Systematic Analysis of Programming Languages and Their Execution Environments for Spectre Attacks

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Outline

Introduction

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It is NOT clear which execution environments have effective mitigations and can securely be used to implement security critical code, and which do not

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- We systematically analyse the security (with respect to Spectre) of programming languages and their execution environments
- We introduce Speconnector
  - It is a novel tool
  - It is to evaluate and exploit Spectre gadgets
  - It works independent of the target programming language
- We demonstrate the security impact with two case studies of security-related libraries, and show that we can leak secrets from them.

Background

Speculative Execution

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- HOWEVER, the microarchitectural state is not reverted

Transient-Execution Attacks

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- Attacks of this type traditionally use side-channel attacks to reconstruct the architectural state

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⇓

Example

```
if(x < length_of_data){
  tmp &= lookup_table[data[x] << 12];
}
```

Program Execution

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Note!

This distinction is orthogonal to programming language choice since every language can be interpreted, compiled, and executed in hybrids.

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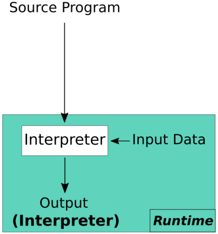

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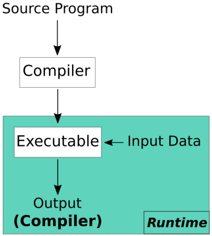

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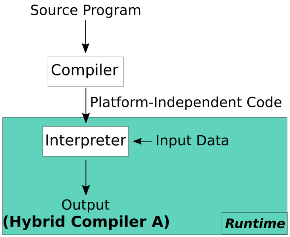

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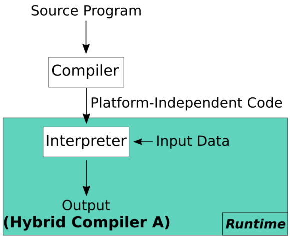

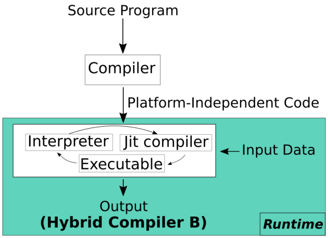

Feasibility of Attacks in Documentations

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Attack \ PLs	Ruby (MRI)	PHP	Shell (Bash)	Perl	PowerShell (pwsh)	TSQL	Lua	Vim script	Emacs Lisp
Spectre-PHT	×	×	×	☒	×	×	×	×	×
Spectre-BTB	×	×	×	☒	×	×	×	×	×
Spectre-RSB	×	×	×	☒	×	×	×	×	×
Spectre-STL	×	×	×	☒	×	×	×	×	×

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Spectre-PHT	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	☑	×	☑	×	⊠
Spectre-BTB	☑	☑	⊠	☑	☑	☑	⊠	☑	☑	☑	☑	×	☑	×	⊠
Spectre-RSB	☑	☑	⊠	⊠	×	☑	⊠	⊠	×	×	×	×	×	×	⊠
Spectre-STL	⊠	×	☑	⊠	×	×	☑	⊠	×	×	×	×	×	×	⊠

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Attack \ PLs	Dart	Java (OracleJDK)	Java (OpenJDK)	Java (GraalVM)	JavaScript (SpiderMonkey)	JavaScript (V8)	JavaScript (Chakra)	TypeScript	CoffeeScript	Python (PyPy)	Scala	C#	Elixir	Clojure	Python (CPython)	OCaml (ocamlc/ocamlrun)	Kotlin	Groovy
Spectre-PHT	×	×	⊠	☑	☑	☑	☑	×	×	⊠	⊠	⊠	⊠	×	×	⊠	⊠	⊠
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Note!

Note that this shows that an attack is possible, and crafting a concrete end-to-end exploit for each language only requires further engineering steps

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- Speconnector uses the information of the process of the target code to scan for the pages that contain the magic value
- Speconnector establishes shared memory between the two processes
- Any victim accesses to one of the now shared pages results in a cache hit and Speconnector catches it by performing *Flush + Reload*

Feasibility of Attacks in Practice

Interpreted Languages

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Depends on setting	-	-	-	-	-	-	-	-	-
Covert Channel	✓	✓	✓	×	✓	✓	×	✓	×
Spectre Attack	×	×	×	×	✓	×	×	×	×

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Depends on setting	*	*	*	*	*	*	*	*	*	*	*	-	*	-	-
Covert Channel	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓
Spectre Attack	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	✓	×	✓

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Spectre Attack	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	×	×	×	✓	✓	✓

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Note!

Both case studies are using the vulnerable programming languages demonsterated in Section Feasibility of Attacks in Practice of this presentation

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- We analysed them in theory and practice
- We introduced Speconnector
- We showed Spectre attacks in 8 programming languages not investigated so far and not known to be vulnerable
- We illustrated the security impact of our results using two case studies

Thank you for your attention