Time Protection: The Missing OS Abstraction

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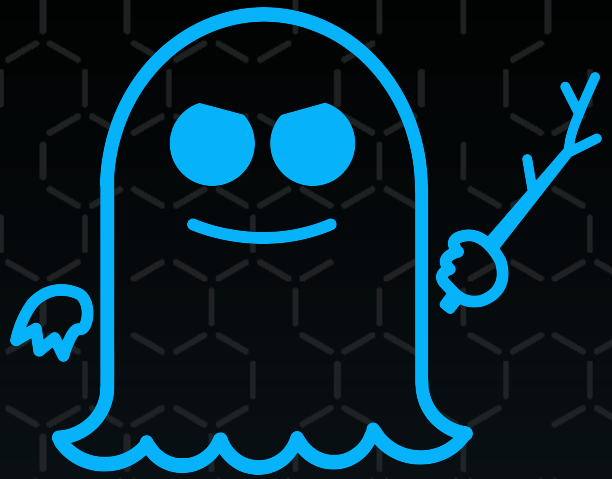
THE UNIVERSITY of ADELAIDE

UNIVERSITY OF BIRMINGHAM



SPECTRE

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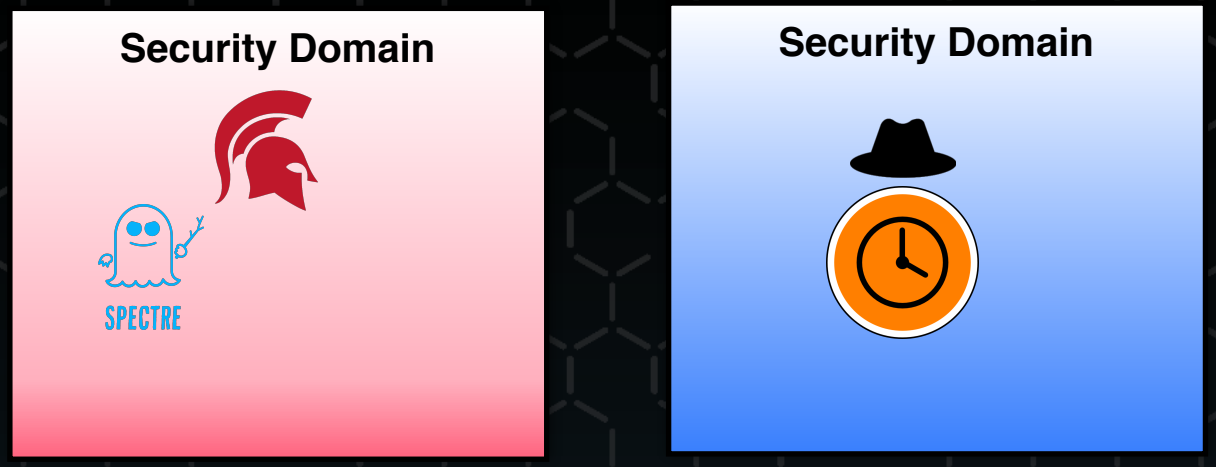
Enforcing time protection at the OS level



Sending information through timing

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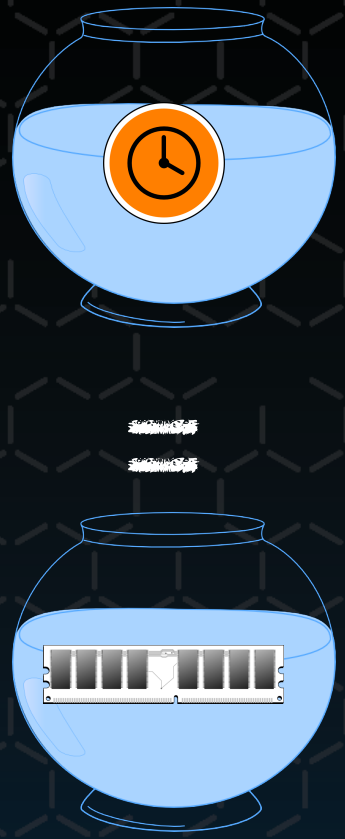

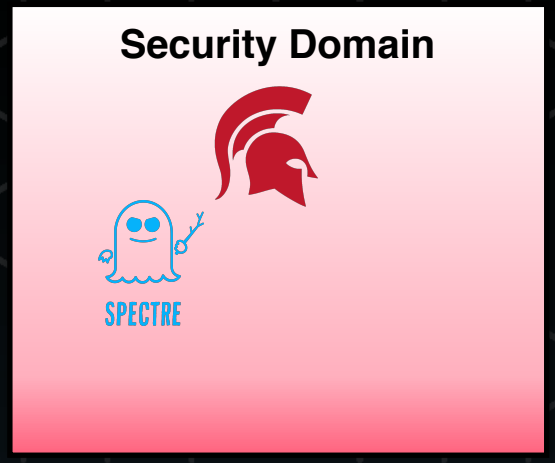

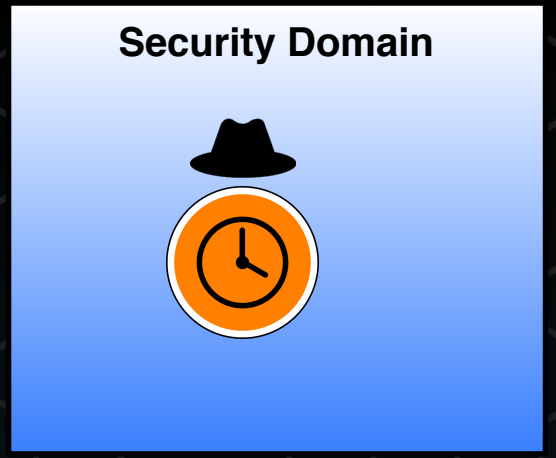

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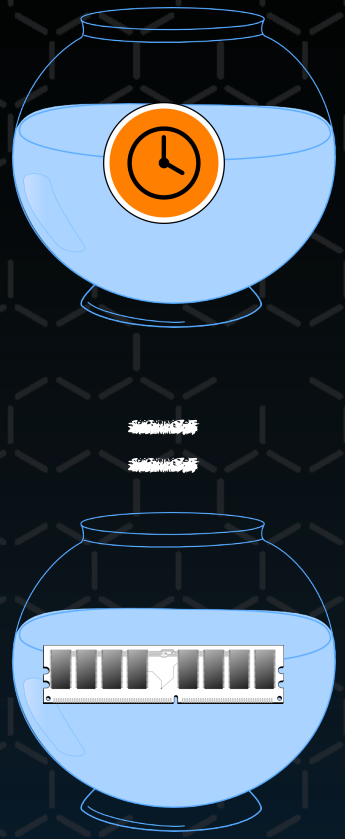

