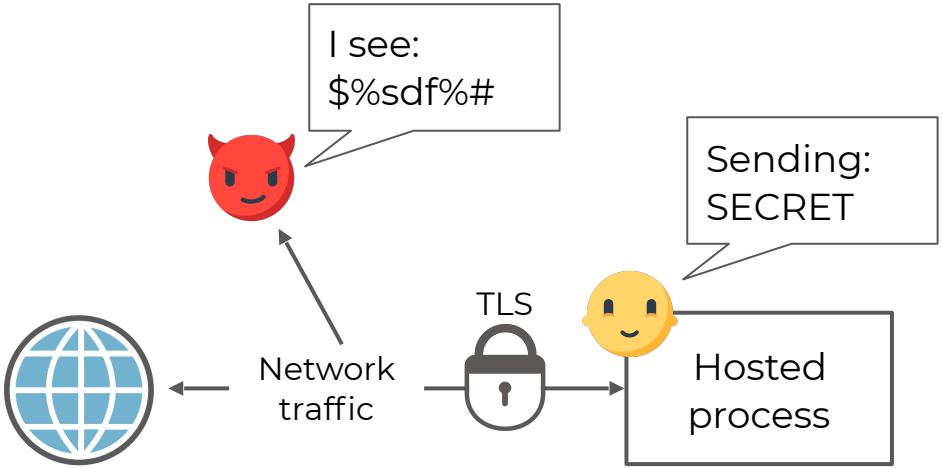

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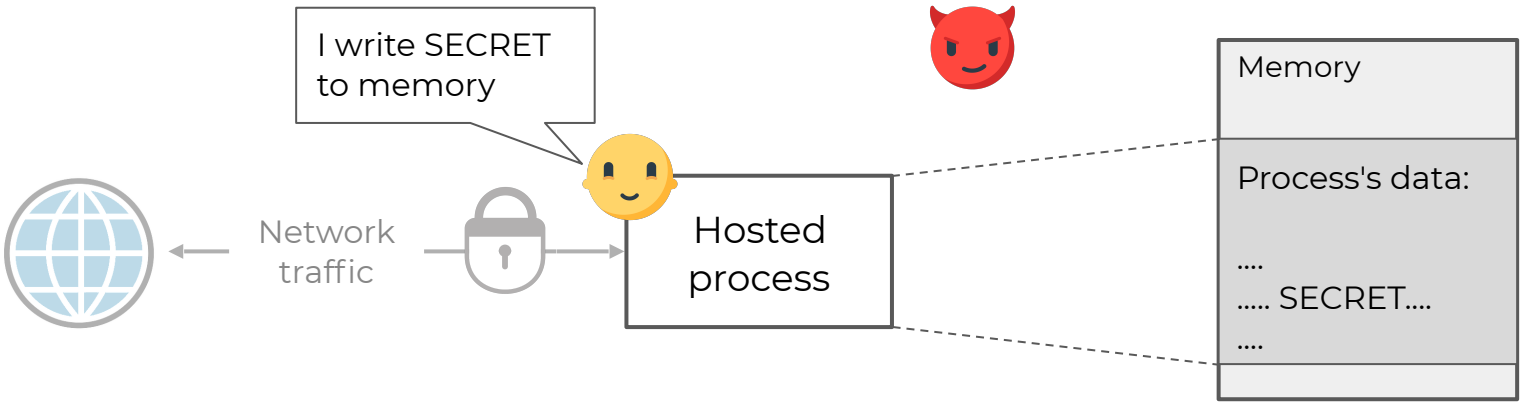

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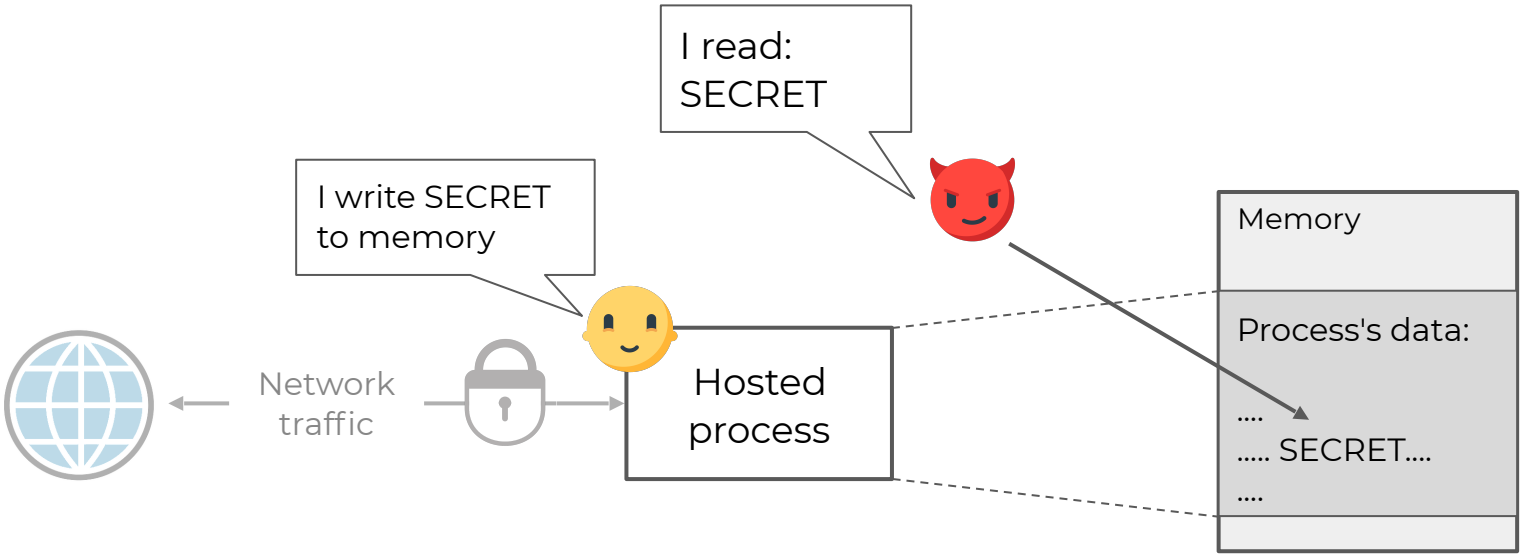

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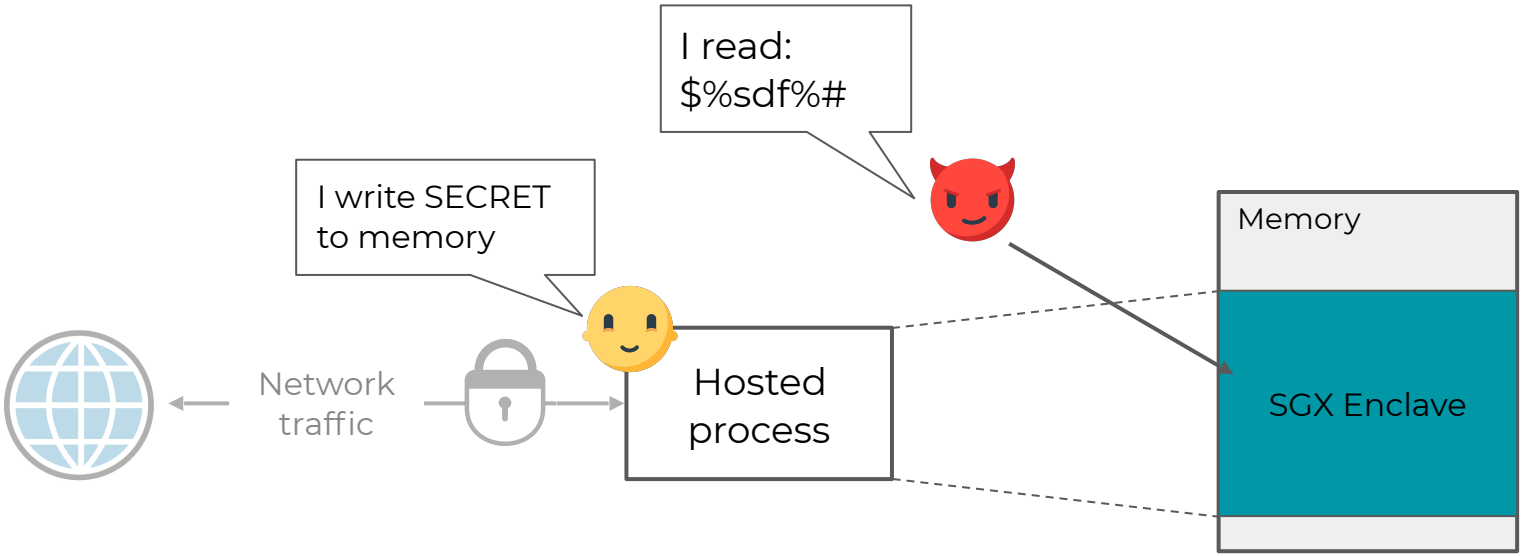

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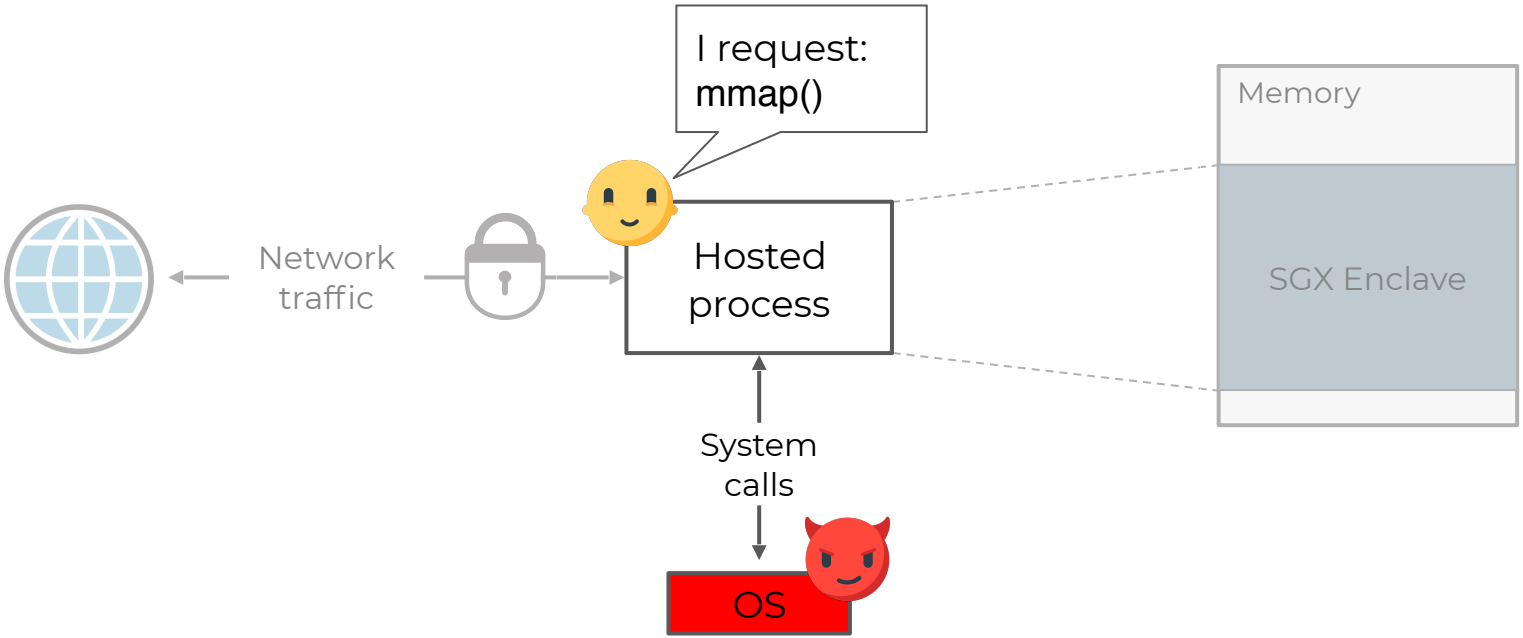

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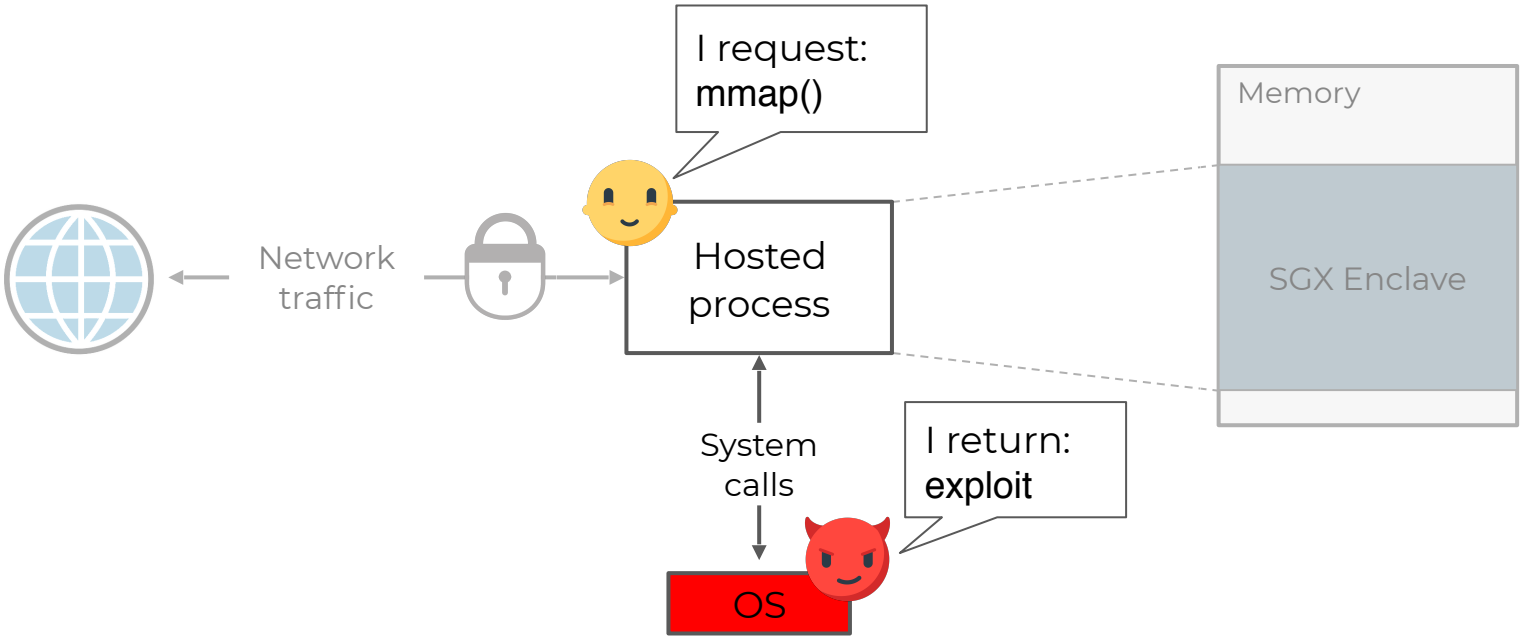

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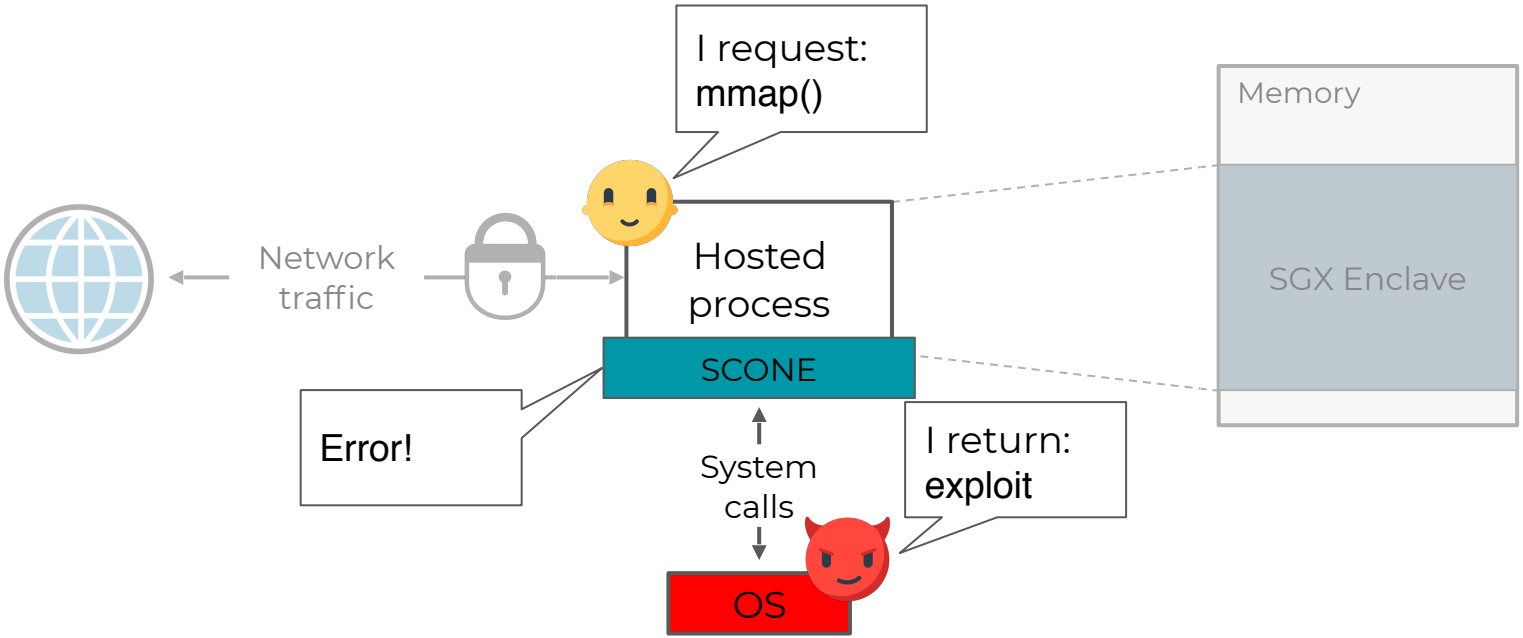

