Ultimate SLH: Taking Speculative Load Hardening to the Next Level

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Spectre-V1 Revisit

Misprediction

👿

Obtain secret

```
if (index < arrayLen) {
 👿= array[i👿x];
  y = array2[👿 4096];
}
```

Covert Channel

👿

Leak

Speculative Load Hardening (SLH)

```
mask = 0;
if (index < arrayLen) {
  r -1  ‹ = index < arrayLen ? mask :  -1
-1  = array[index] | r -1  k;
}
```

Fixed memory access under misprediction

Track speculative state

Poison memory

Limitation of SLH

- Only protect memory

- Leakages could also from ***Control Flow*** ***(CCS 2021)***

	SLH	SSLH (CCS 2021)
Memory	✓	✓
Control Flow	✗	✓

Leakage Model

- Constant-time Model
  - Memory
  - Control Flow
  - Variable-time Instructions
- Bring constant-time model to speculative execution

	SLH	SSLH (CCS 2021)
Memory	✓	✓
Control Flow	✗	✓
Variable-time	✗	✗

Really Leak?

Timing variable-time instructions

```
value = sqrtsd(value);
value = mulsd(value, value);
```

On i7-10710U:

ecuting a pair of SQRTSD and MULSD:

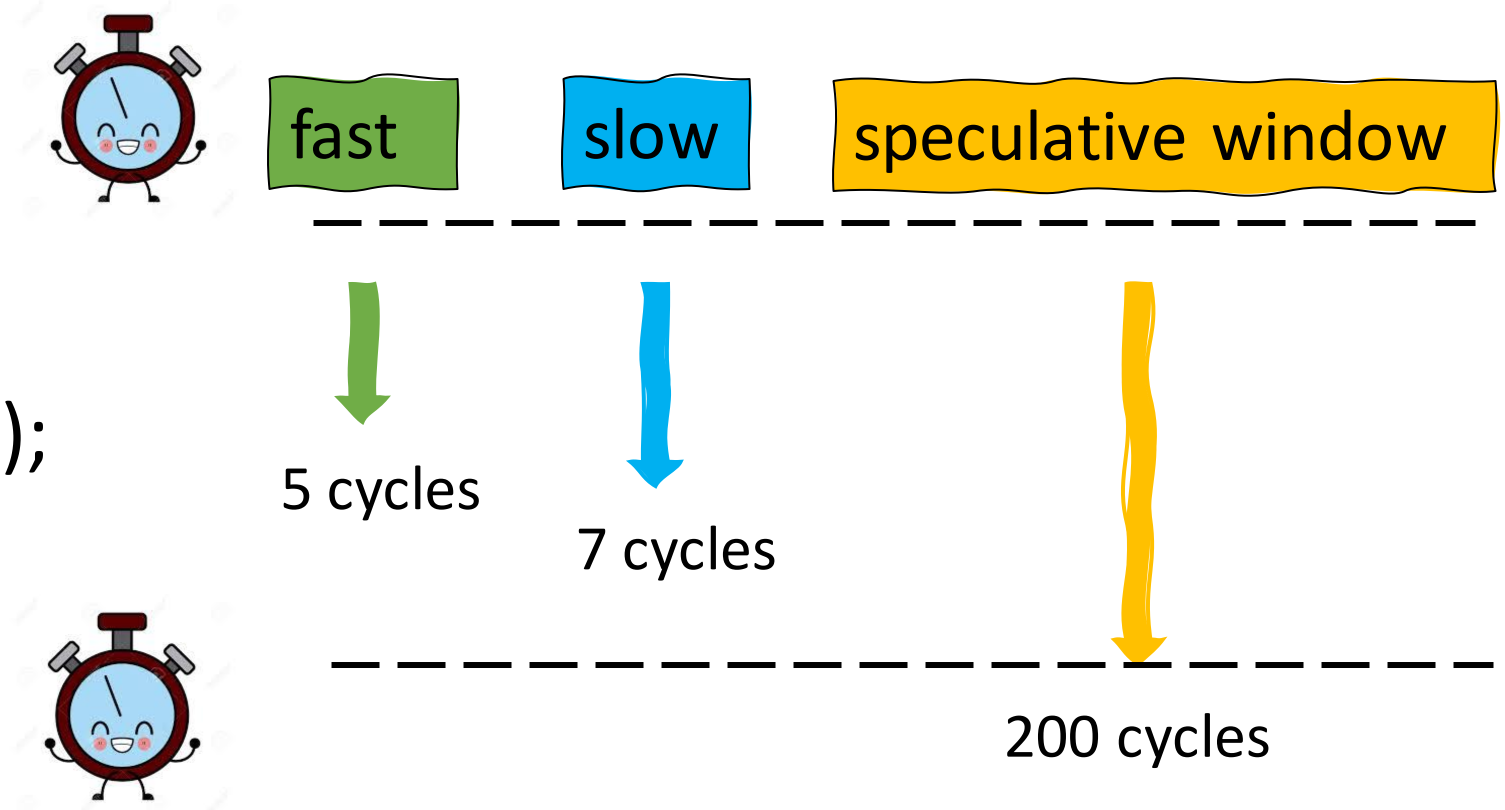
- 65536: 5 cycles
- 2.34e-308: 7 cycles

fast

slow

Timing speculative variable-time instructions

```
if (isPublic) {
  value = sqrtsd (value);
  value = mulsd (value, value);
}
```