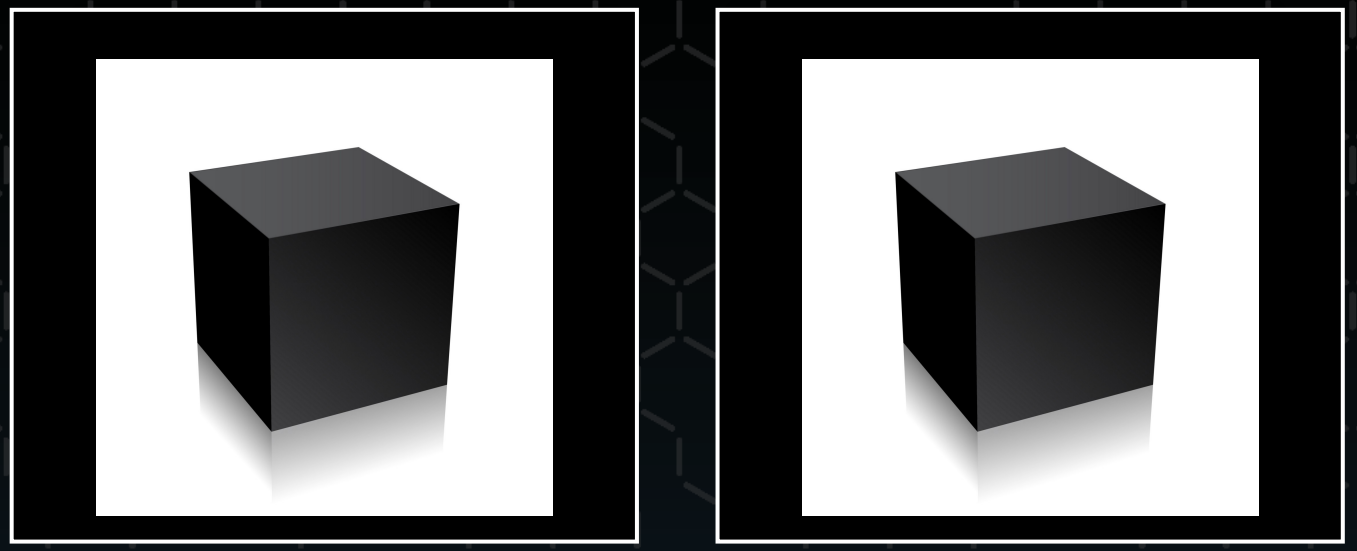

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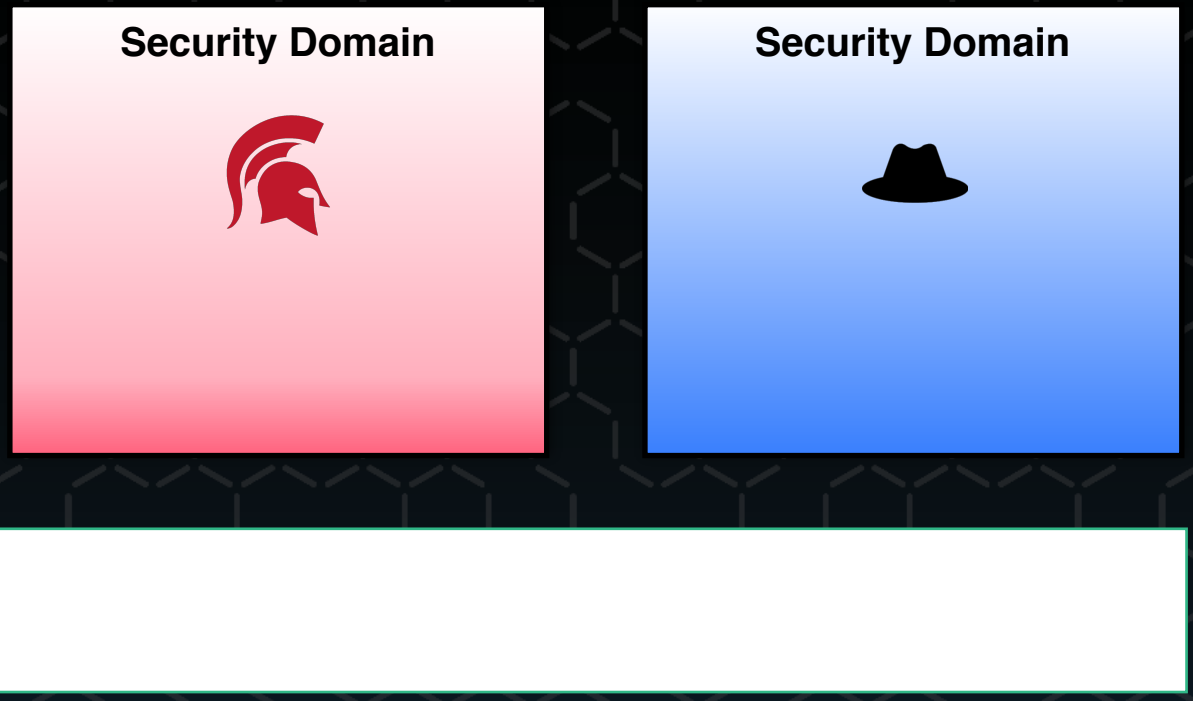
Microarchitectural Timing Channels



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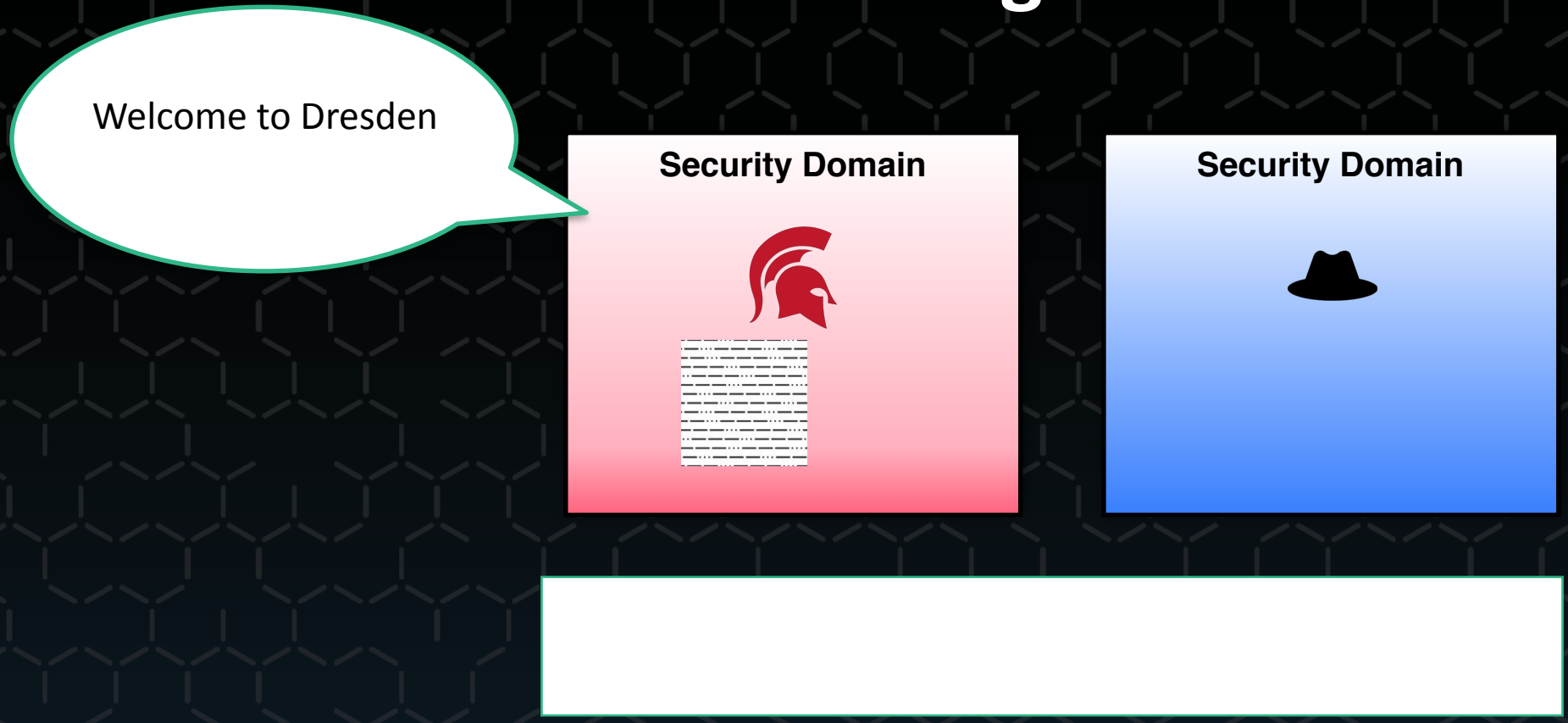
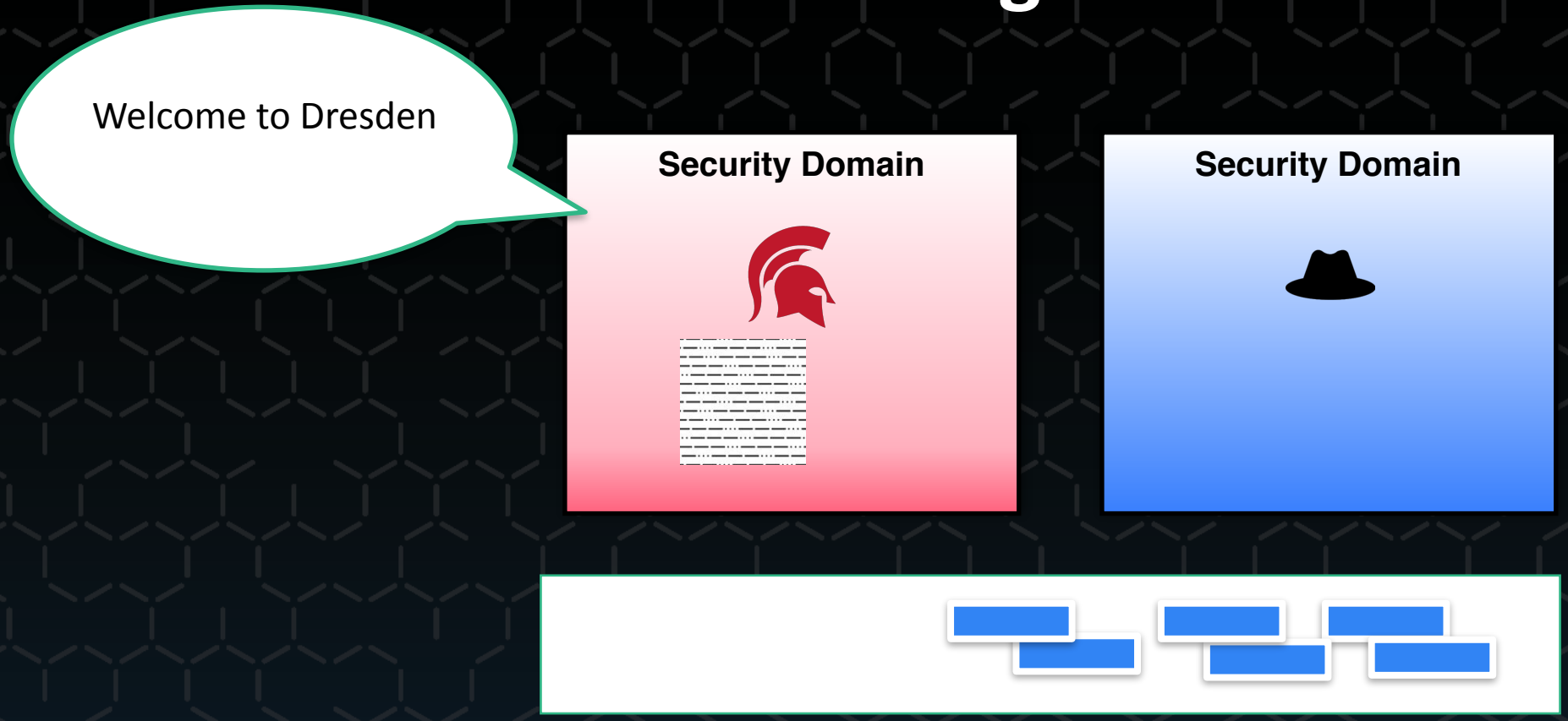