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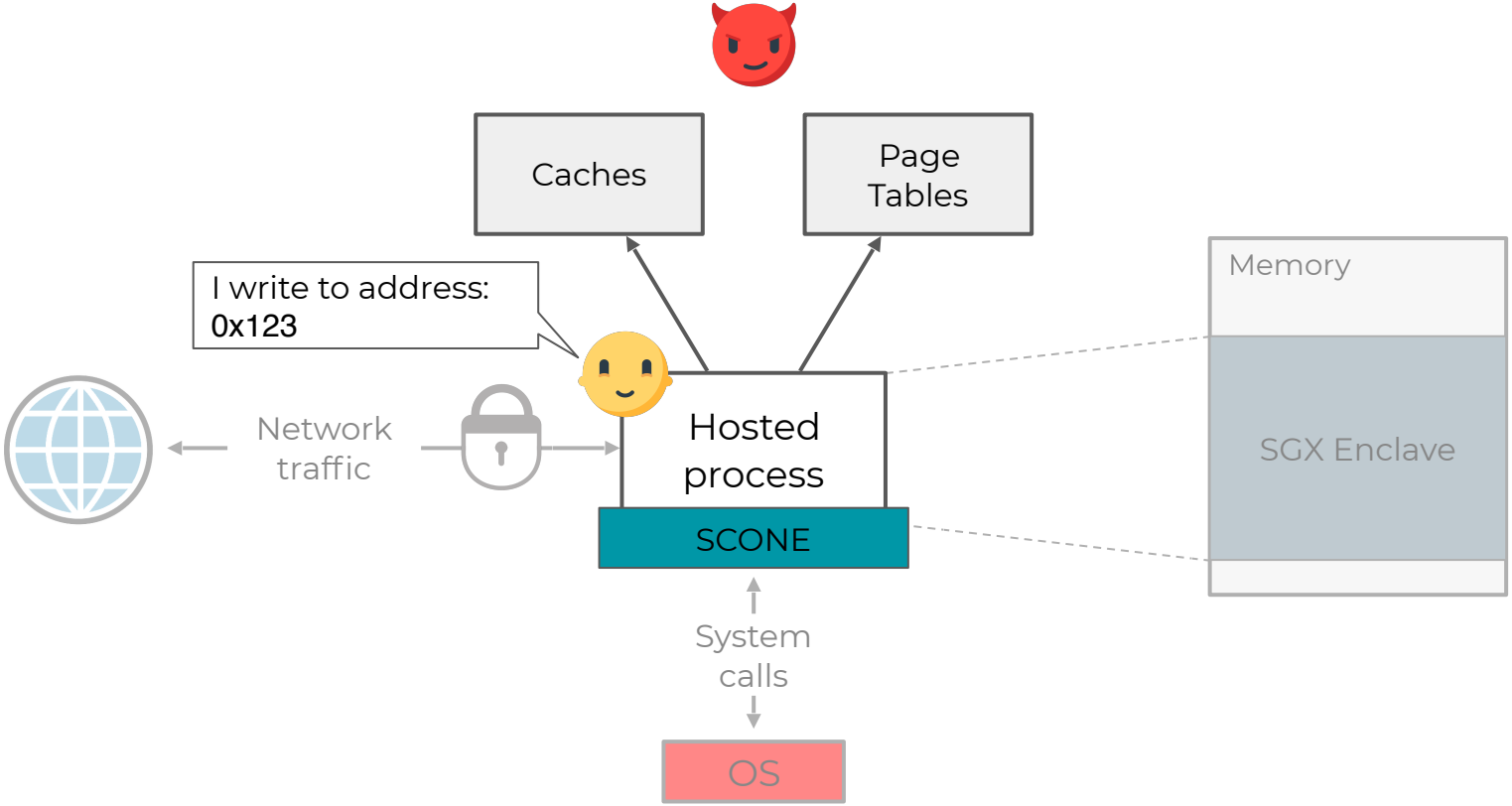

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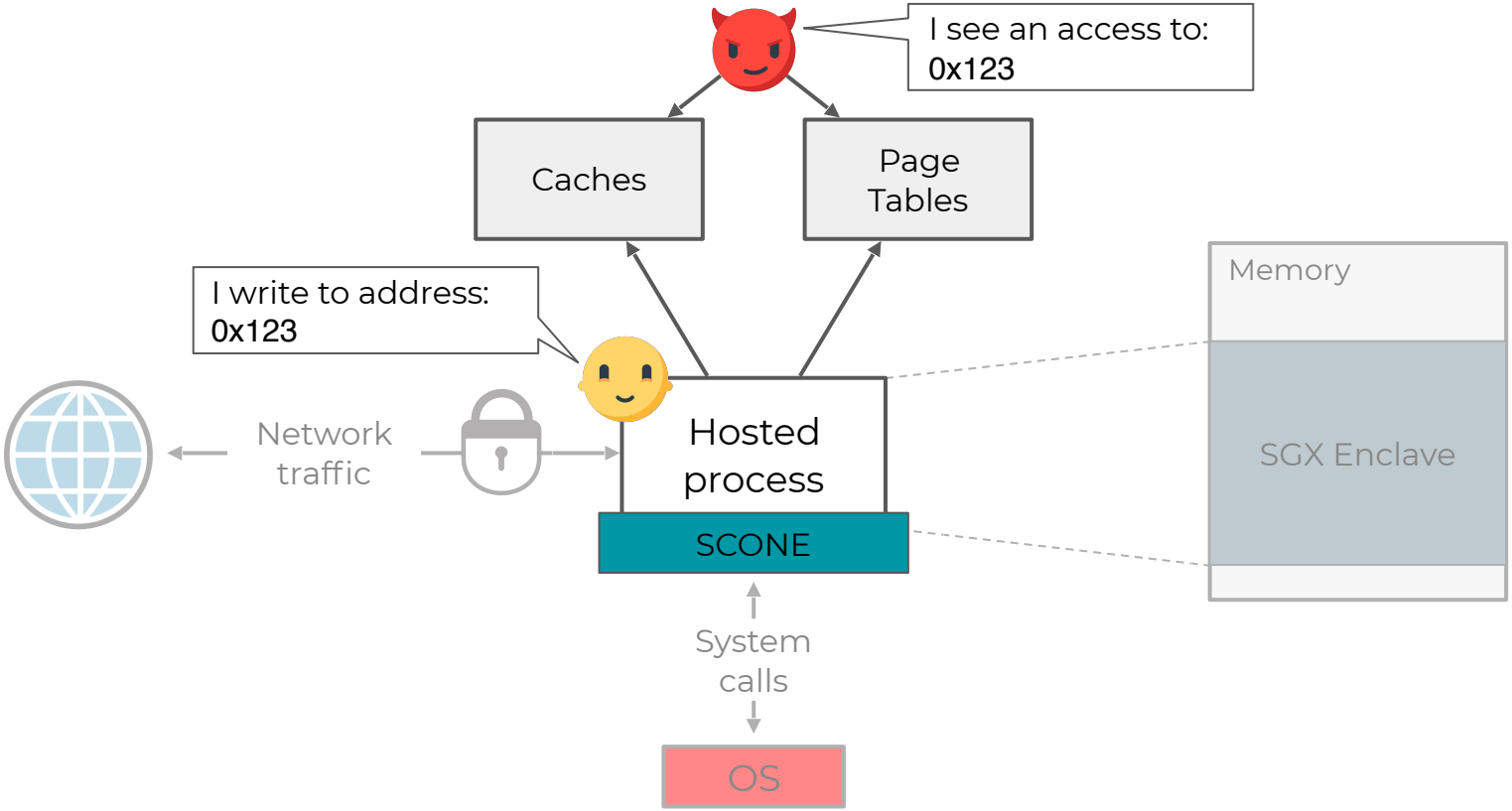

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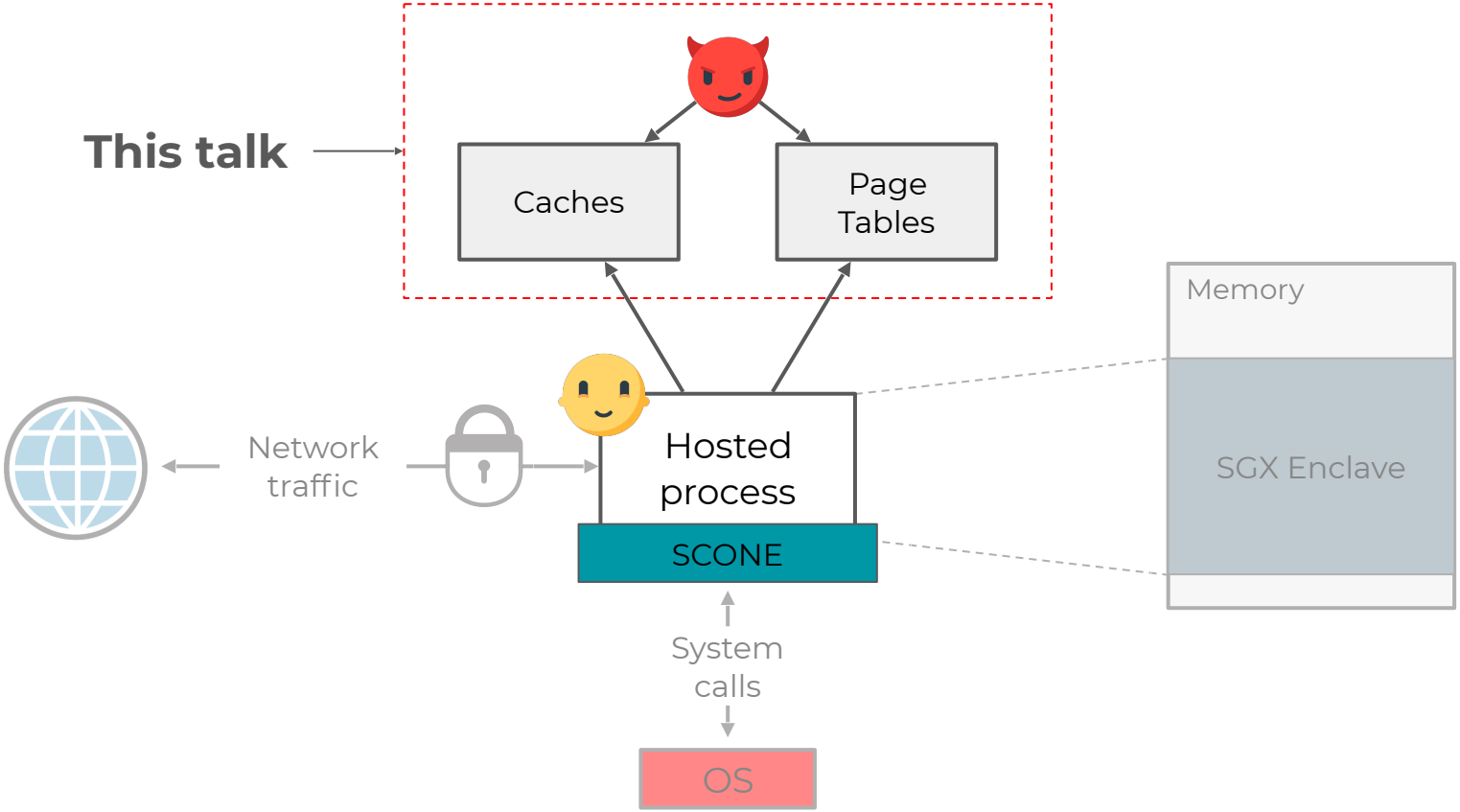
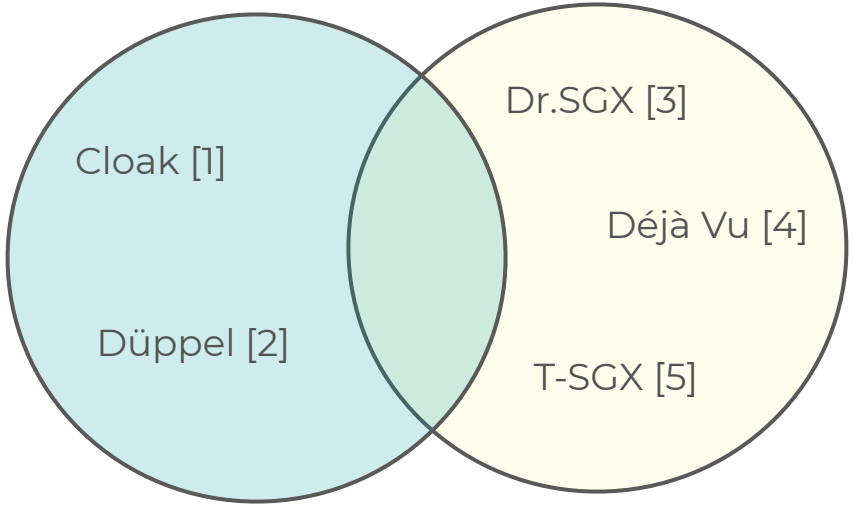


Existing solutions

Low overhead



Low effort

(no code changes required)

[1] Gruss, D., Lettner, J., Schuster, F., Ohrimenko, O., Haller, I., & Costa, M. Strong and Efficient Cache Side-Channel Protection using Hardware Transactional Memory. In *Usenix Security 2017*.
[2] Zhang, Y., Reiter, M. K., Zhang, Y., & Reiter, M. K. Düppel: Retrofitting Commodity Operating Systems to Mitigate Cache Side Channels in the Cloud. *In CCS 2013*.
[3] Brasser, F., Capkun, S., Dmitrienko, A., Frassetto, T., Kostiainen, K., Müller, U., & Sadeghi, A.-R. DR.SGX: Hardening SGX Enclaves against Cache Attacks with Data Location Randomization. In arXiv 2017.
[4] Chen, S., Reiter, M. K., Zhang, X., & Zhang, Y. Detecting Privileged Side-Channel Attacks in Shielded Execution with Déjà Vu. In *ASIA CCS '17*.
[5] Shih, M., Lee, S., & Kim, T. T-SGX: Eradicating controlled-channel attacks against enclave programs. In *NDSS 2017*.

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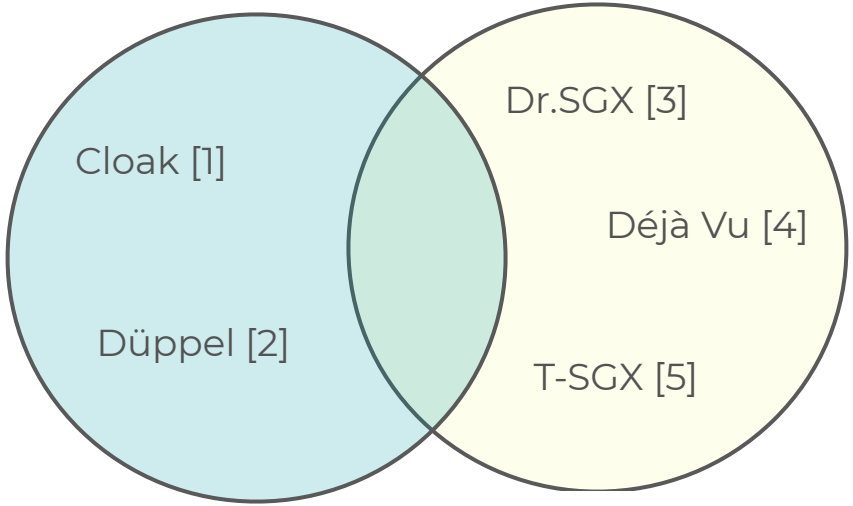

Low effort

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Varys

- 15% average slowdown
- No code changes

Approach

Rely but verify

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Request isolation from the untrusted OS

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Check within the enclave

Complete description

Varys implements a low-cost protection for Intel SGX enclaves against side-channel attacks by creating an isolated environment and verifying it at runtime.