fast

slow

speculative window

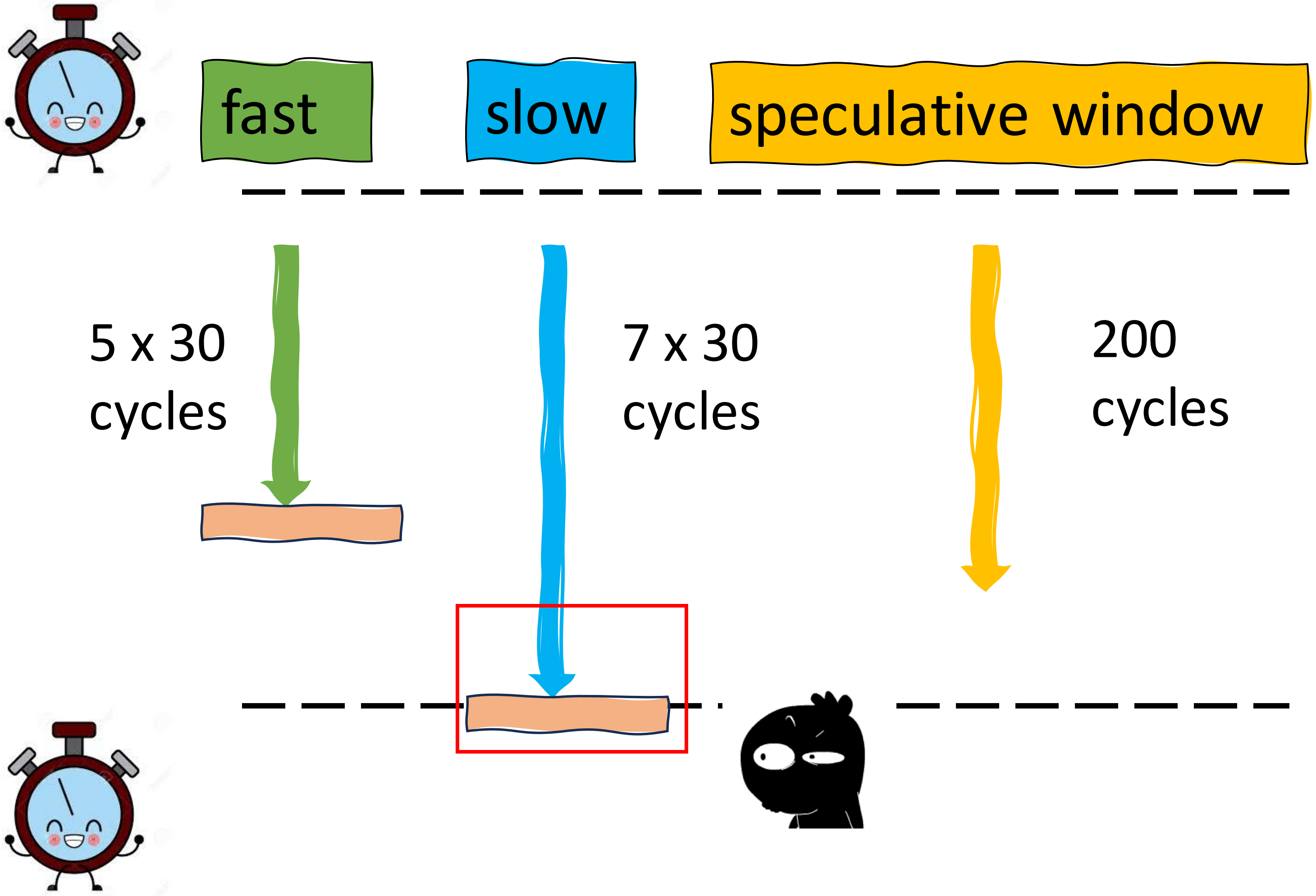
5 cycles

7 cycles

200 cycles

Timing speculative variable-time instructions

```
if (isPublic) {
  value = sqrtsd (value);
  value = mulsd (value, value);
  value = sqrtsd (value);
  value = mulsd (value, value);
  ……
}
  independent_access(x);
```



Ultimate Speculative Load Hardening

- Constant-time Model
  - Memory access (load + store)
  - Control Flow Transfers
  - Variable-time Instructions
- Bring constant-time model to speculative execution

Really Leak?