Microarchitectural Timing Channels



Microarchitectural Timing Channels

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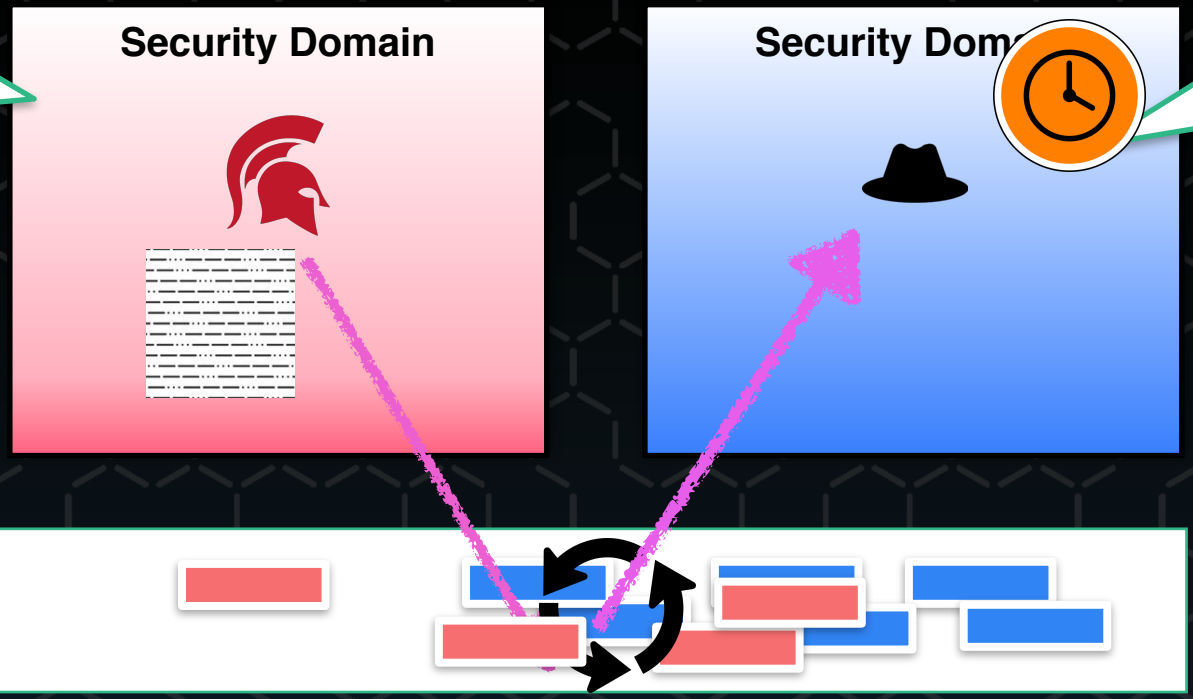
Microarchitectural Timing Channels

Welcome to Dresden



Fast Fast Slow Fast Fast
….. S F S FFF SSSS F

Not English, but our protocol…

Shared hardware caches

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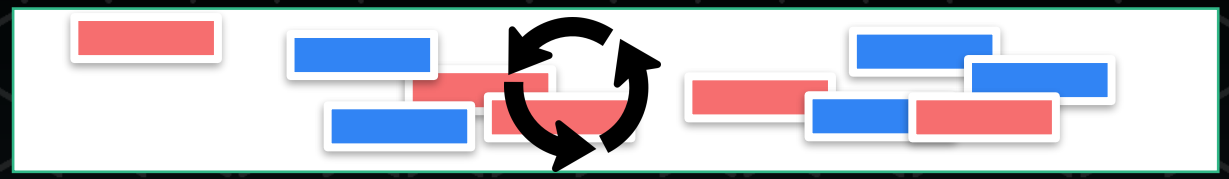
Contention, Contention, Contention…



Shared hardware caches

- Contention leaks information via timing
- Caches:
  - capacity-limited
  - stateful
- Resulting on temporal interference during:
  - time-shared access
  - concurrent access

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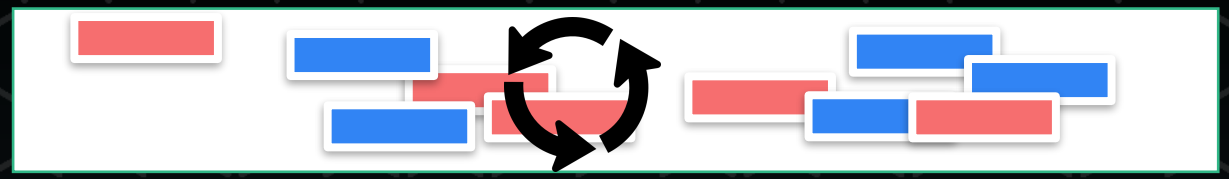

Shared hardware caches

Any state-holding microarchitectural feature:

- Caches, branch predictor, TLB

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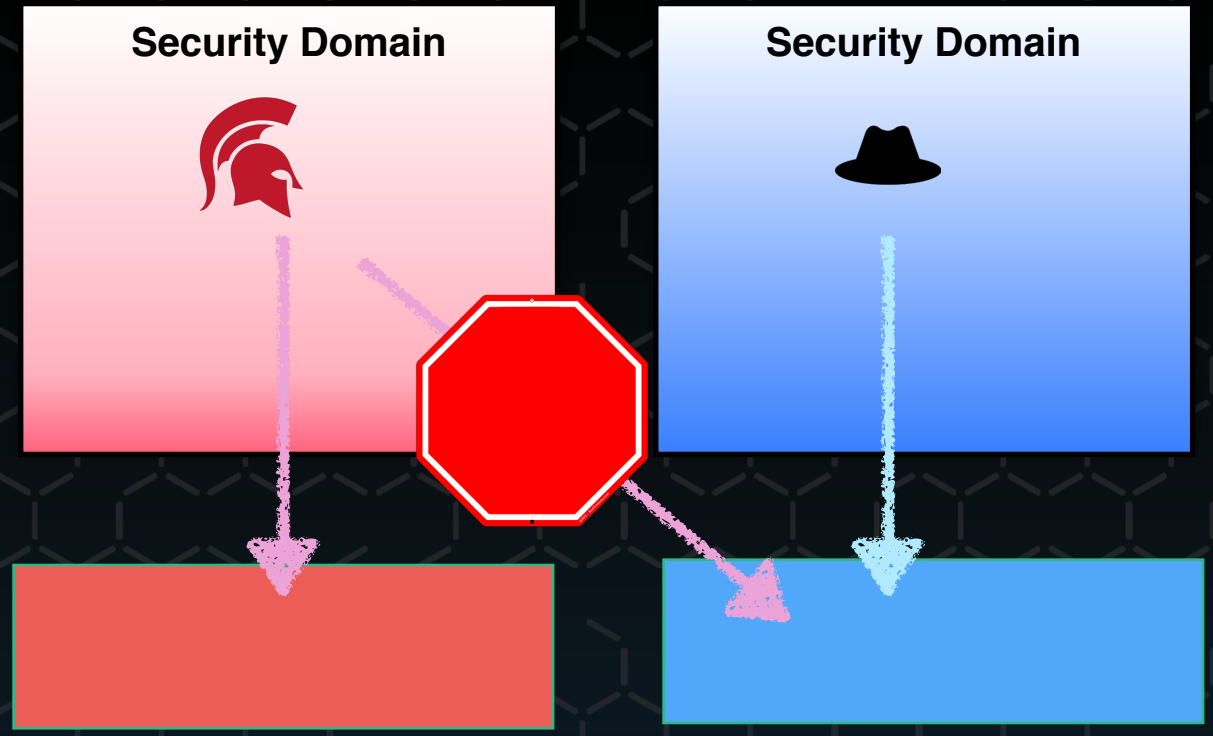
Preventing Contention by Partitioning



Partitioned caches

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Spatial Partitioning

Cache colouring:

- Distributing coloured cache sets to coloured memory frames
- Memory management policy

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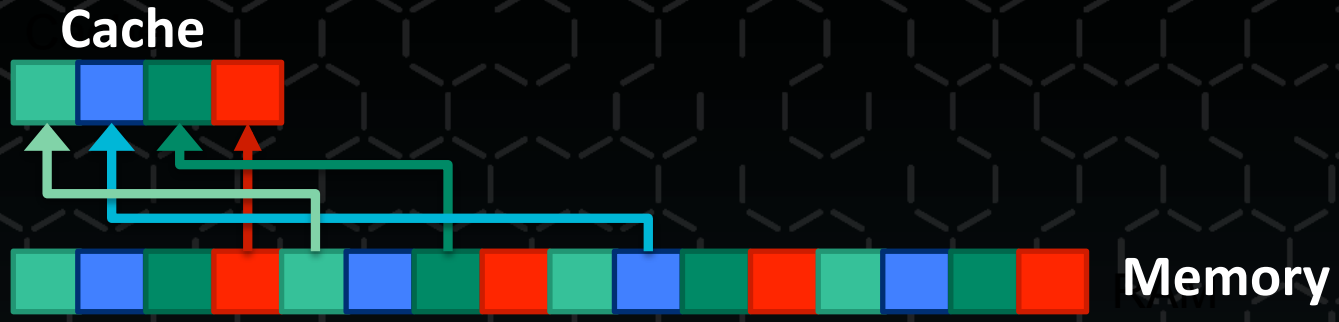
Spatial Partitioning