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Rest of the talk explains this sentence

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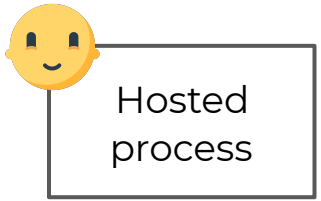
Side-channel attacks



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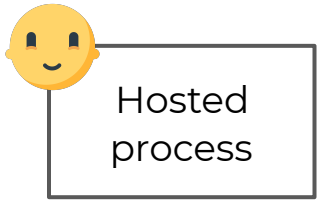

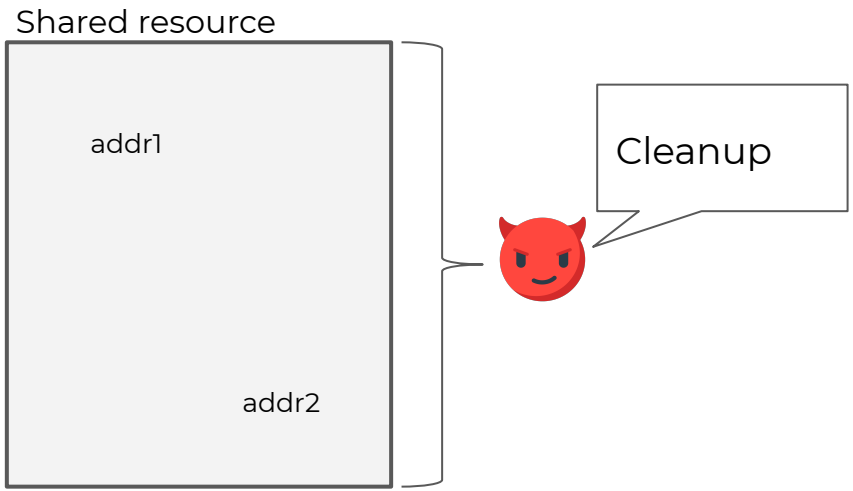

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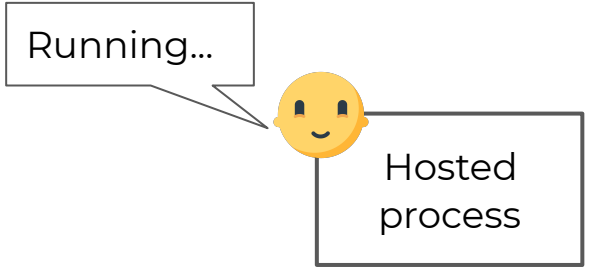

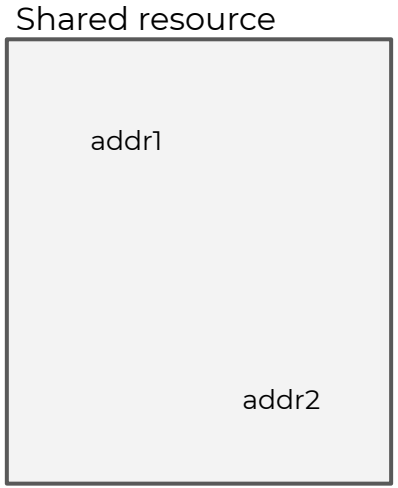

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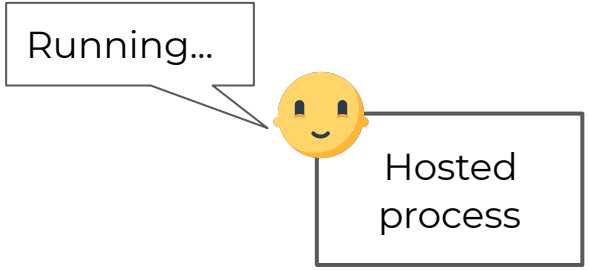

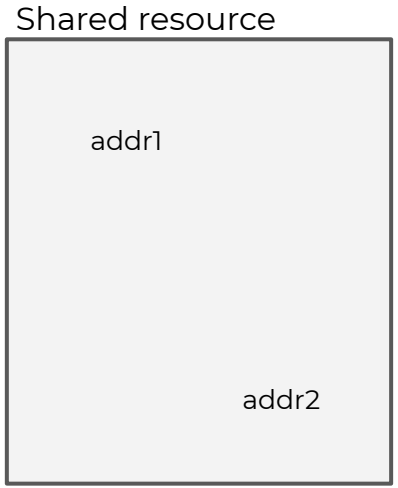

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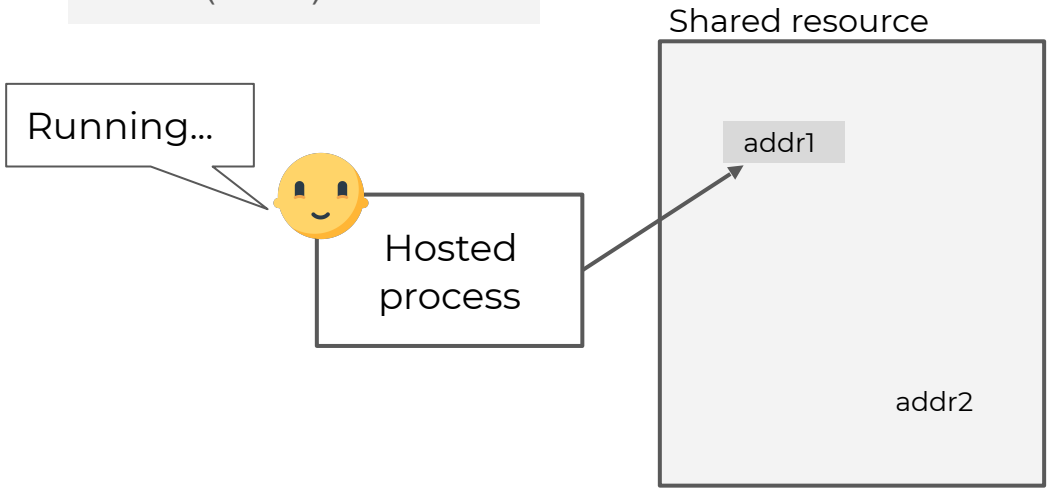

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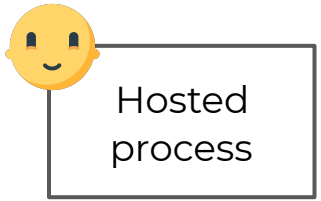

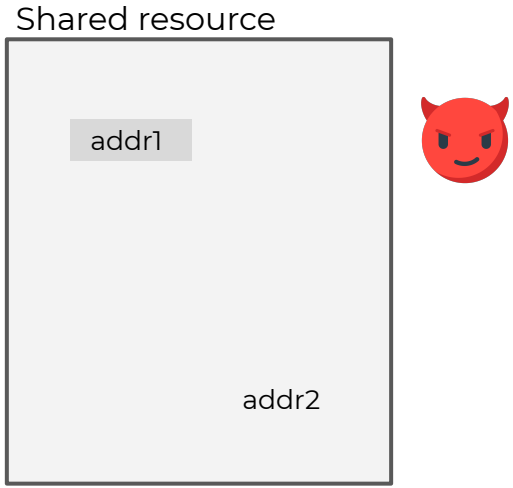

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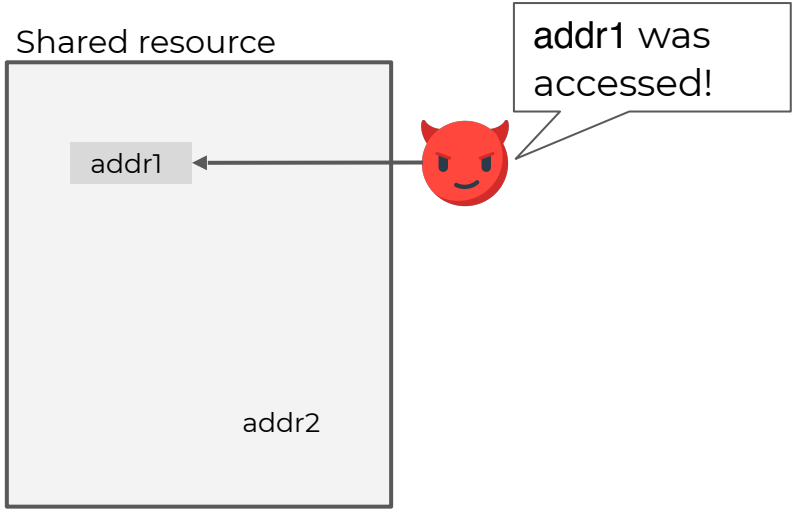

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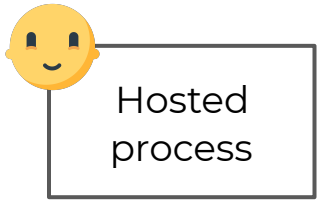

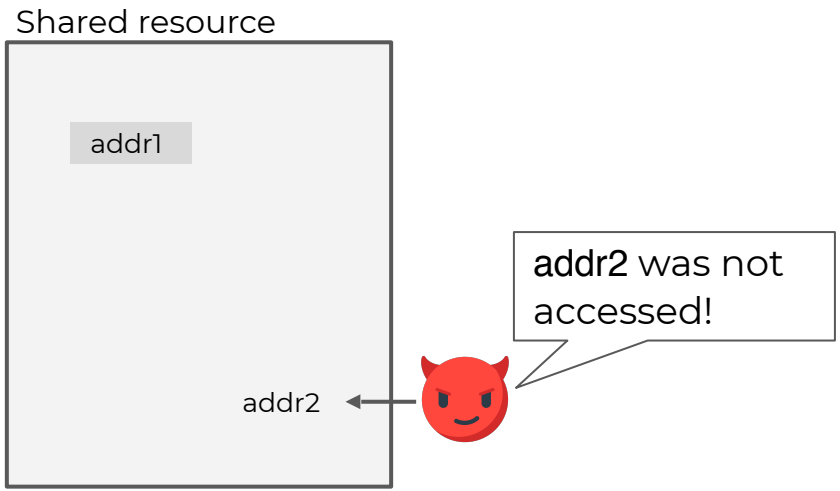

Side-channel attacks

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This line was executed

Shared resource

addr1

addr2

Hosted process

Side-channel attacks

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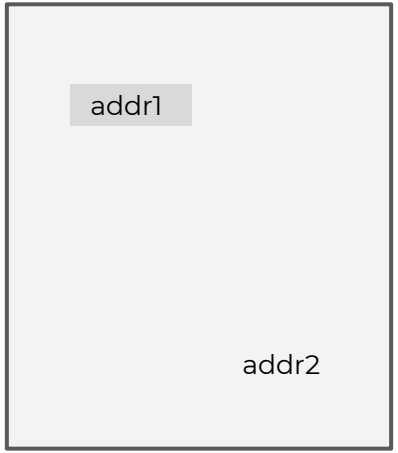
The secret is **0**

Shared resource



Hosted process

Vulnerable shared resources

- CPU caches
- Page tables
- FPU
- Memory bus
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Attack requirements

- High interrupt rate
- Predefined cache state
- Shared core

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} Isolated environment

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Design

- High preemption rate
- Predefined cache state
- Shared core

Restrict and terminate

Cache eviction

Trusted reservation

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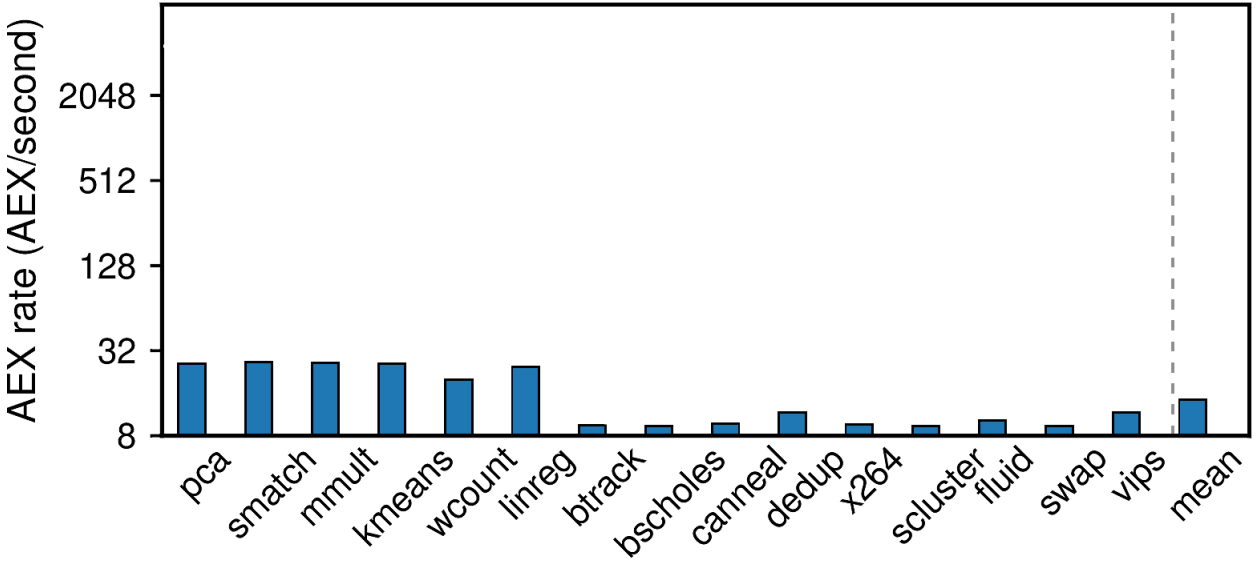

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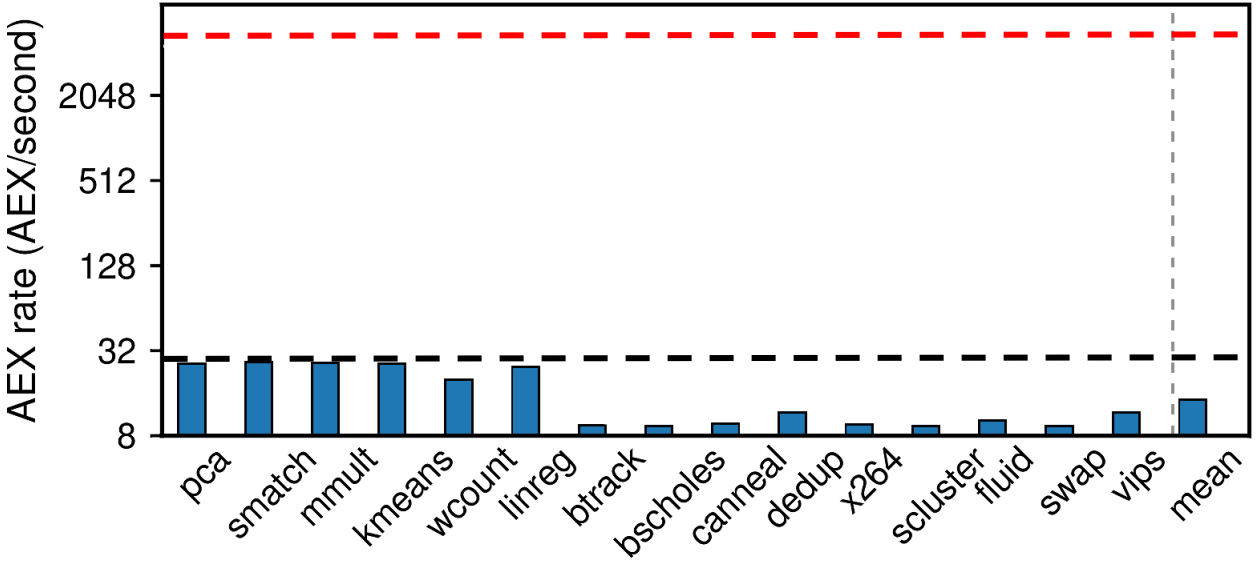
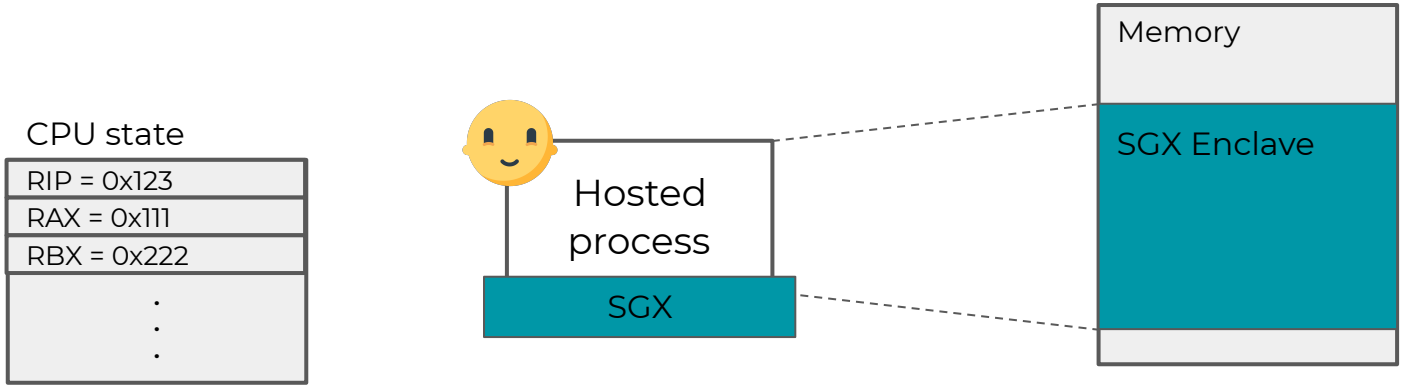


Asynchronous Enclave Exit (AEX)



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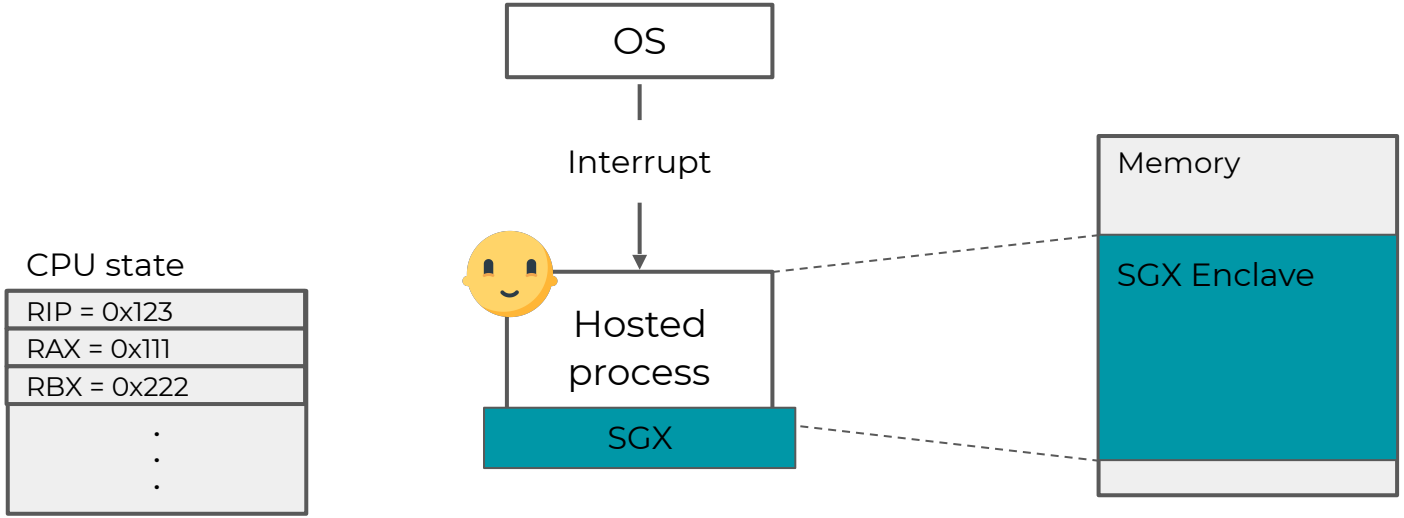

