# *Spectector: Principled detection of speculative information flows*

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# How can we reason about speculative leaks?

## Speculative semantics

- Parametric in branch predictor
- Execute mispredicted branches for fixed number of steps
- Backtrack on wrong decisions

## Attacker model

Attacker observes:

- locations of ***memory accesses***
- ***branch/jump*** targets
- ***start/end*** speculative execution

## Speculative non-interference

Compares a program's leakage w.r.t. two semantics:

- Standard, non-speculative semantics (proxy for intended program behavior)
- Speculative semantics (proxy for speculative leaks)

**Formally:**

A program **P** is ***speculatively non-interferent*** if

∀ program states ***s*** and ***s′***,

$$\mathbf{P}_{\text{non-spec}}(s) = \mathbf{P}_{\text{non-spec}}(s') \Rightarrow \mathbf{P}_{\text{spec}}(s) = \mathbf{P}_{\text{spec}}(s')$$

# Automatically detecting speculative leaks!

## Spectector

```
    mov rax, A_size
    mov rcx, x
    cmp rcx, rax
    jae END
L1: mov rax, A[rcx]
    mov rax, B[rax]
```

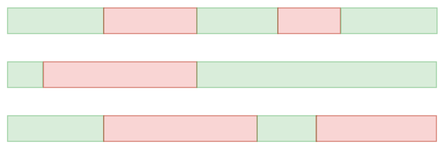
Assembly program

x64 to μASM

```
    rax <- A_size
    rcx <- x
    beqz rcx<rax, END
L1: load rax, A + rcx
    load rax, B+rax
END:
```

μASM program

Symbolic execution



Symbolic traces

Speculative leaks detection

Security decision

## Case study: compiler countermeasures

***Goals:***

- Determine if speculative non-interference captures speculative leaks on 15 variants of SPECTRE v1
- Assess Spectector's precision

***How:***

Analyze 240 microbenchmarks obtained by compiling 15 variants of SPECTRE v1 with Clang, Intel ICC, and Microsoft Visual C++

***Results:***

| Ex. | Vcc | | | | | | Icc | | | | Clang | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unp | | Fen 19.15 | | Fen 19.20 | | Unp | | Fen | | Unp | | Fen | | Slh | |
| | -O0 | -O2 | -O0 | -O2 | -O0 | -O2 | -O0 | -O2 | -O0 | -O2 | -O0 | -O2 | -O0 | -O2 | -O0 | -O2 |
| 01 | ○ | ○ | ● | ● | ● | ● | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ● | ● |
| 02 | ○ | ○ | ● | ● | ● | ● | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ● | ● |
| 03 | ○ | ○ | ● | ○ | ● | ● | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ● | ● |
| 04 | ○ | ○ | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ● | ● |
| 05 | ○ | ○ | ● | ○ | ● | ○ | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ● | ● |
| 06 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ● | ● |
| 07 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ● | ● |
| 08 | ○ | ● | ○ | ● | ○ | ● | ○ | ● | ● | ● | ○ | ● | ● | ● | ● | ● |
| 09 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ● | ● |
| 10 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ● | ○ |
| 11 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ● | ● |
| 12 | ○ | ○ | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ● | ● |
| 13 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ● | ● |
| 14 | ○ | ○ | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ● | ● |
| 15 | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ○ | ● | ● | ○ | ○ | ● | ● | ○ | ● |

## Case study: Xen Project hypervisor

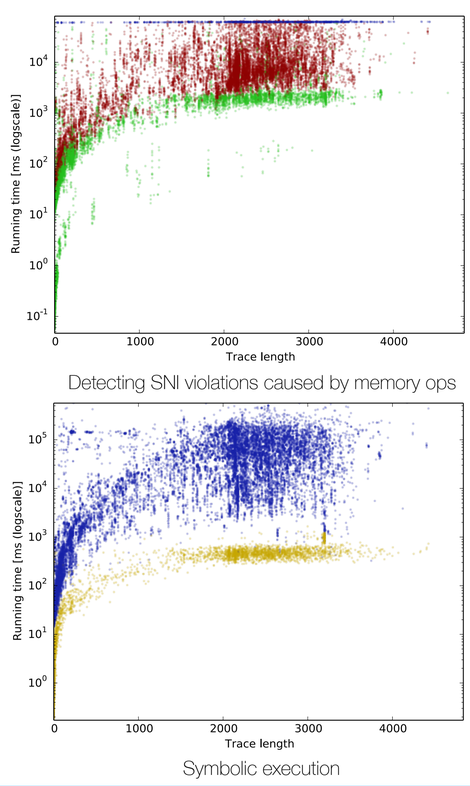
***Goal:***

Assess Spectector's scalability

***How:***

Compare time spent on discovering new symbolic paths with the time spent on checking SNI

***Results:***




Symbolic execution

Symbolic execution versus checking SNI

Supported by Intel Strategic Research Alliance (ISRA) "Information Flow Tracking across the Hardware-Software Boundary"

Available at: ***https://spectector.github.io***

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We're ***hiring*** interns and PhD students!