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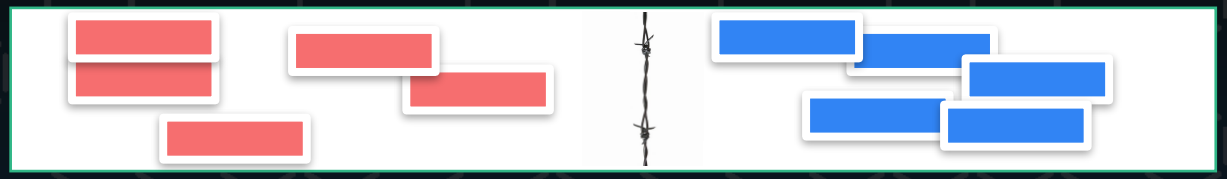
Partition security domains on disjoint cache sets



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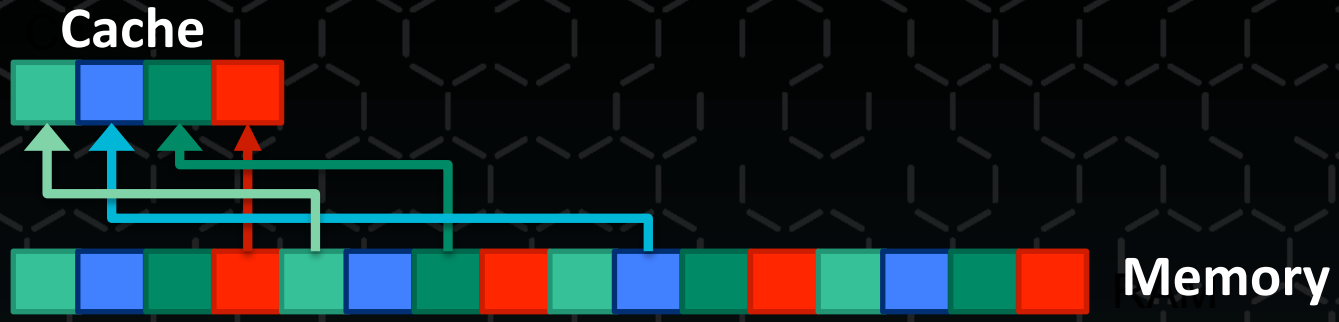

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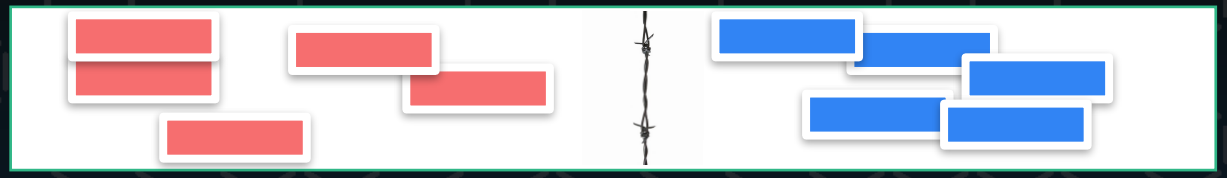

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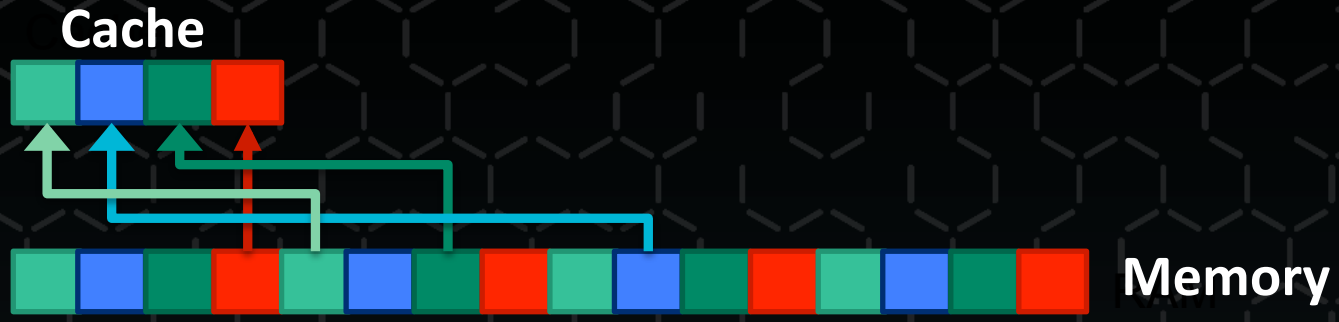

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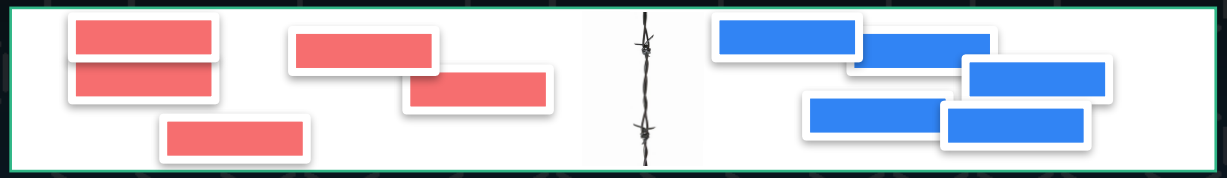

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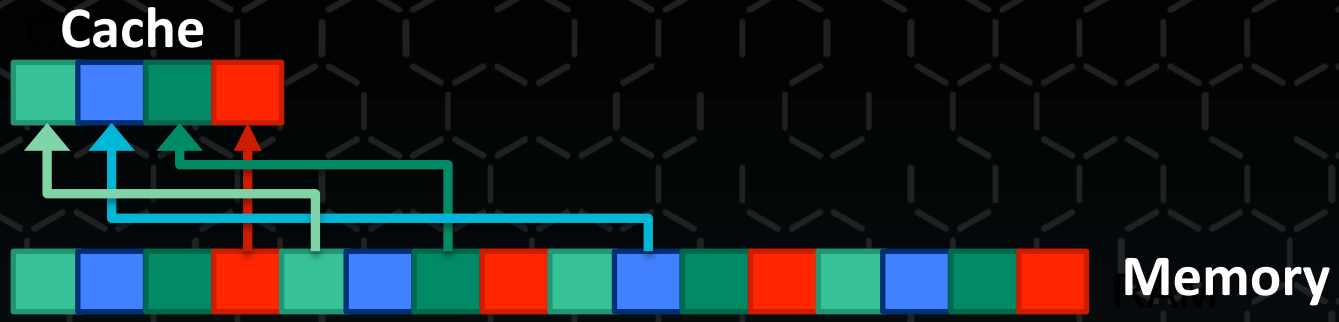

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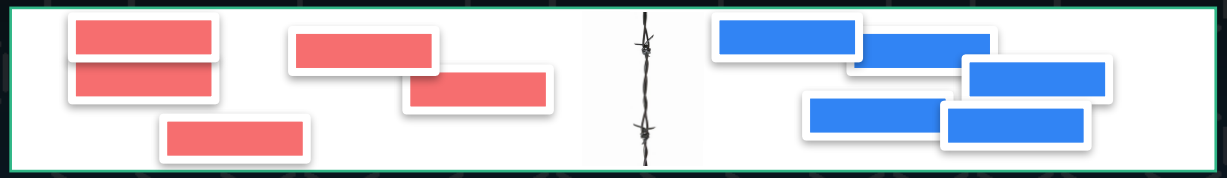

Shared hardware caches

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Cannot be supported by on-core caches

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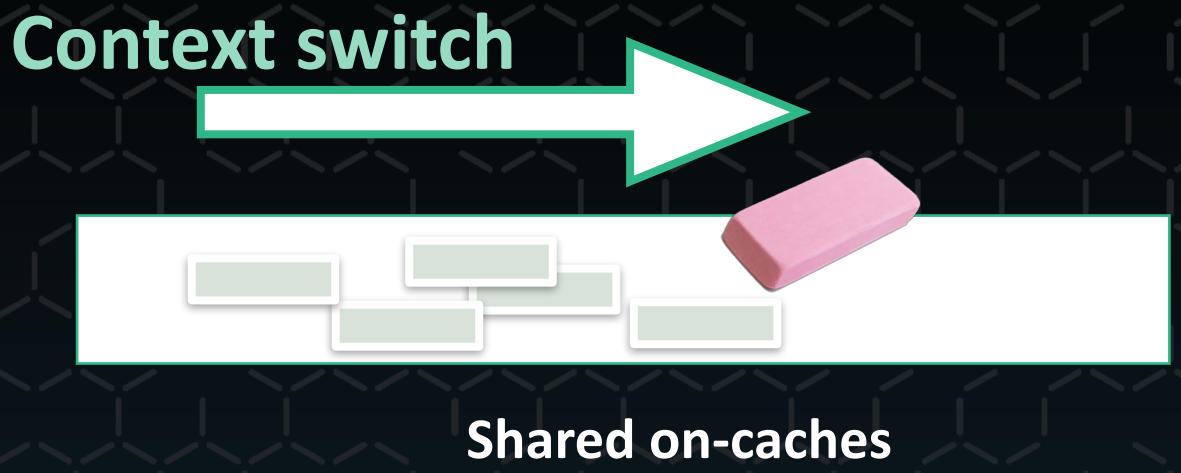
Temporal Partitioning



Flushing on-core caches:

- Resetting states

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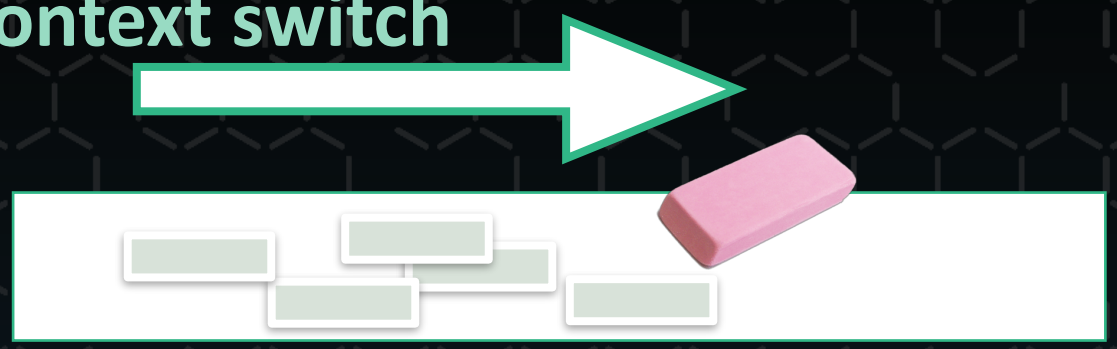
Temporal Partitioning



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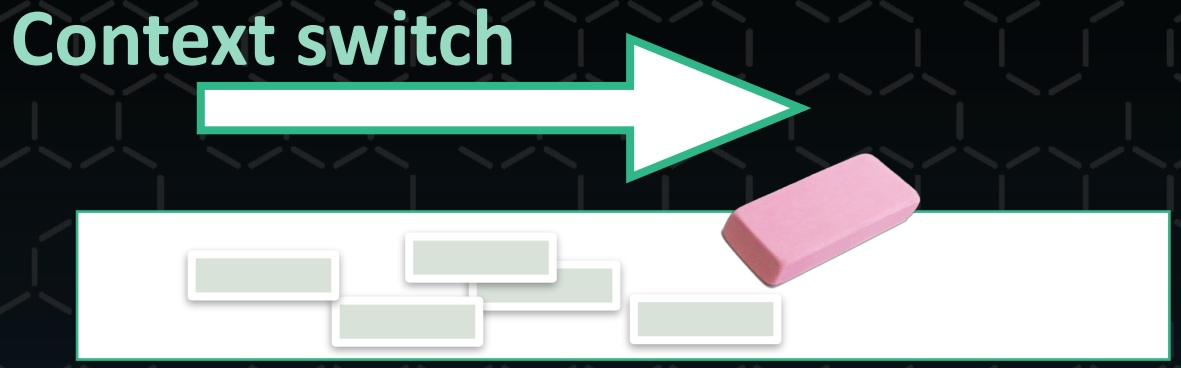

Flushing on-core caches:

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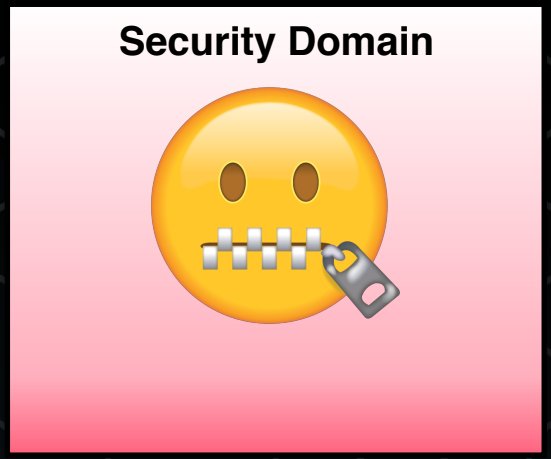
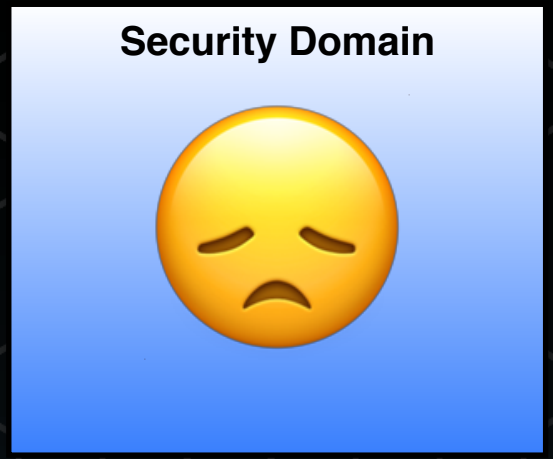
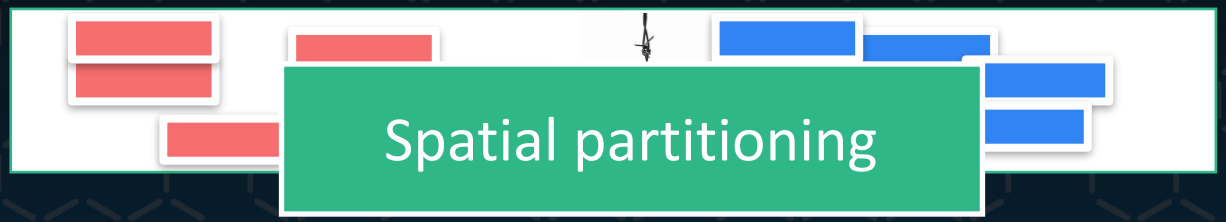
Preventing Temporal Interference through Partitioning







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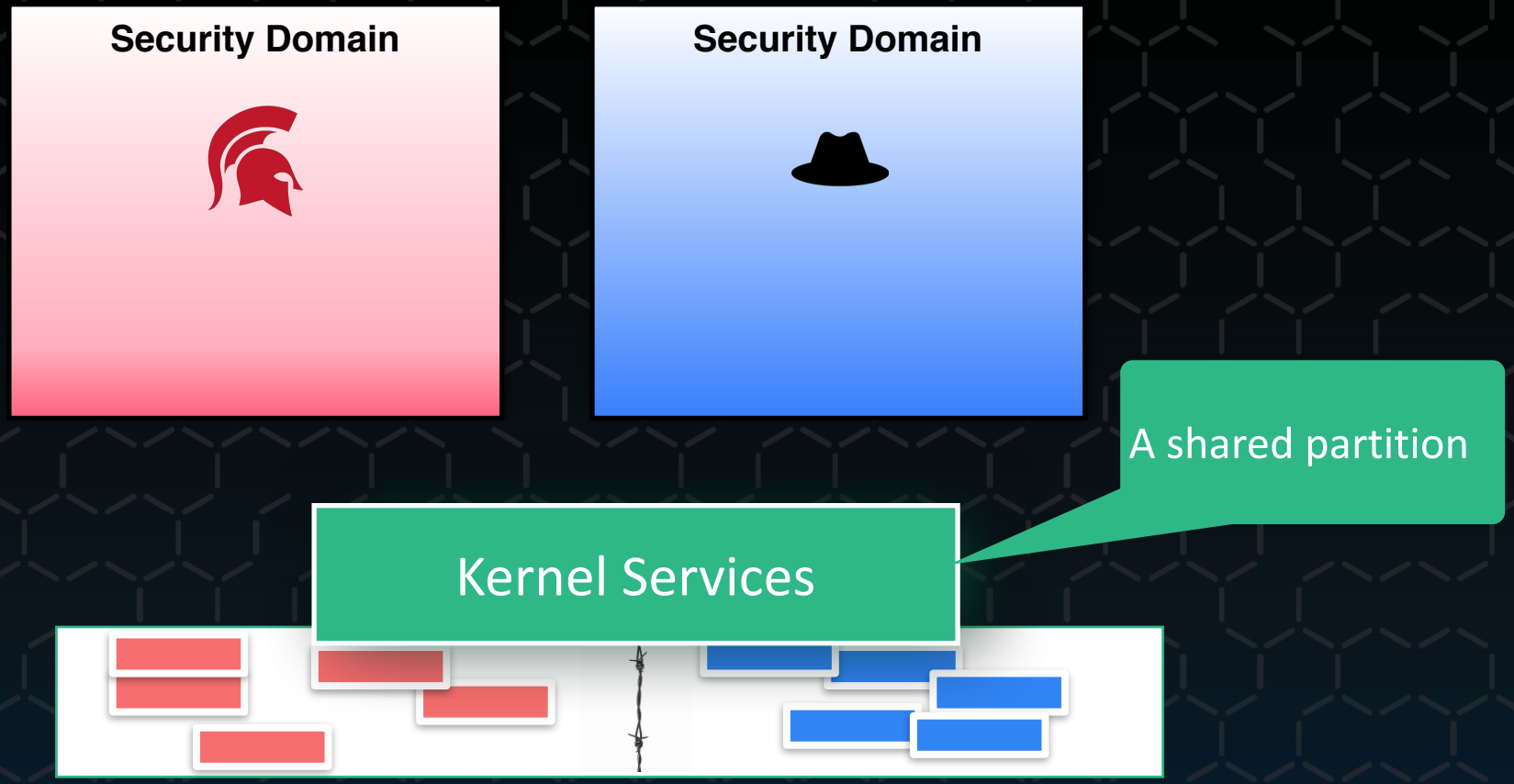
Wait, Everyone Shares the Kernel….