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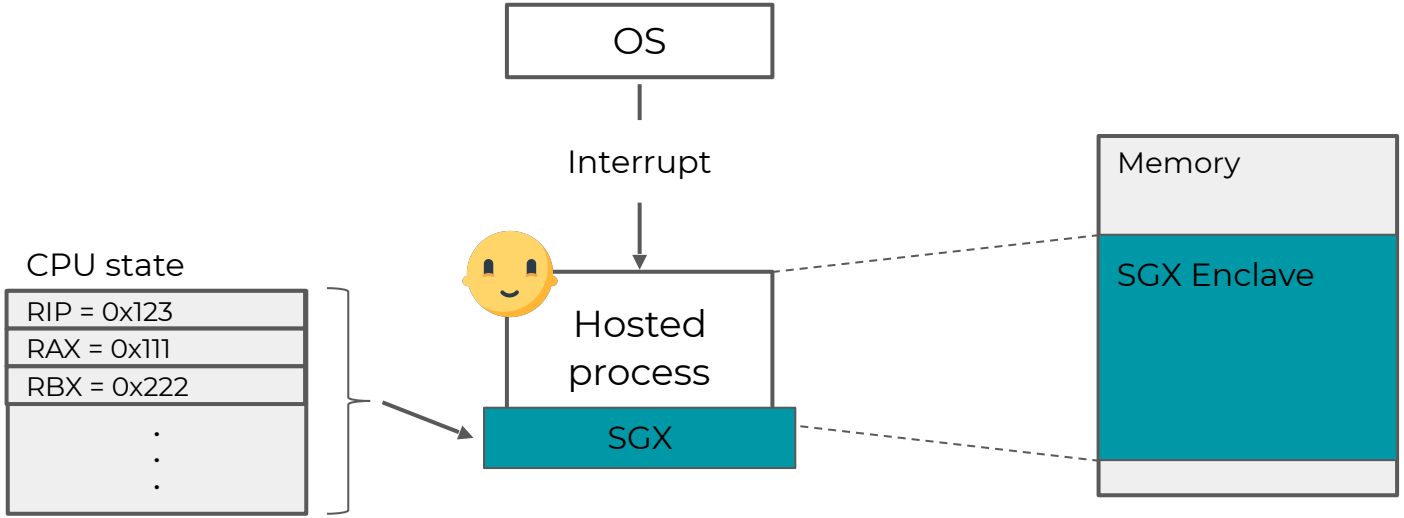

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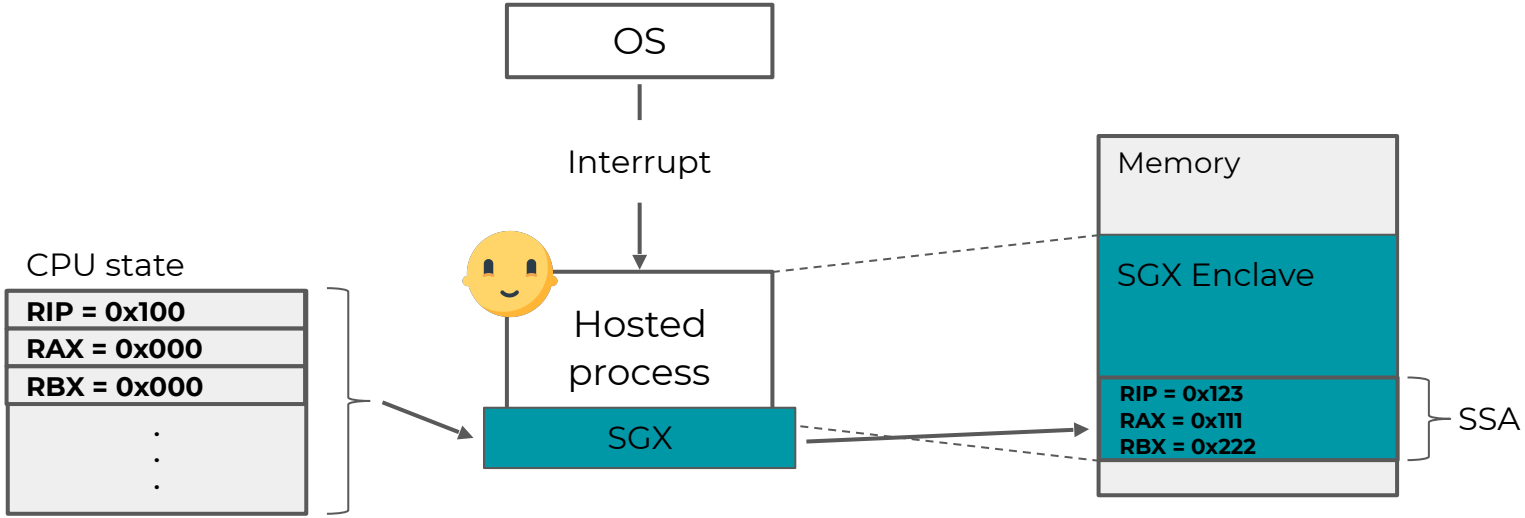

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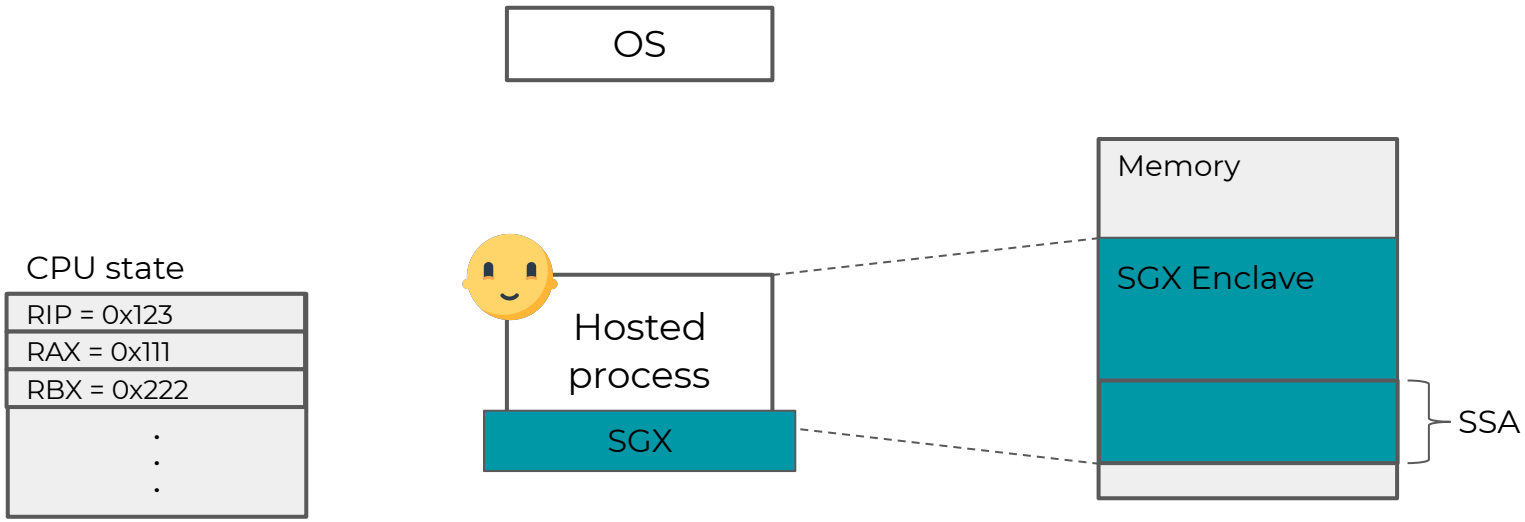

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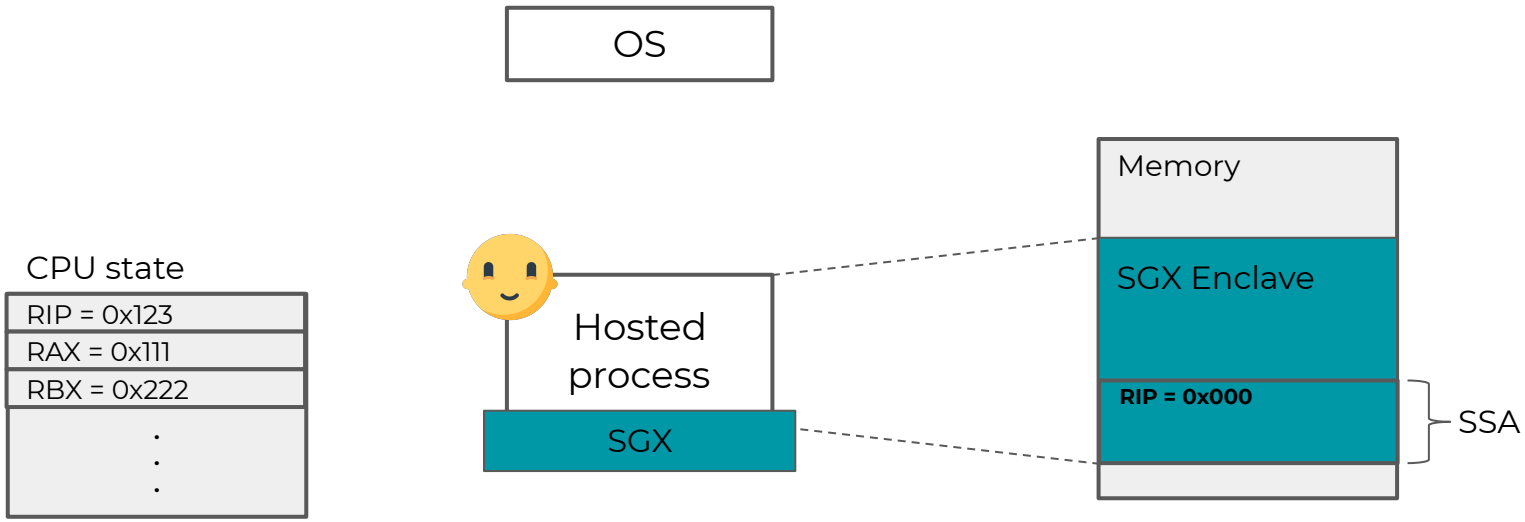

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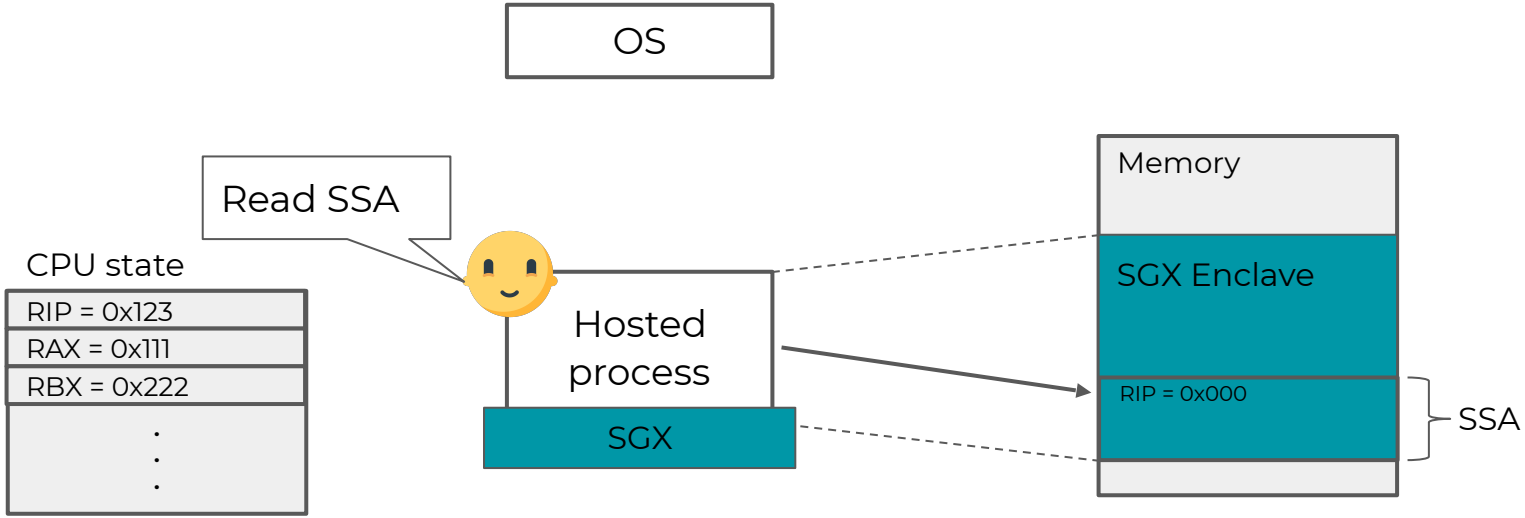

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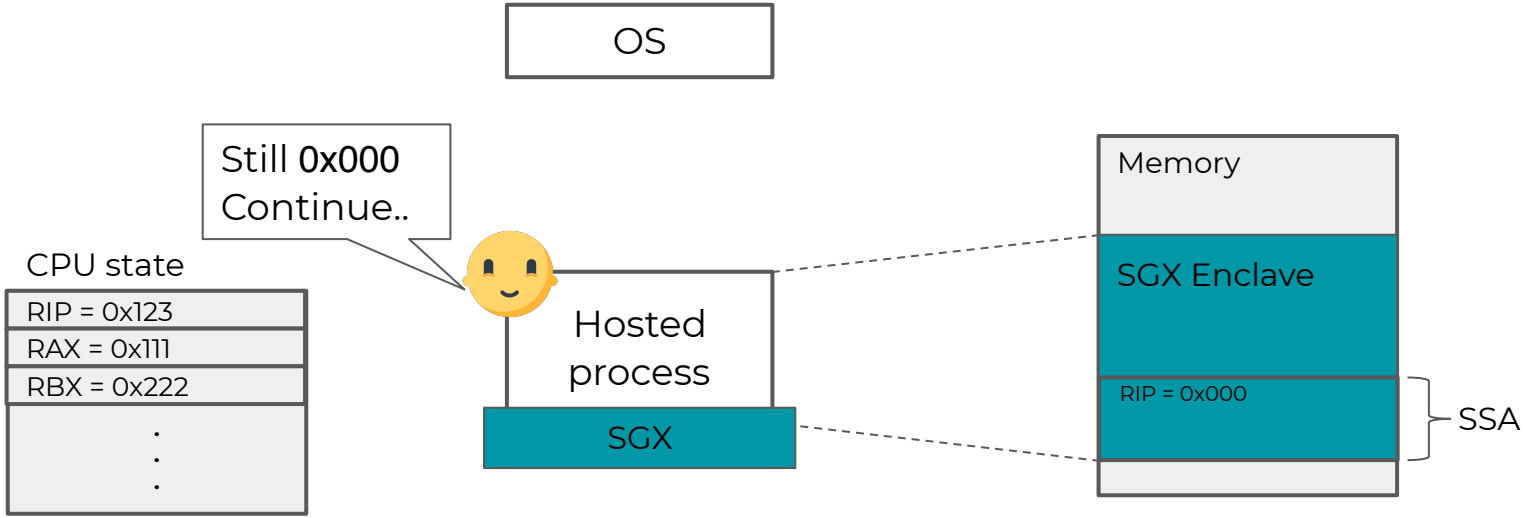

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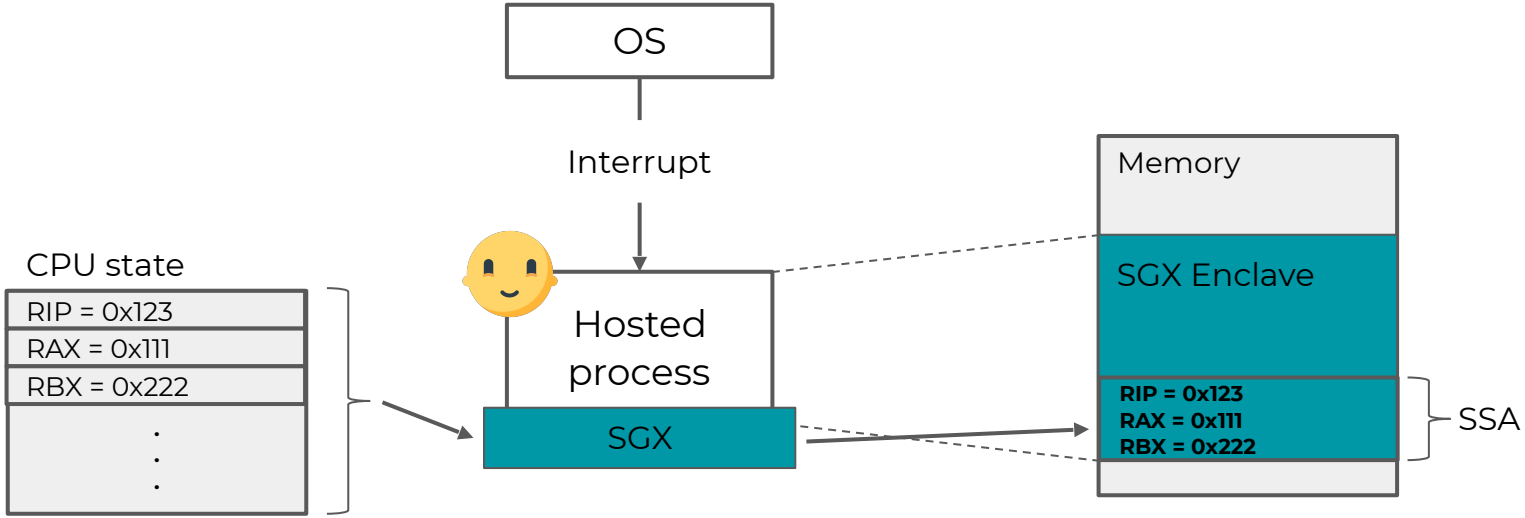