Really Leak!

	SLH	SSLH (CCS 2021)	USLH
Memory	✓	✓	✓
Control Flow	✗	✓	✓
Variable-time	✗	✗	✓

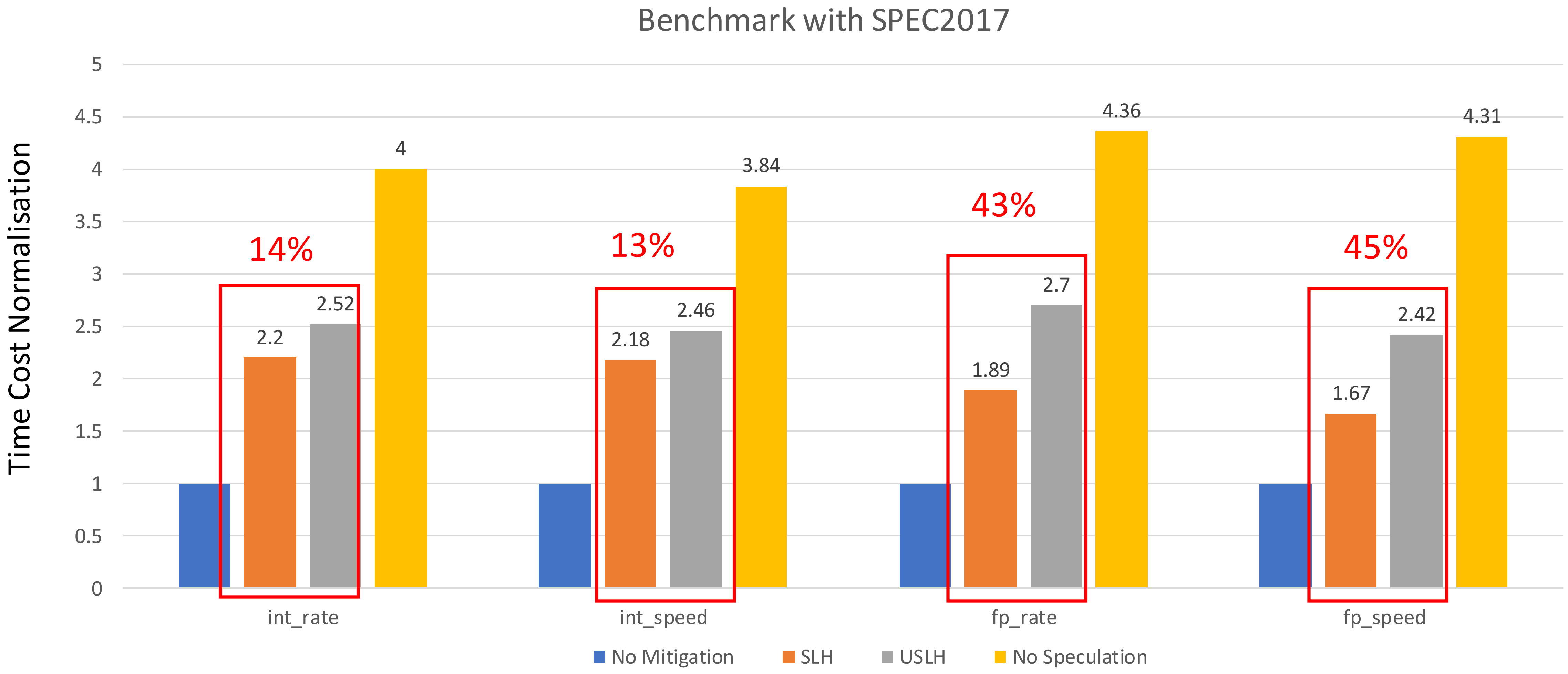
Ultimate Speculative Load Hardening

```
if (isPublic) {
  mask = isPublic ? Mask : -1;
  value = value | mask;
  value = sqrtsd (value);
  value = mulsd (value, value);
  ……
  independent_access(x);
}
```

🟩 Compiled by SLH

🟦 Compiled by USLH

USLH Benchmark



Summary

- Leakages could from variable-time operations
- Implement and benchmark Ultimate SLH
- Gadget search tool
- Formal Proof

https://github.com/0xADE1A1DE/USLH

Code

ARTIFACT EVALUATED usenix ASSOCIATION AVAILABLE

ARTIFACT EVALUATED usenix ASSOCIATION FUNCTIONAL

ARTIFACT EVALUATED usenix ASSOCIATION REPRODUCED

Paper