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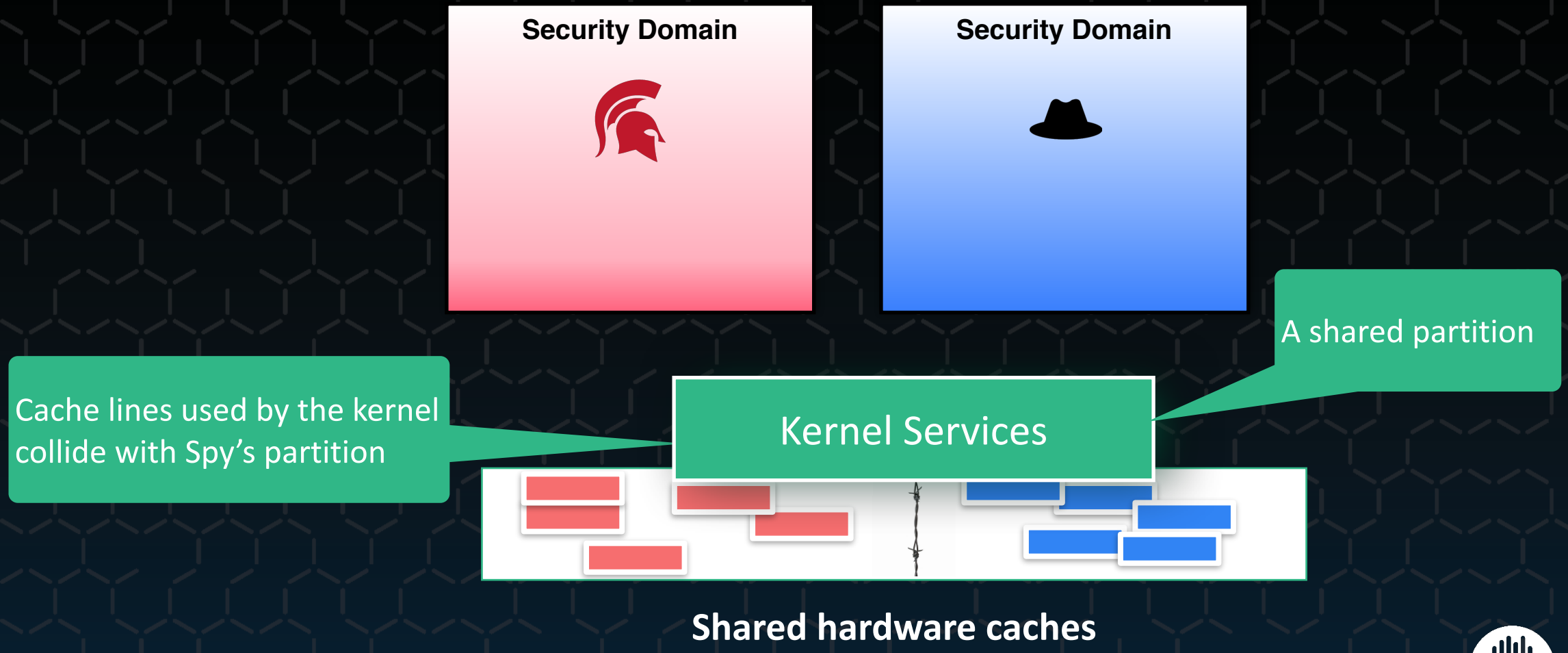

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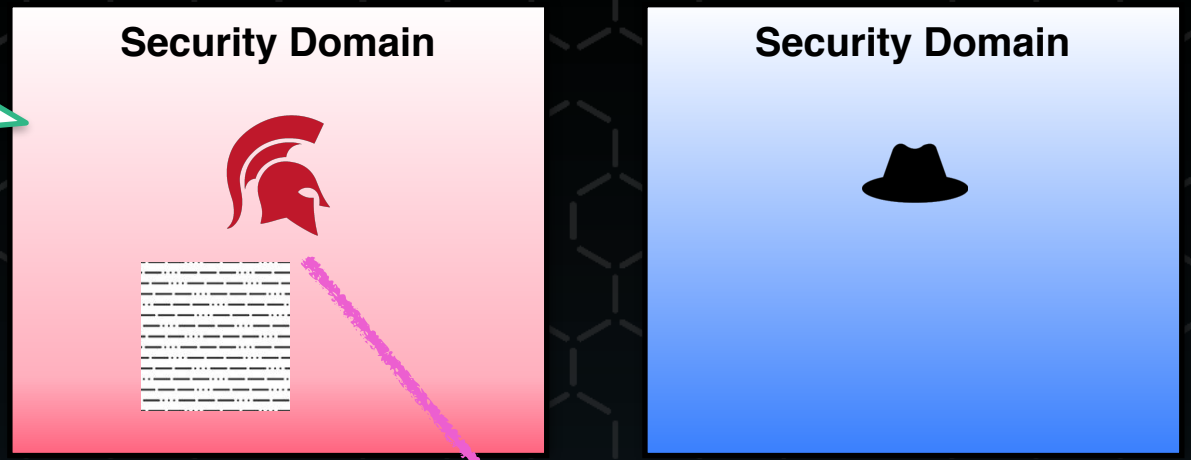
Poster Session
@ 17:15



Cache lines used by the kernel collide with Spy's partition

A shared partition

Kernel Services

Shared hardware caches

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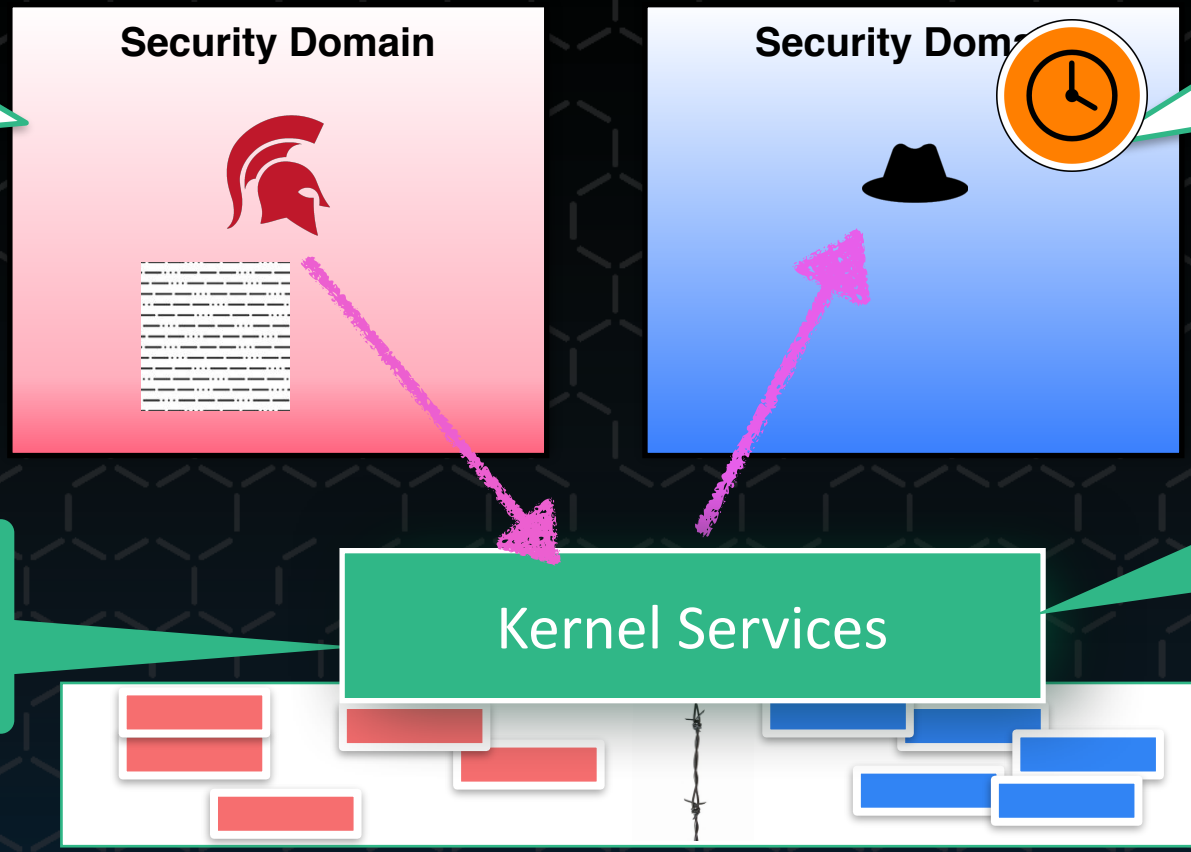

Fast Fast Slow Fast Fast
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Kernel Services