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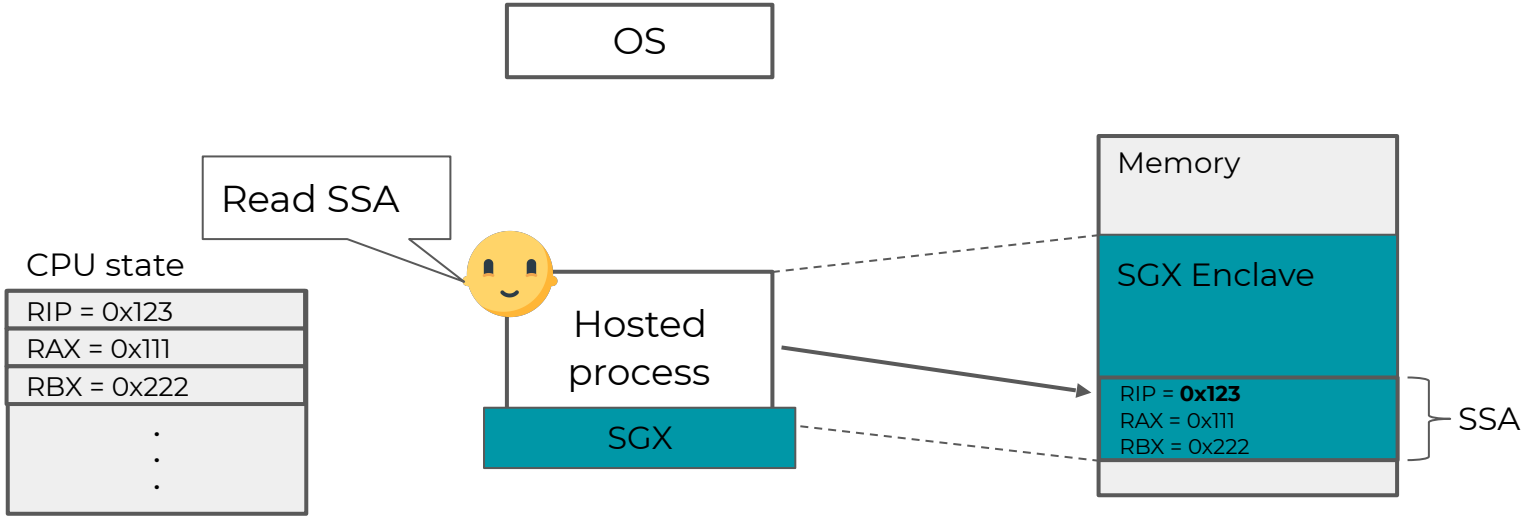

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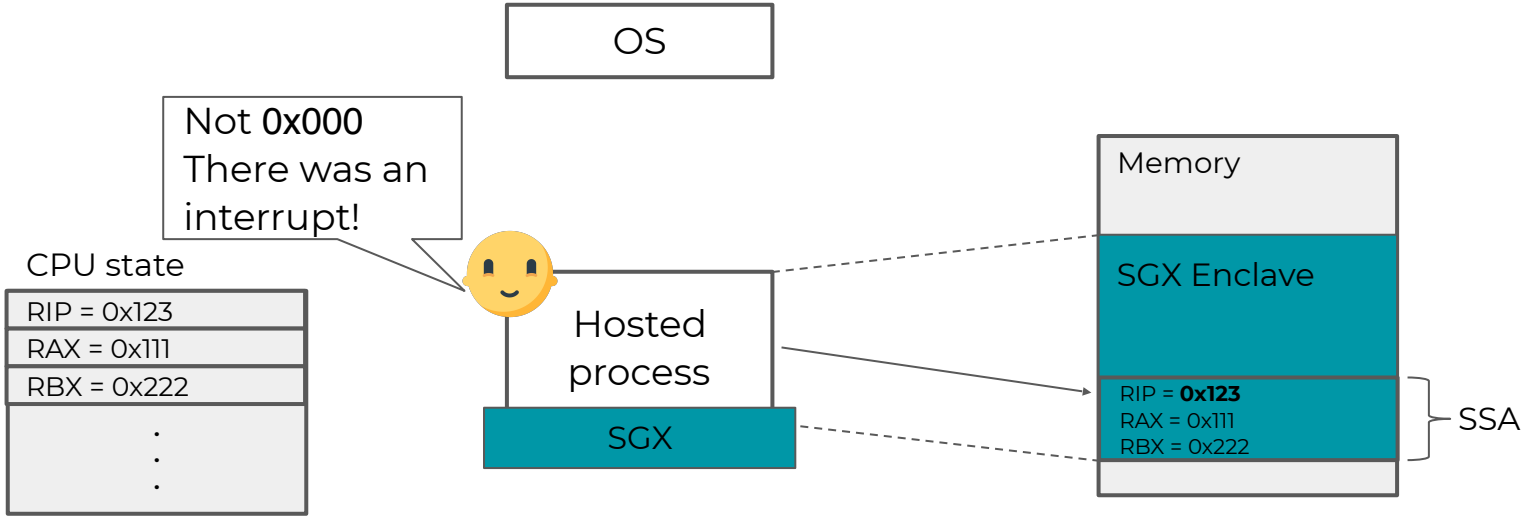

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Restrict and terminate

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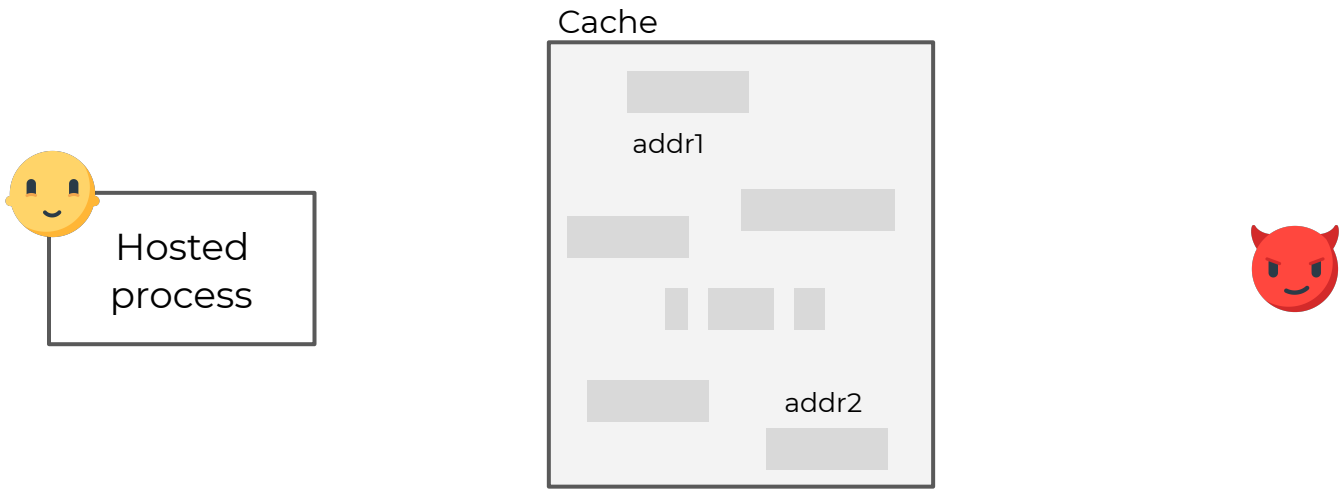
Hiding cache traces



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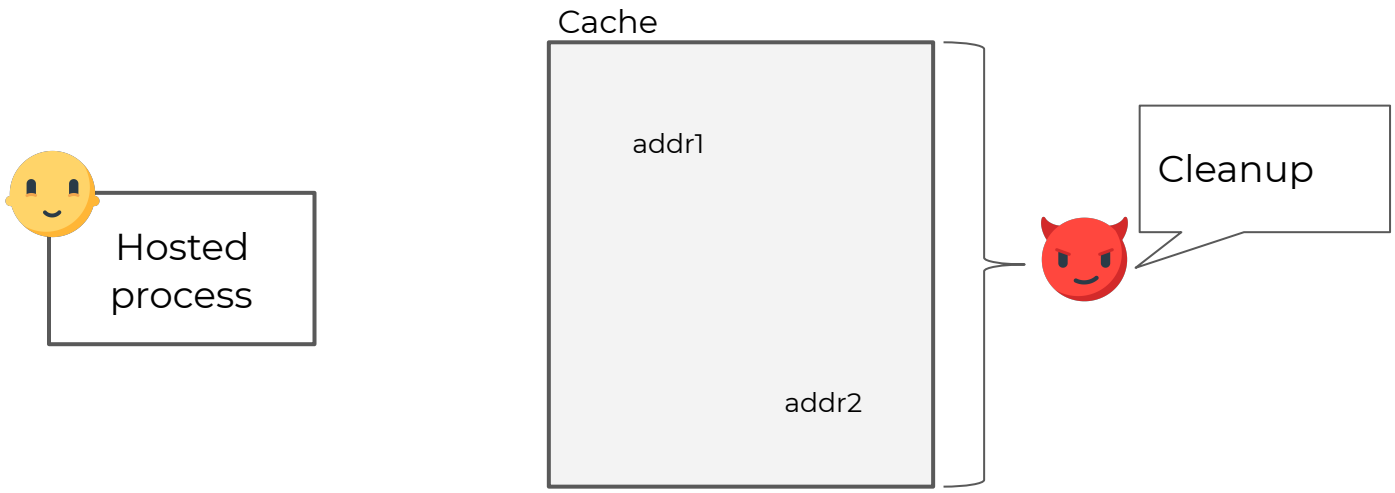

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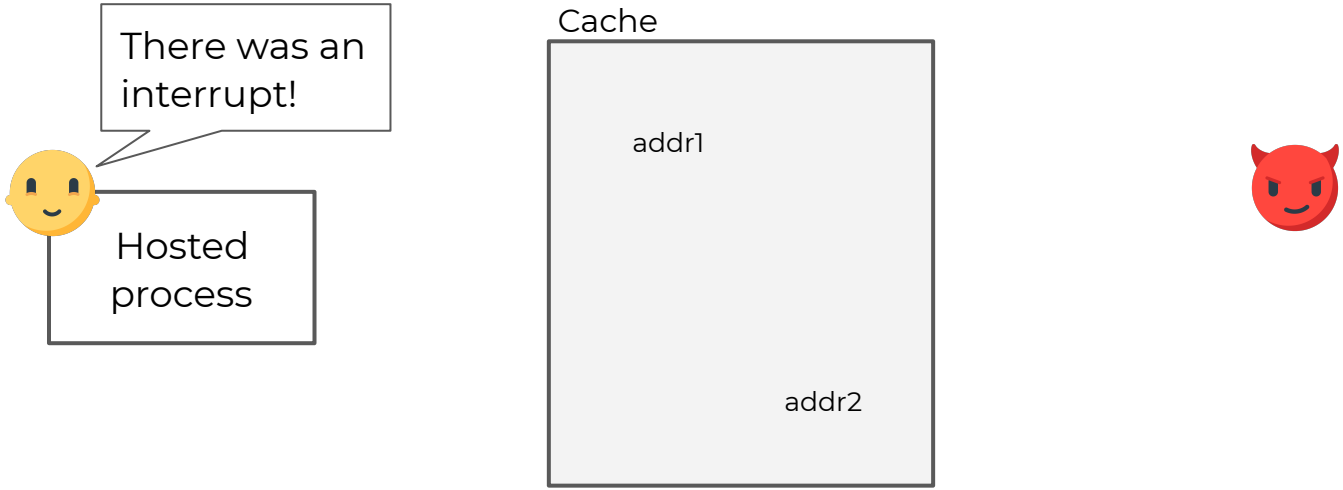

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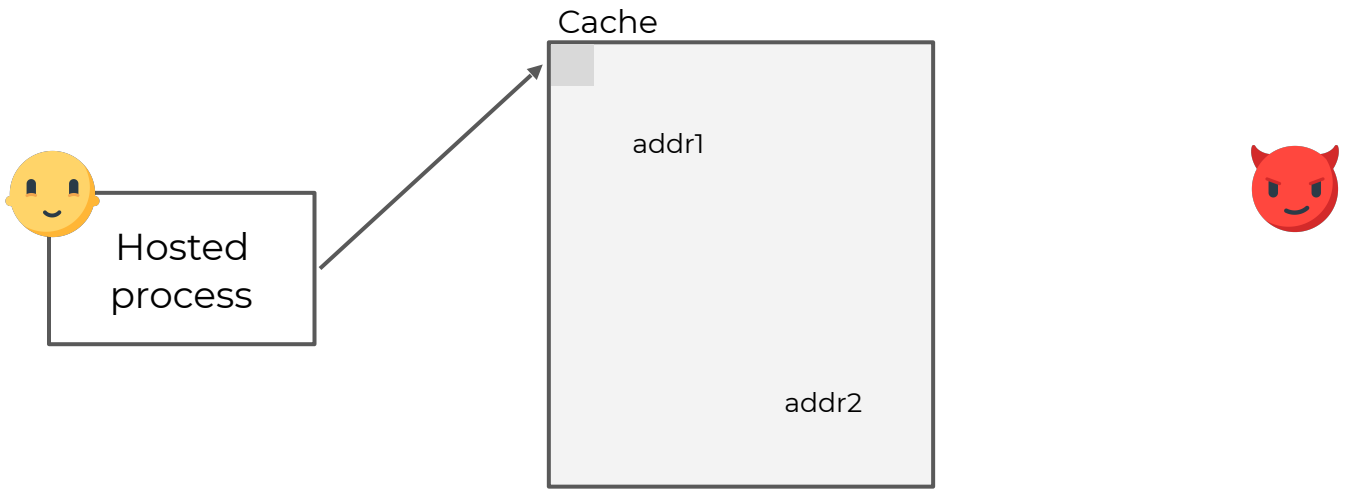

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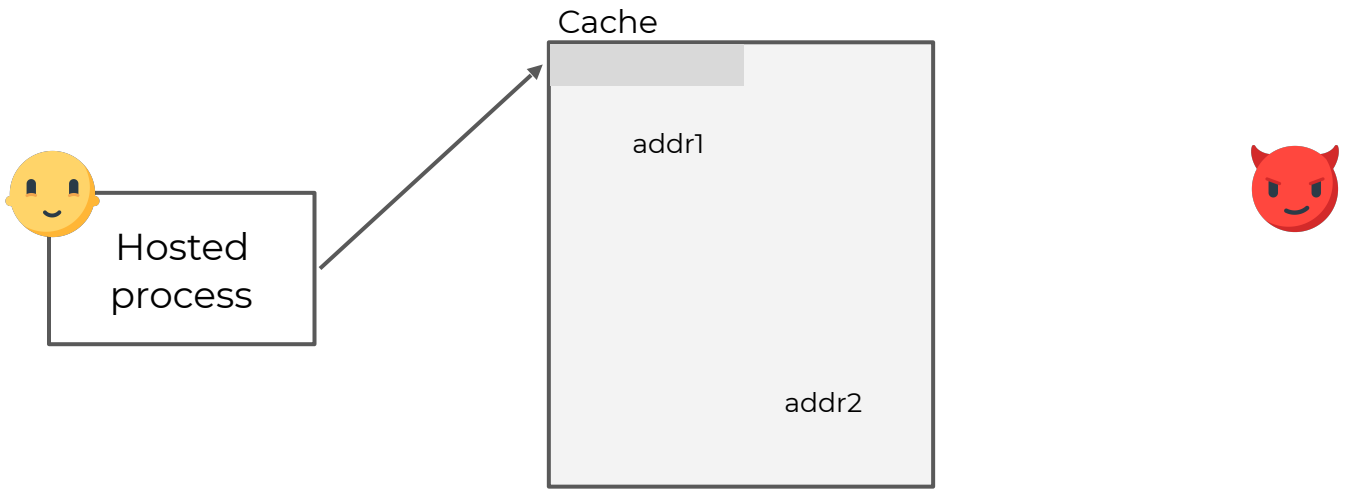
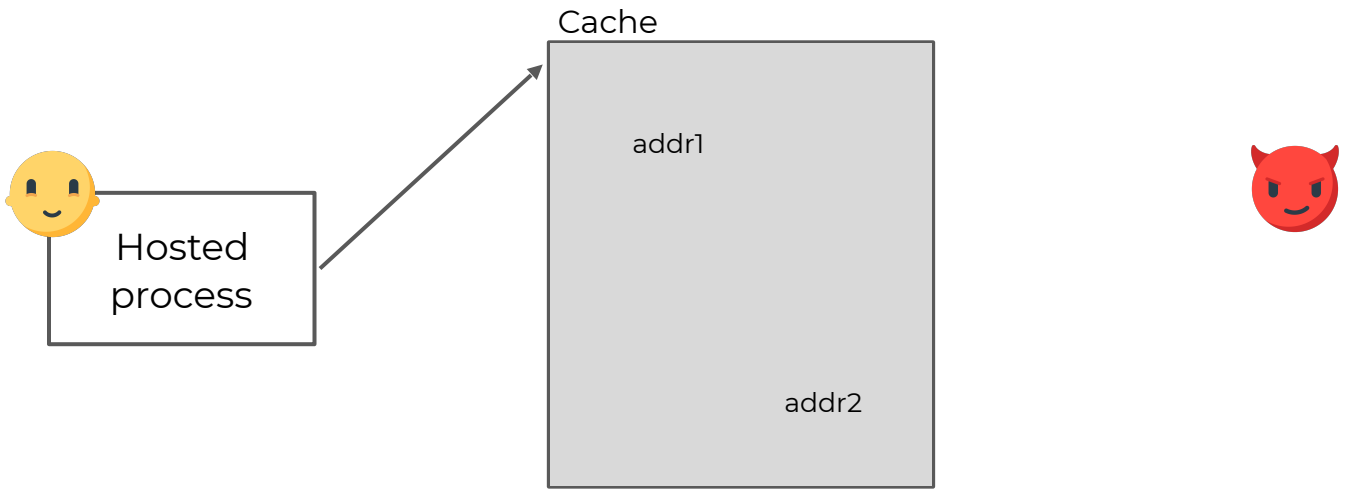
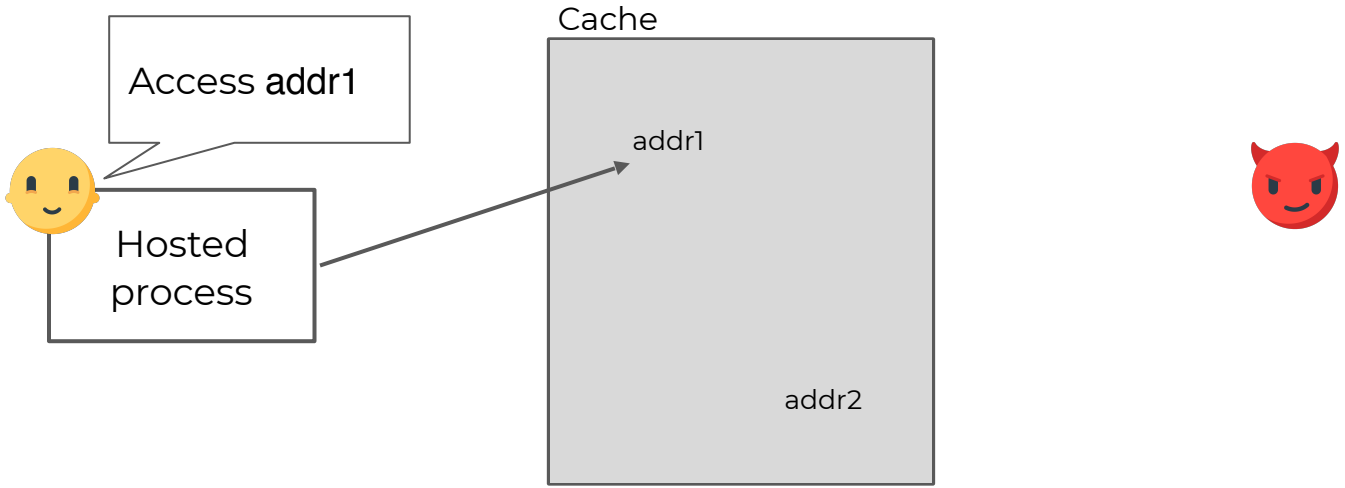


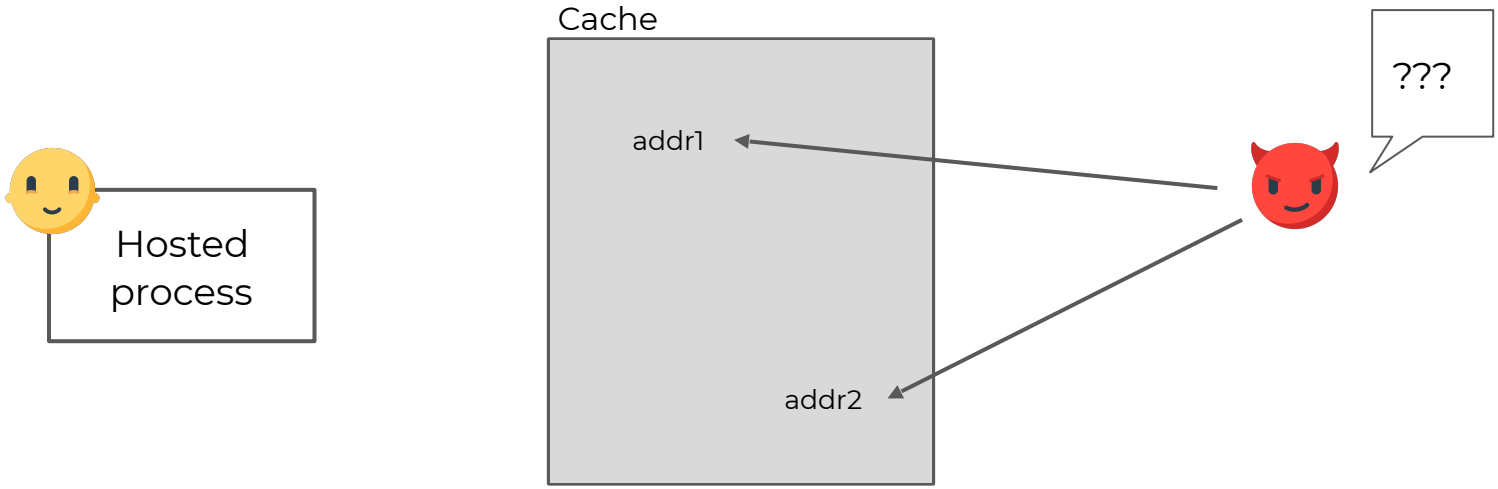
Hiding cache traces



Hiding cache traces



Hiding cache traces



Design

- High preemption rate
- Predefined cache state
- Shared core

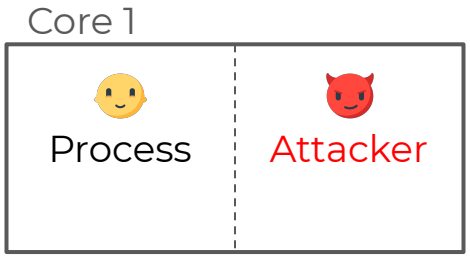
Restrict and terminate

Cache eviction

Trusted reservation

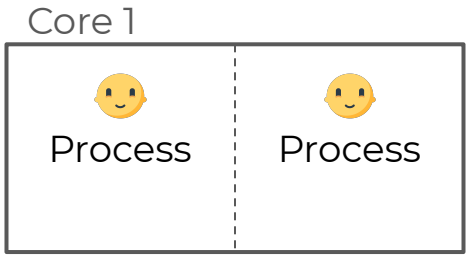
Preventing core sharing

- Occupy both hyperthreads

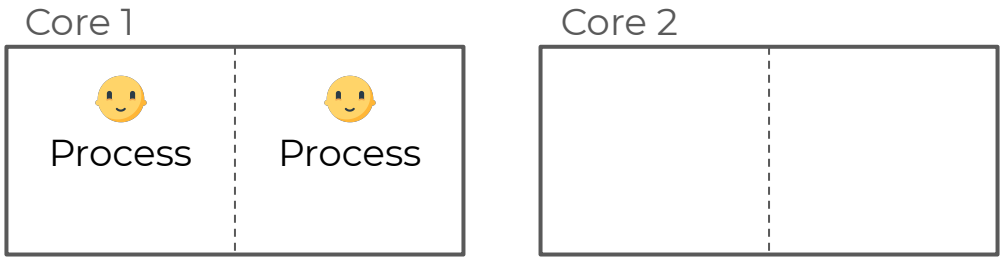


Preventing core sharing

- Occupy both hyperthreads
  - Use process affinity



How do we ensure reservation?



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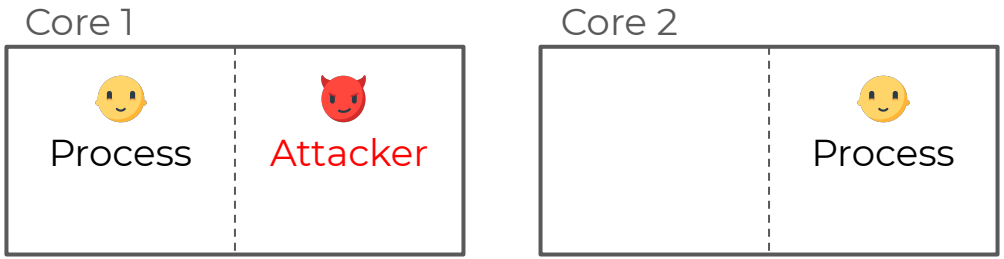
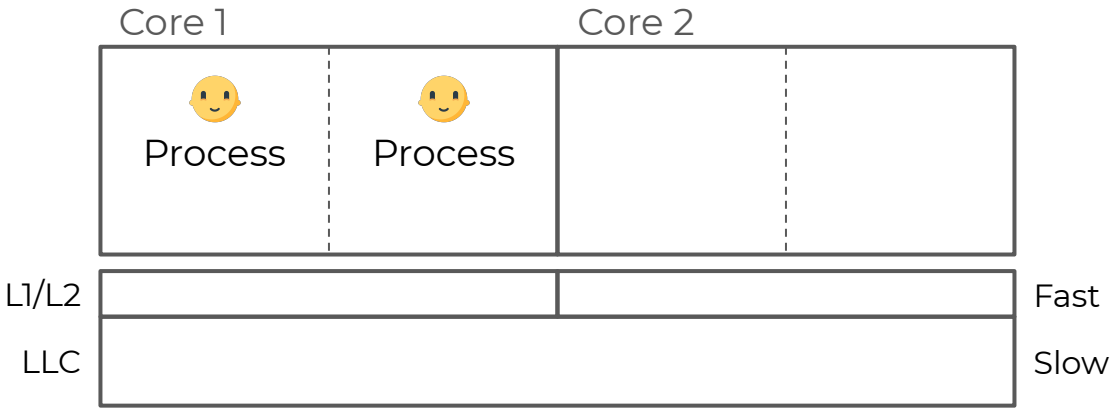


Handshake

- Use shared access timing



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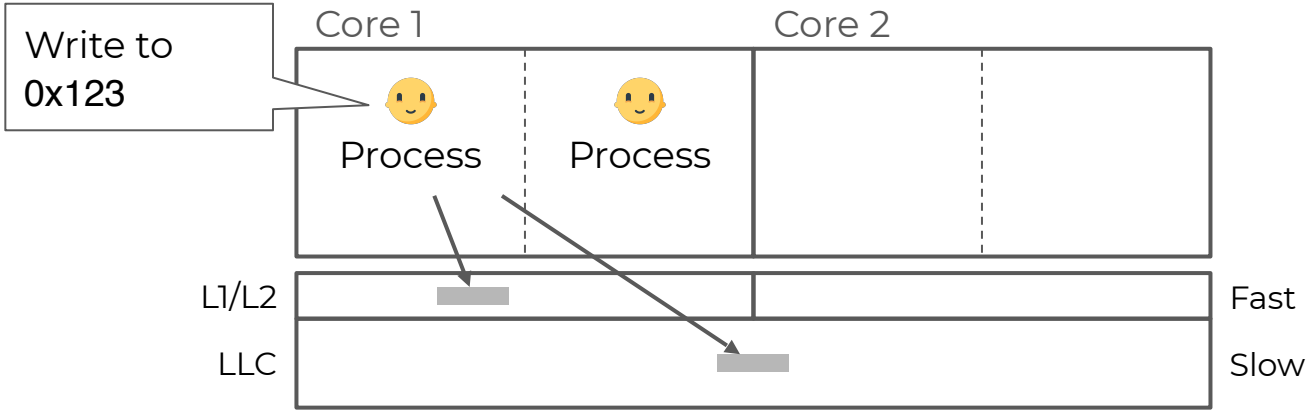

Handshake

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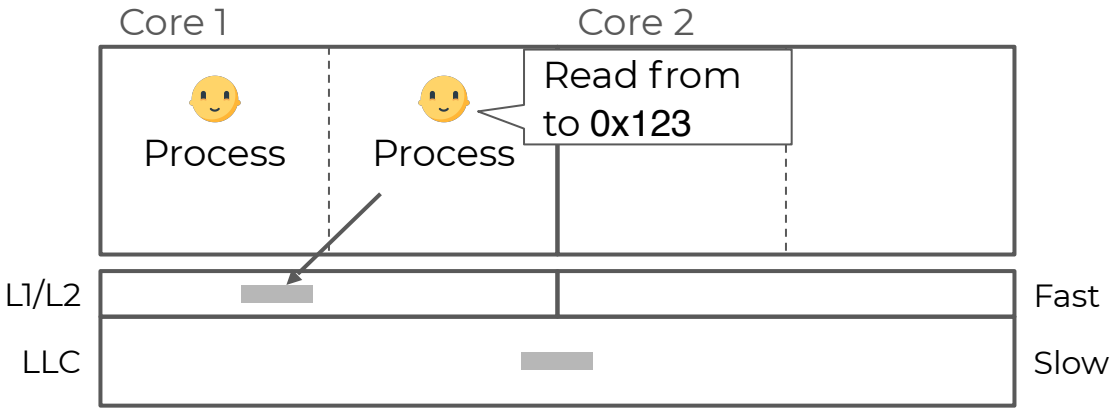

Handshake

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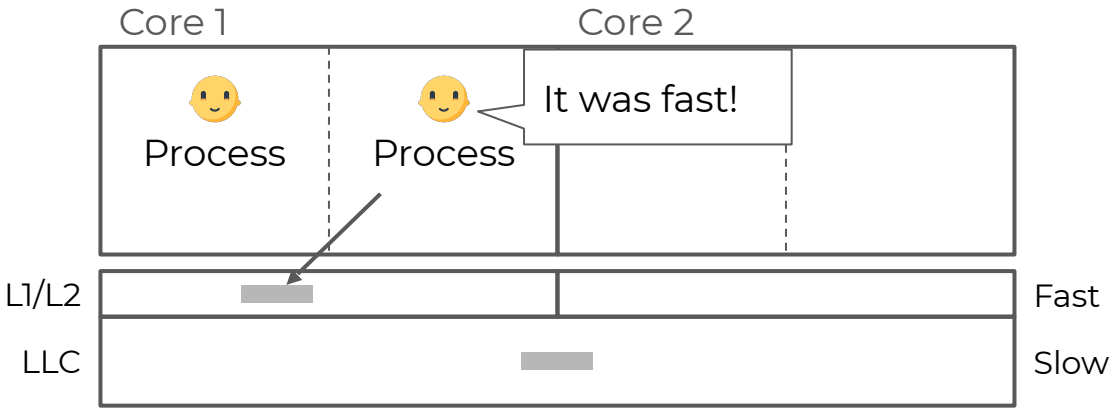

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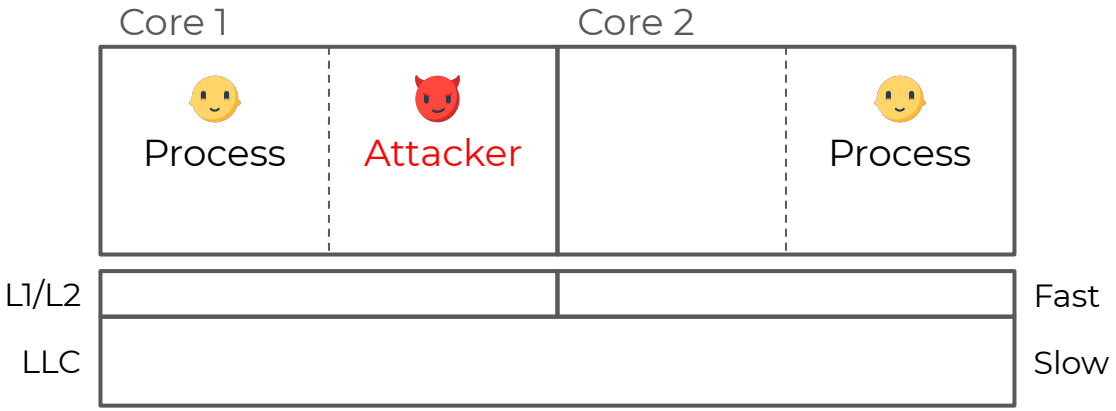
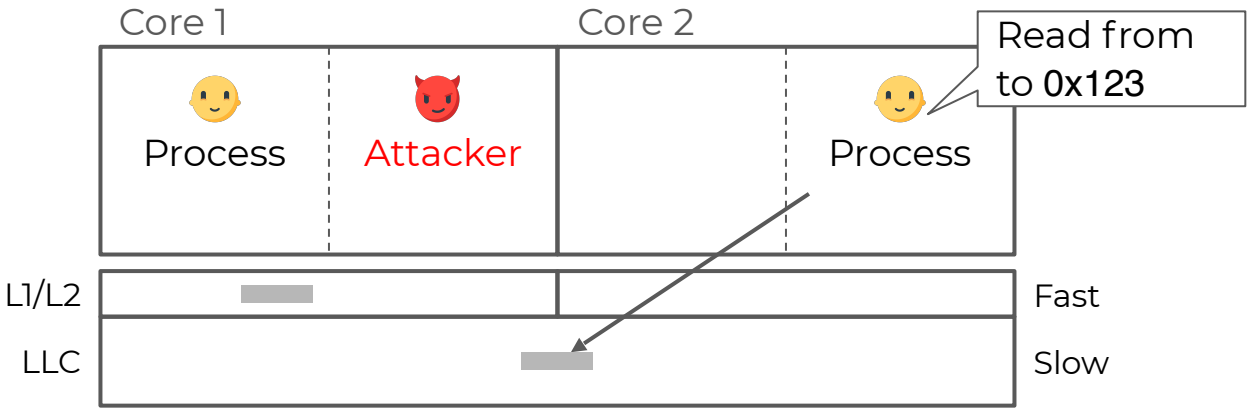
- Use shared access timing