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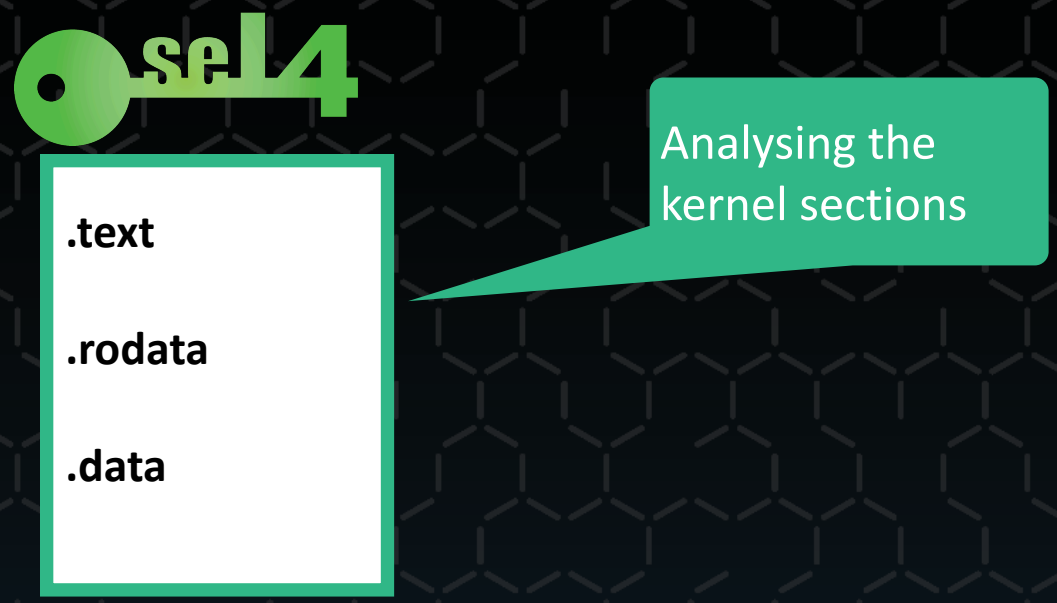
Cloning the Kernel Image



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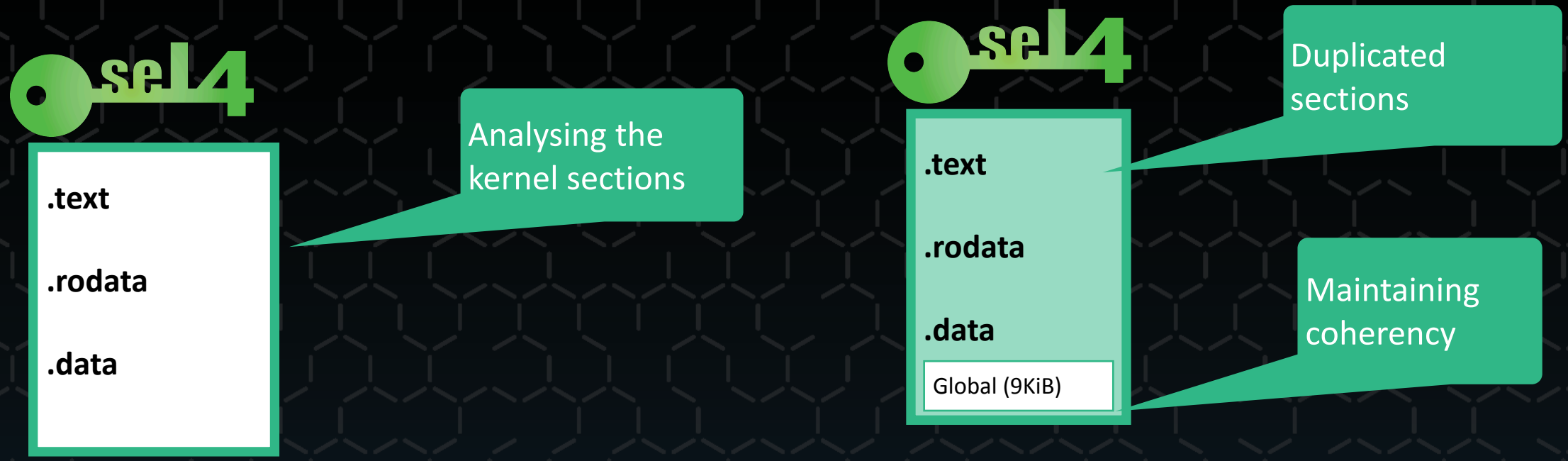

Cloning the Kernel Image

.text

.rodata

.data

Analysing the kernel sections

.text

.rodata

.data

Global (9KiB)

Duplicated sections

Maintaining coherency

Kernel Clone:
Generating a copy of the kernel image with user-level managed memory

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Cloning the Kernel Image

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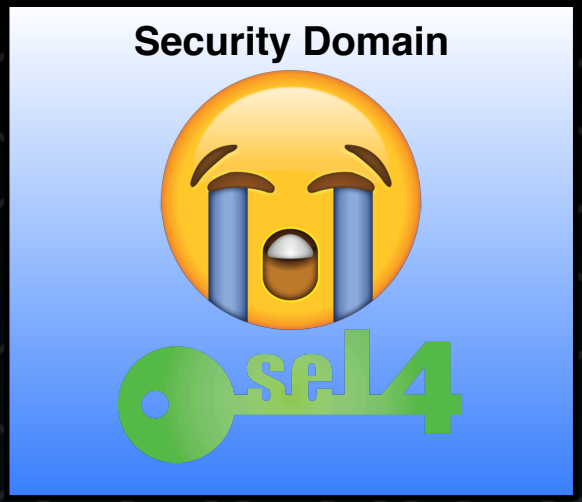
Dedicated Kernel Images



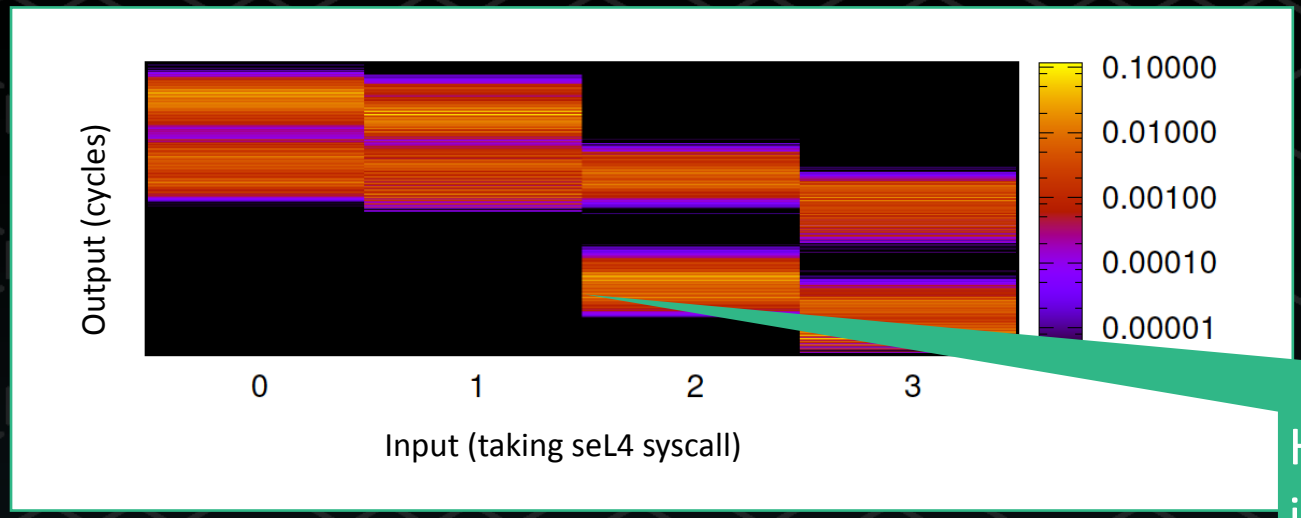
Shared Global Data

Temporal partitioning

Deterministic usage

Spatial partitioning

Timing Channel through the Shared Kernel



Channel matrix: conditional probability of observing the output signal (time, spy) given the input signal (system-call number, Trojan)

Raw channel

Horizontal variation indicates a channel

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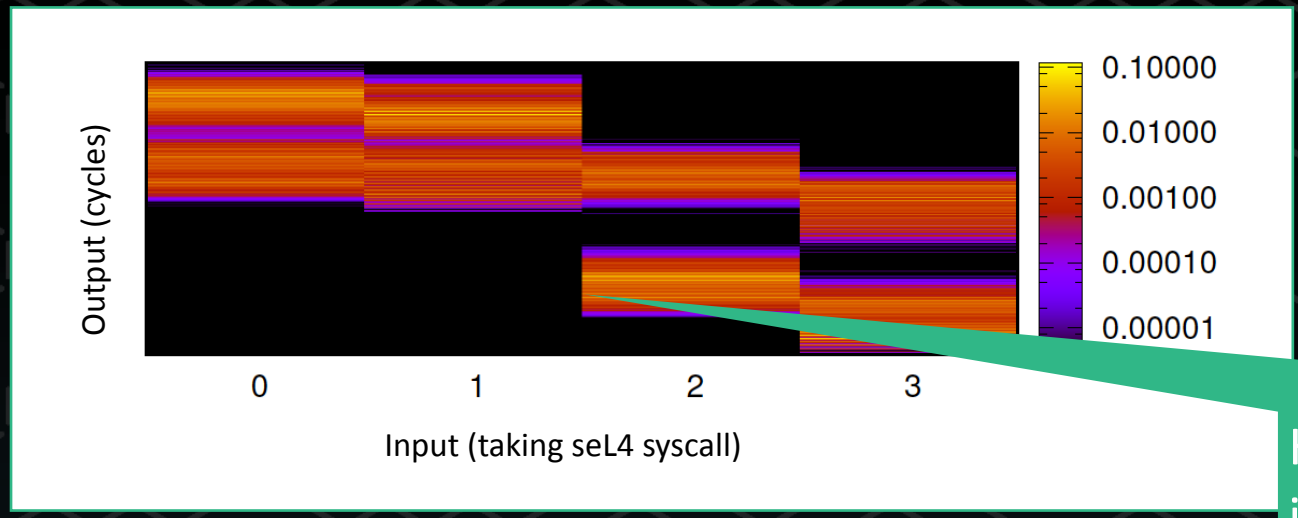