Handshake

- Use shared access timing



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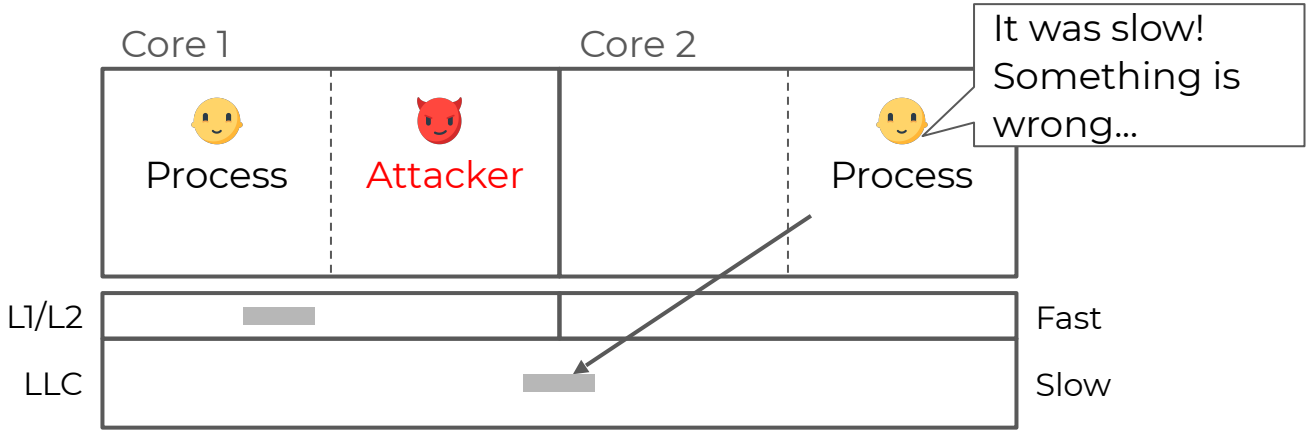

Design

- High preemption rate
- Predefined cache state
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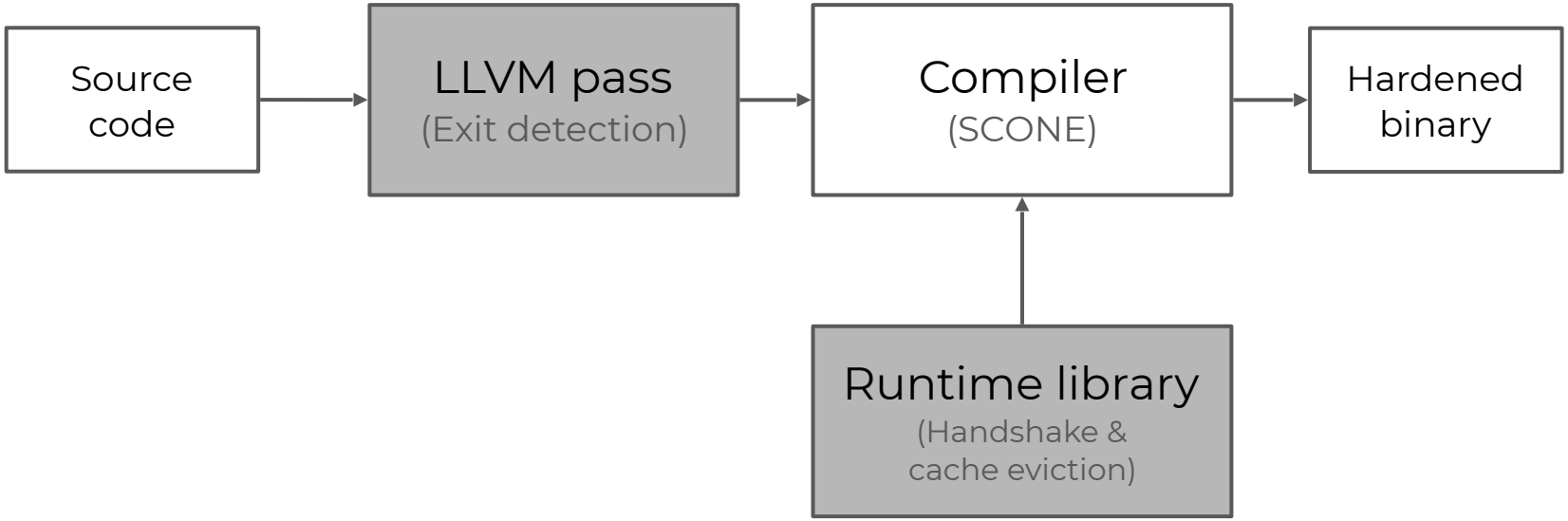
Restrict and terminate

Cache eviction

Trusted reservation

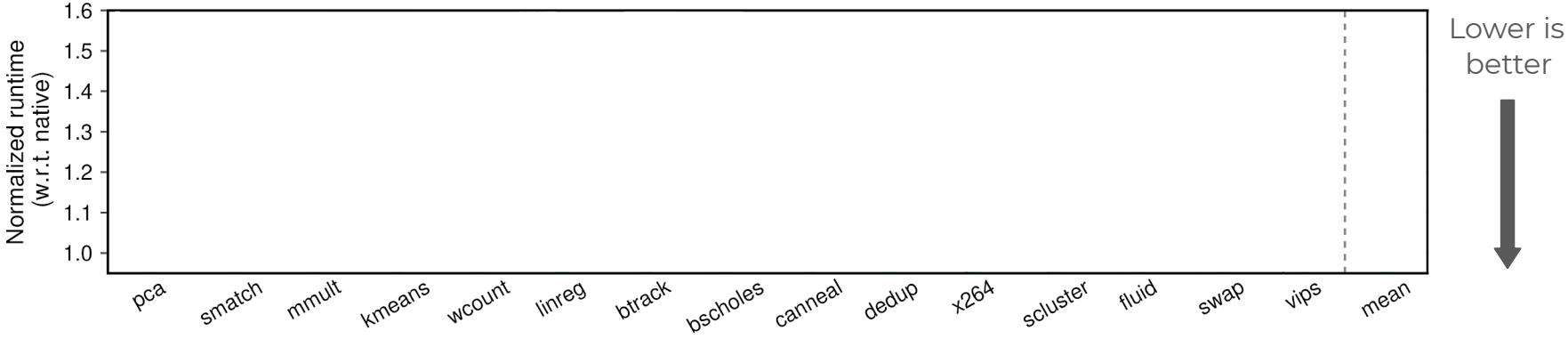
Varys **implements** a low-cost protection for Intel SGX enclaves against side-channel attacks by creating an isolated environment and verifying it at runtime.

Implementation

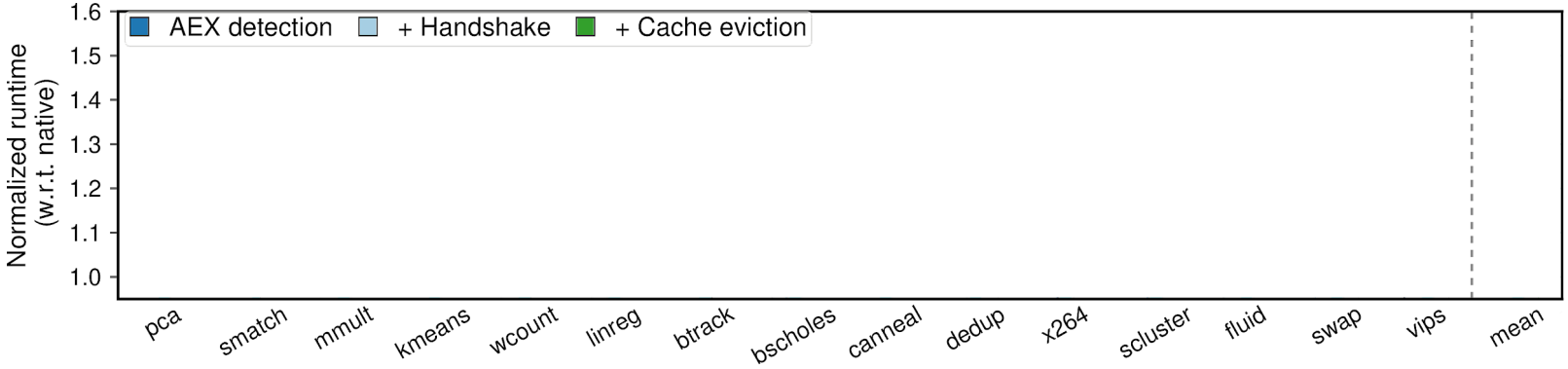


Varys implements a **low-cost** protection for Intel SGX enclaves against side-channel attacks by creating an isolated environment and verifying it at runtime.

Evaluation: performance

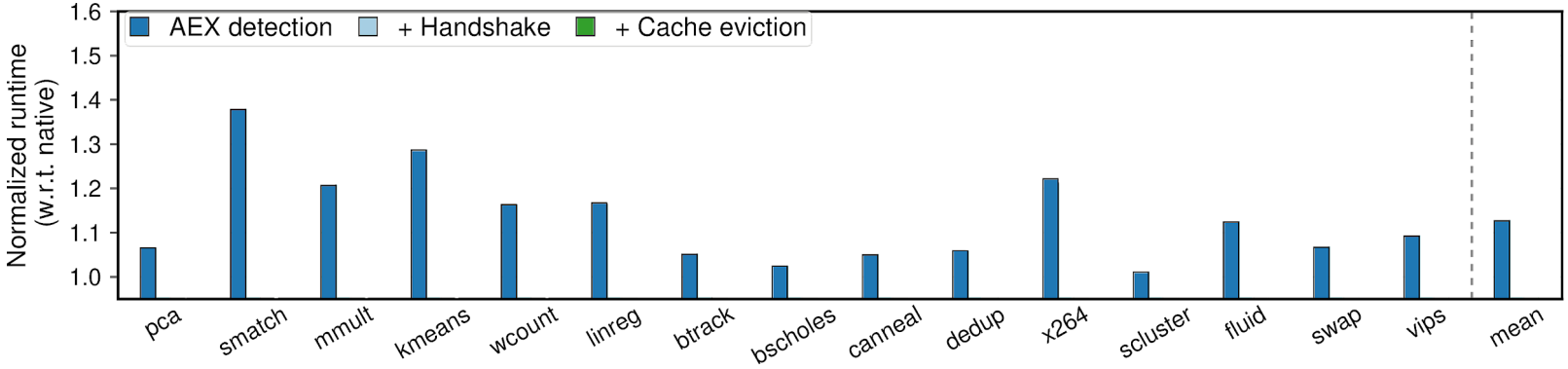


Evaluation: performance



Lower is better

Evaluation: performance



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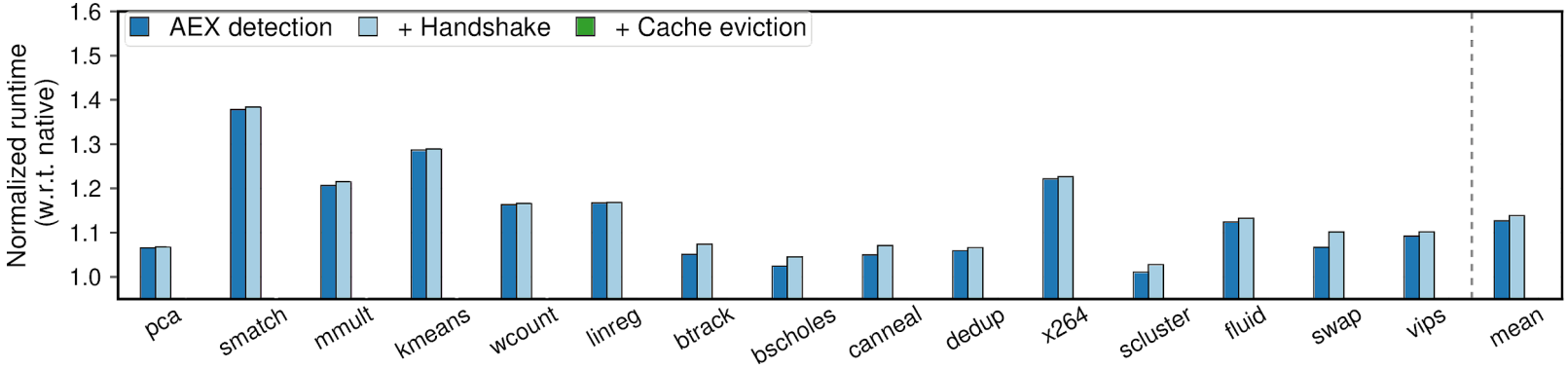

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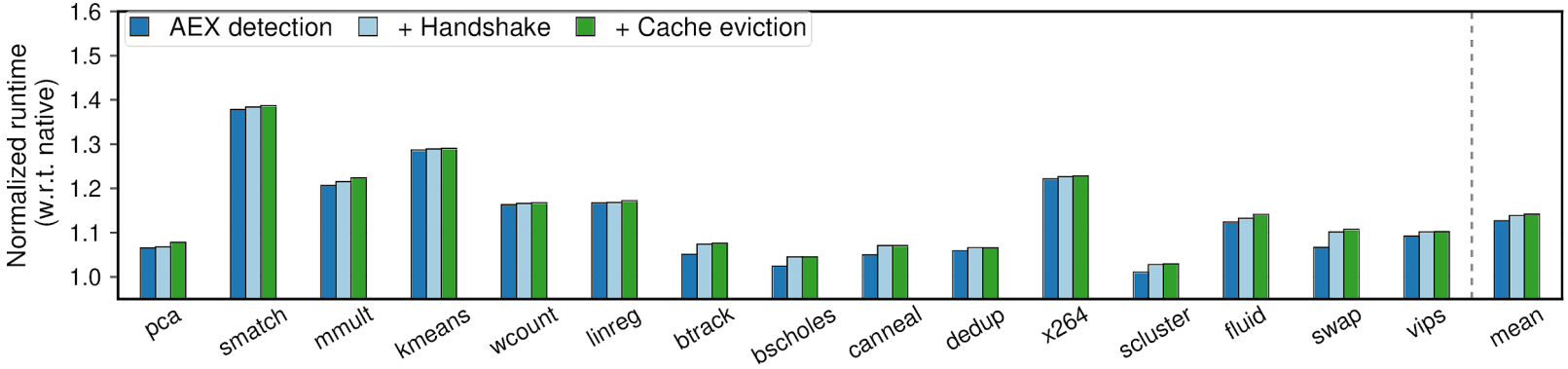

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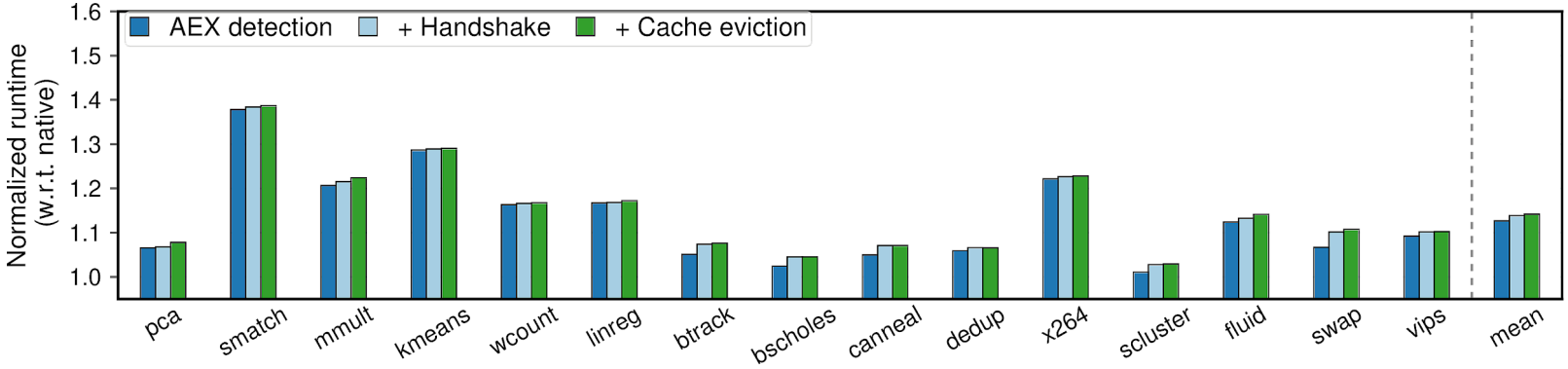

Lower is better

Handshake and eviction **only at enclave exits**

- 20-30 times per second

Evaluation: multithreading

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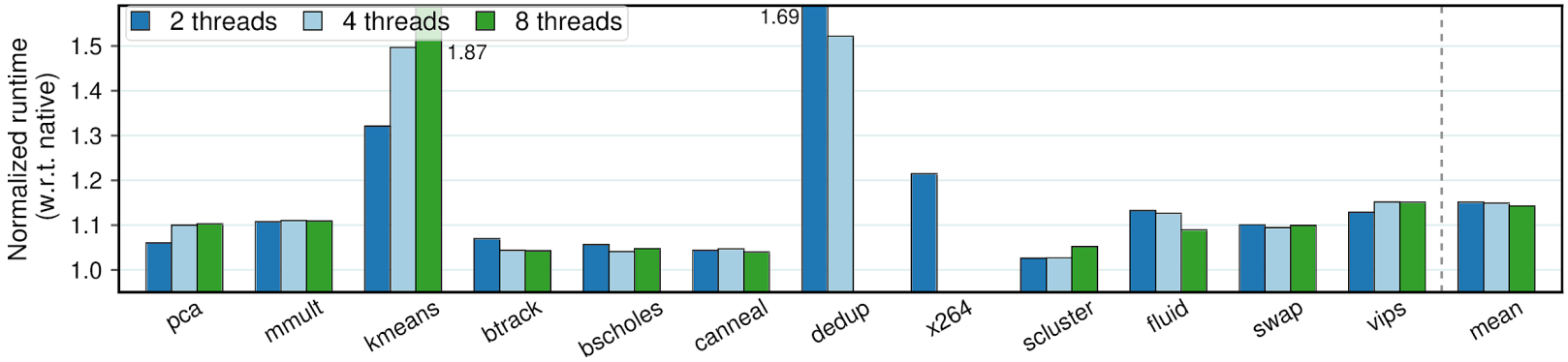
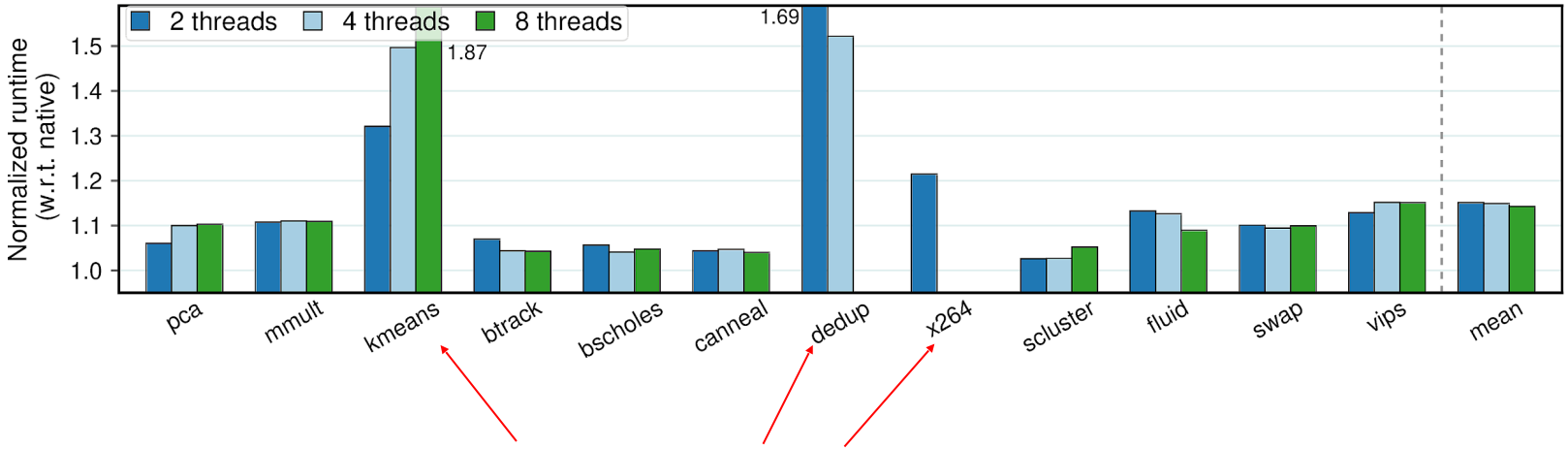


Lower is better

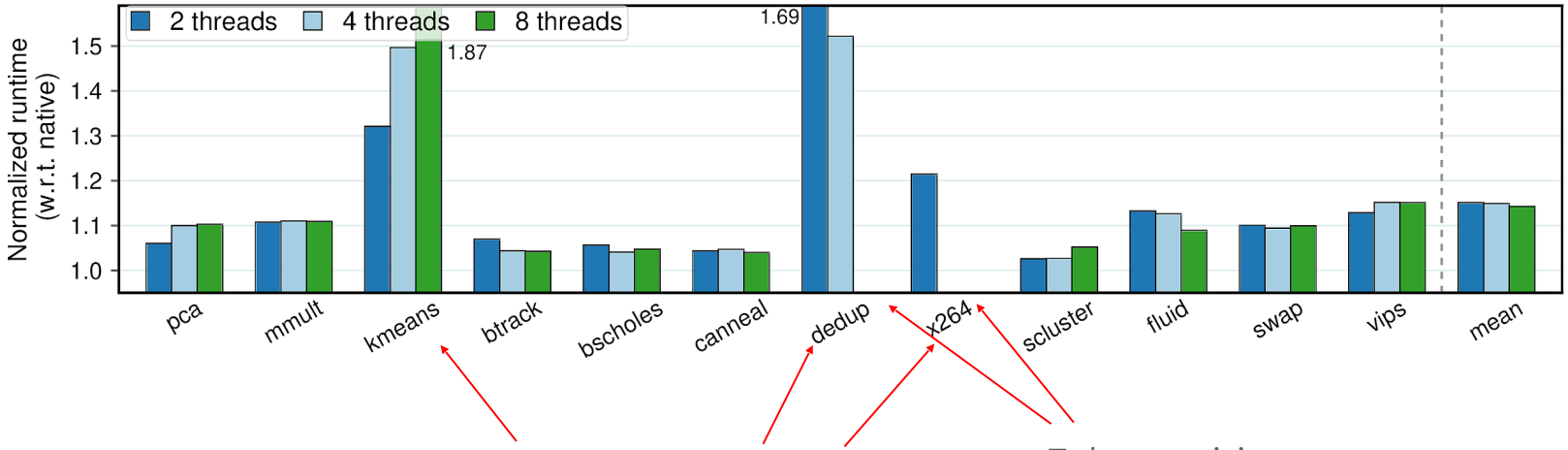
Evaluation: multithreading



Lower is better

EPC paging ⇒ higher exit rate

Evaluation: multithreading



Lower is better

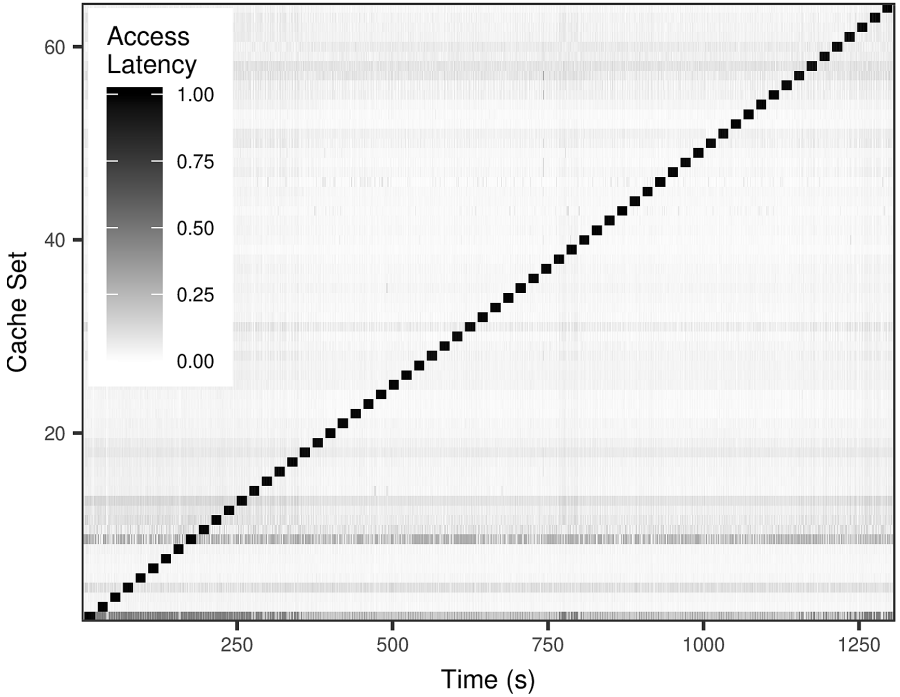
EPC paging ⇒ higher exit rate

False positives

Varys implements a low-cost **protection** for Intel SGX enclaves against side-channel attacks by creating an isolated environment and verifying it at runtime.

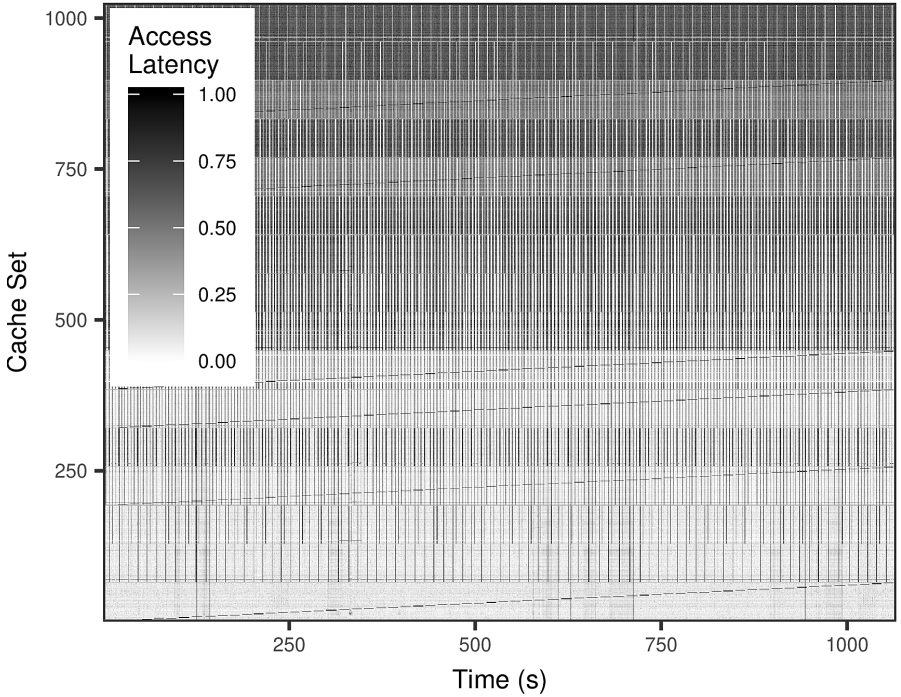
Evaluation: security

- Privileged cache SCA
  - Target: L1 cache
- No eviction



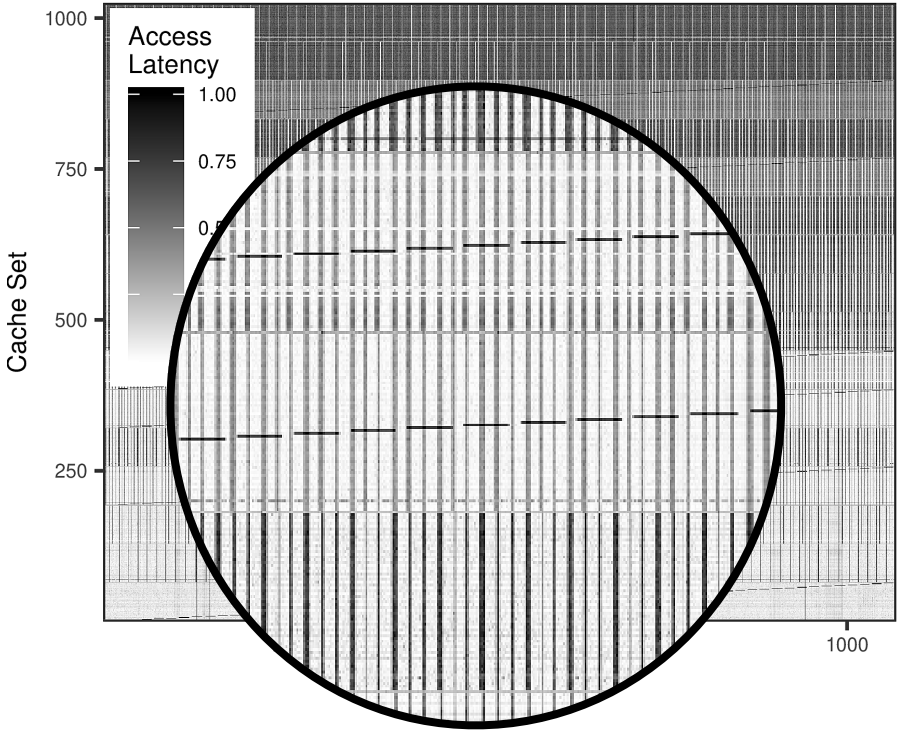
Evaluation: security

- Privileged cache SCA
  - Target: L2 cache
- No eviction



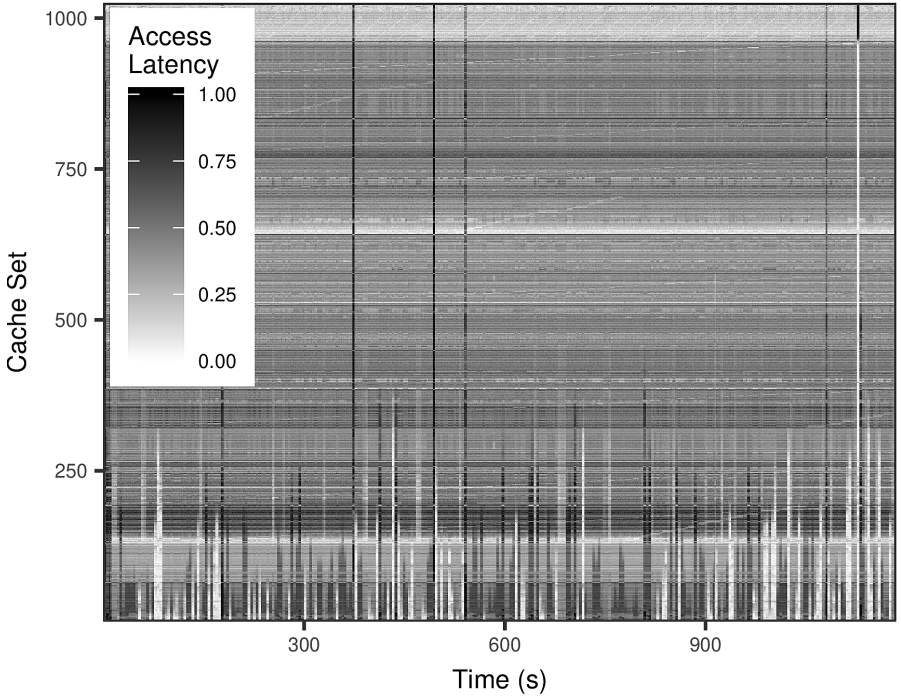
Evaluation: security

- Privileged cache SCA
  - Target: L2 cache
- No eviction



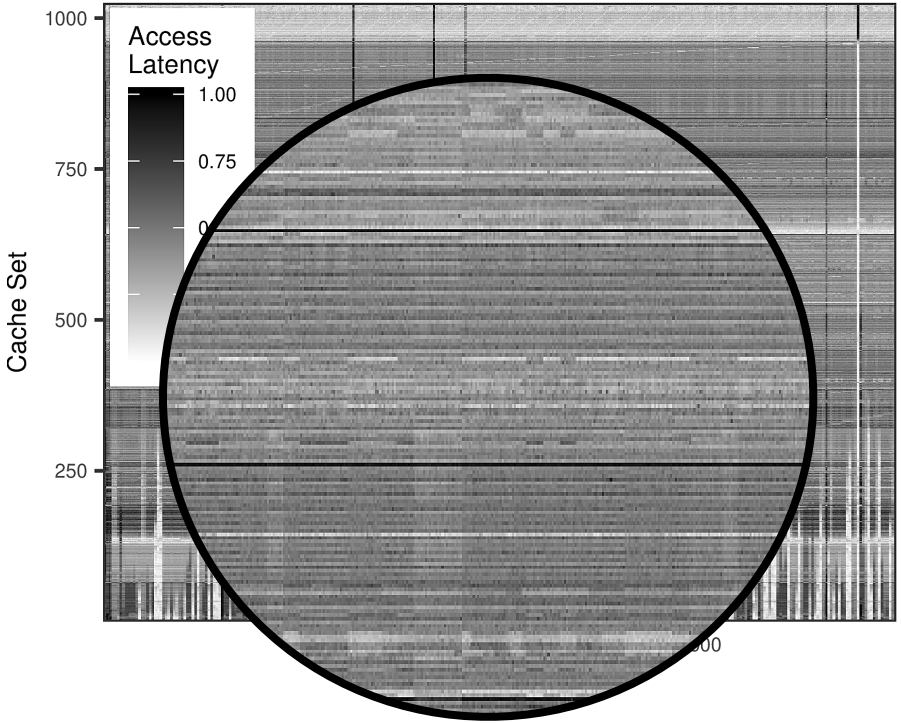
Evaluation: security

- Privileged cache SCA
  - Target: L2 cache
- Varys protection



Evaluation: security

- Privileged cache SCA
  - Target: L2 cache
- Varys protection



Summary

- Varys: side-channel protection for SGX enclaves
- "Rely but verify" approach
  - Ask OS for
    - Lower interrupt rate
    - Paired thread allocation
  - Verify the request
- Evict caches on enclave exits

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- "Rely but verify" approach
  - Ask OS for
    - Lower interrupt rate
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Thanks!

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@oleksii_o