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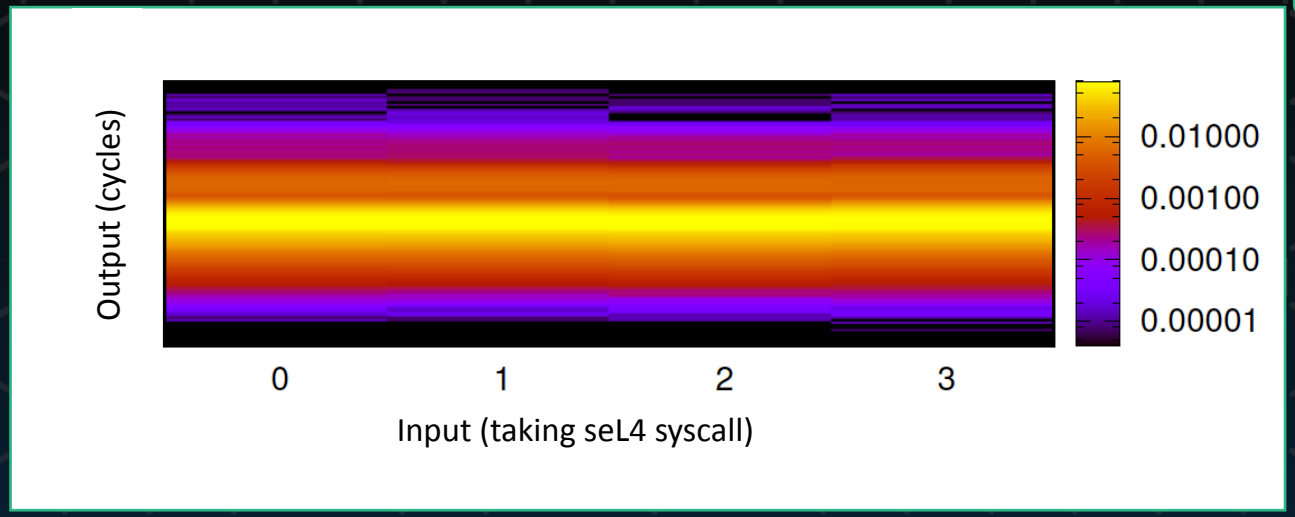

Prevented by cloned kernel

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How realistic is cloning?

.text

.rodata

.data

Global (9KiB)

x86	Arm
224 KiB	120 KiB

Memory consumption

Arch	seL4 Clone	Linux fork + exec
x86	79 µs	257 µs
Arm	608 µs	4,300 µs

Efficiency

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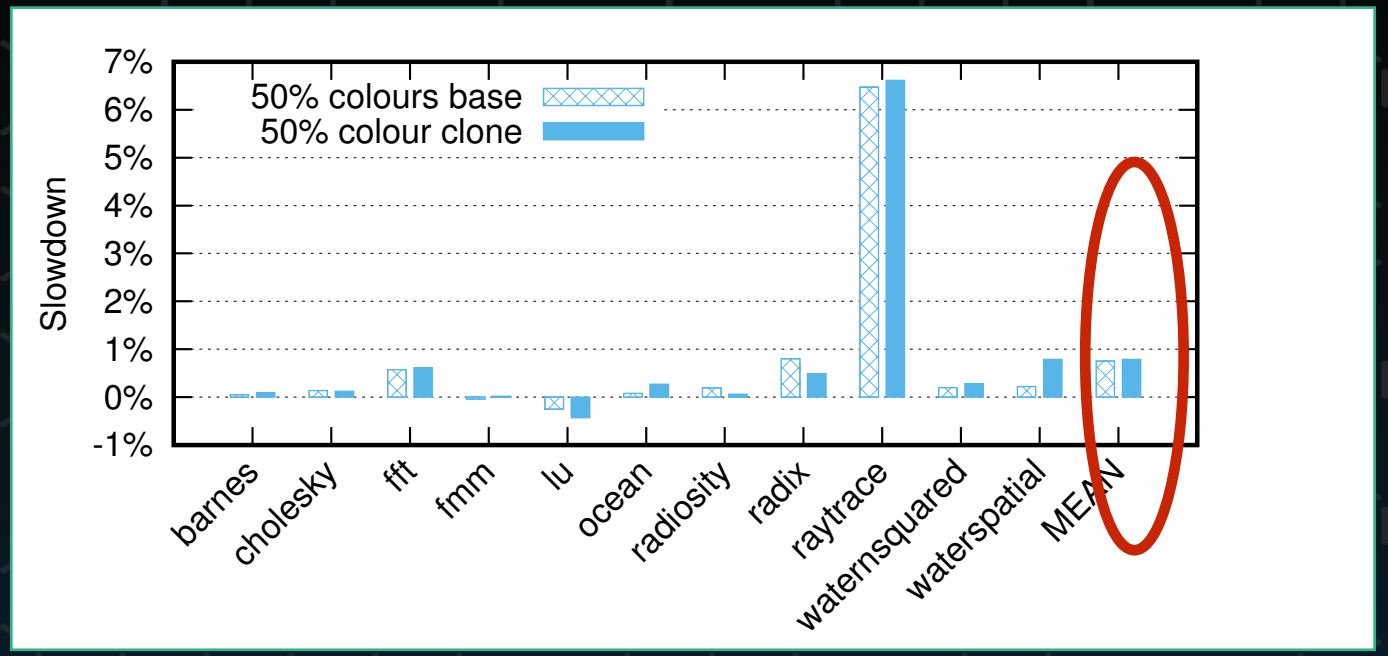
Performance Impact

The cost of colouring a domain:

- 50% of the cache colour
- 50% of the cache colour + a coloured kernel



The slowdown of splash-2 against base line kernel

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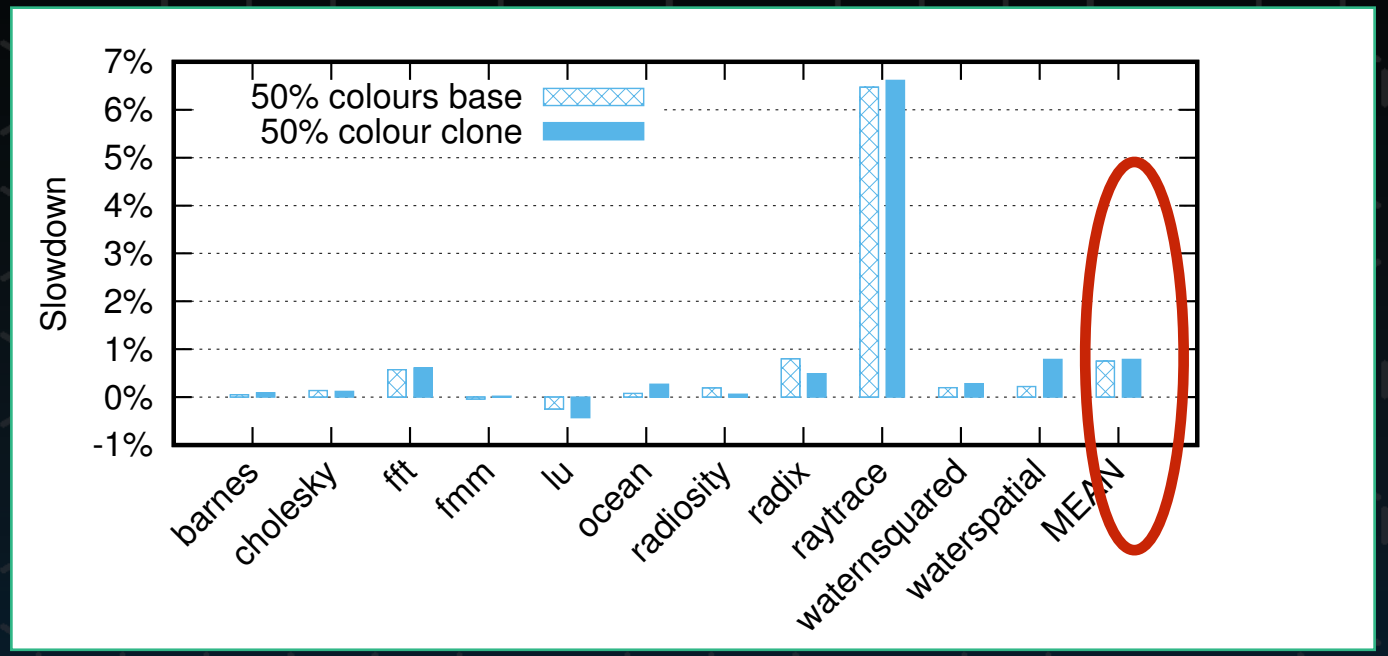

The slowdown of splash-2 against base line kernel

The cost of time protection:

- spatial partition + temporal partition

x86	Arm
3.38%	1.09%

The geometric mean

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We have also done:

- Partition IRQs
- Domain-switch actions
- A deterministic domain switching latency
- Preventing timing channels:
  - Shared kernel, Intra-core, cross-core, domain-switch latency, timer
- Performance evaluation:
  - IPC, domain switching latency, kernel cloning, cache colouring, time protection

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Summary

- Define temporal isolation as a mandatory (black-box mechanisms) enforcement provided by the OS.
- Time protection for preventing microarchitectural timing channels
- Effective on closing studied timing channels
- Low overhead

THANK YOU

Trustworthy Systems
Qian Ge
PhD candidate

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w https://ts.data61.csiro.au/projects/TS/timingchannels/

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