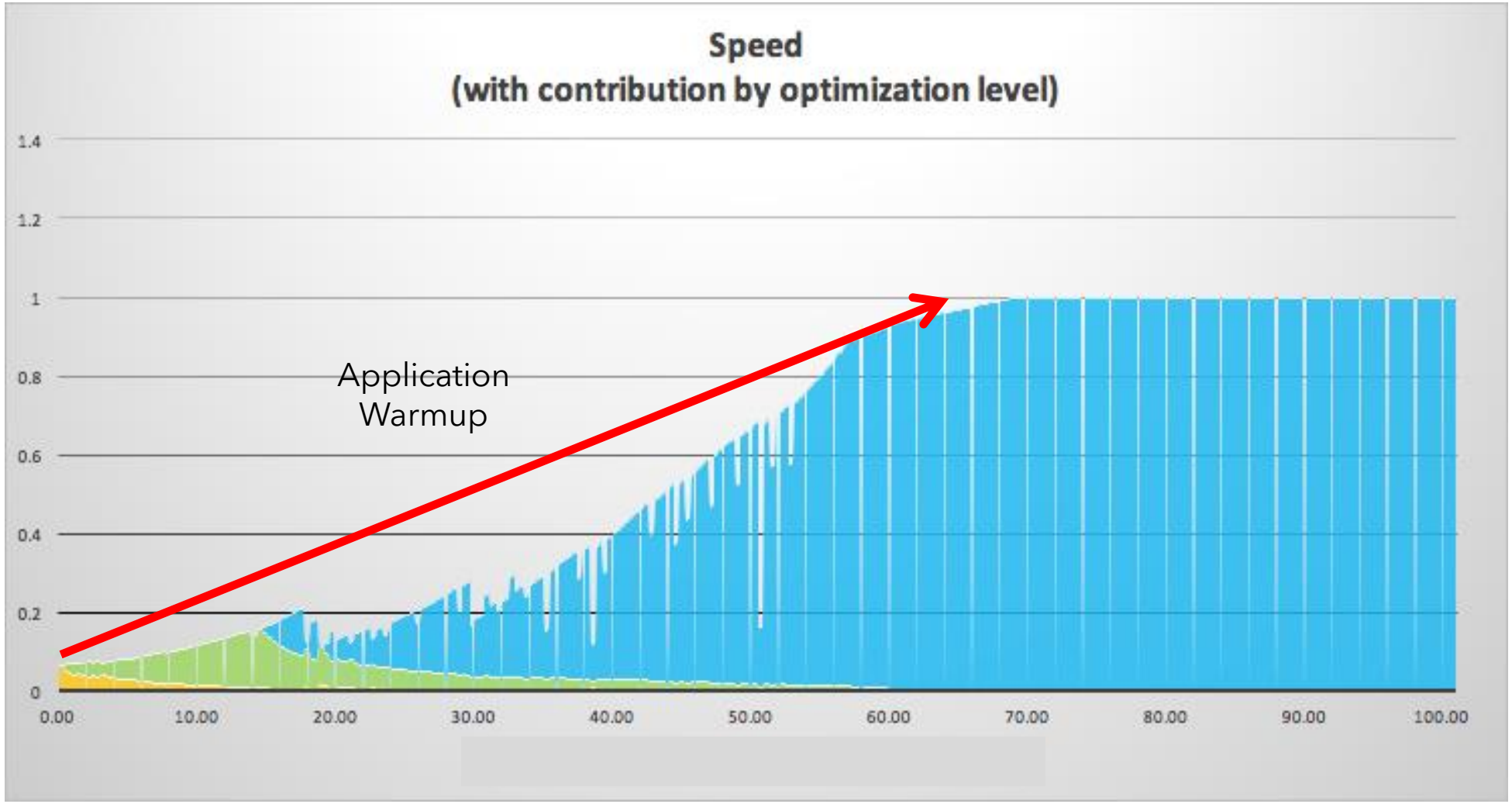
Microsoft

Instant Coffee: How To Eliminate Java Performance Warmup

Simon Ritter, Deputy CTO, Azul

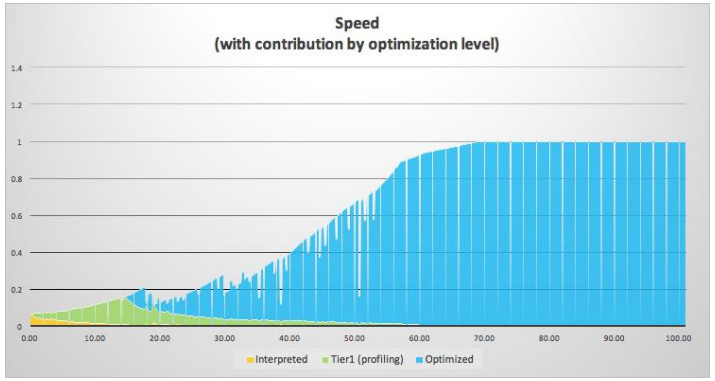
Code. Cloud. Community.

JVM Performance Graph



JVM Performance Graph

First run



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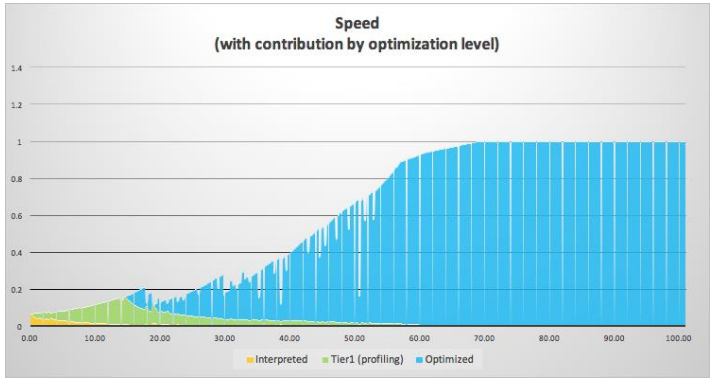
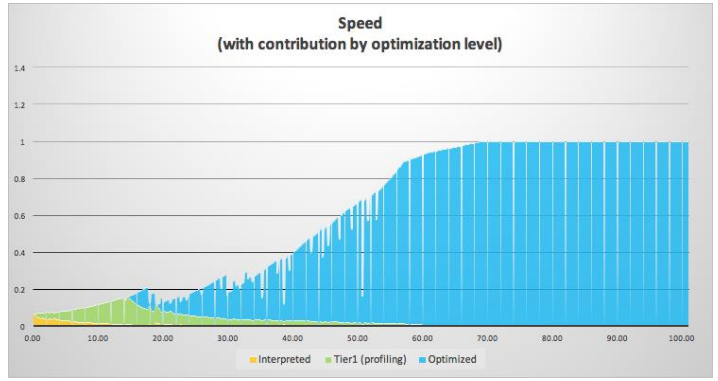
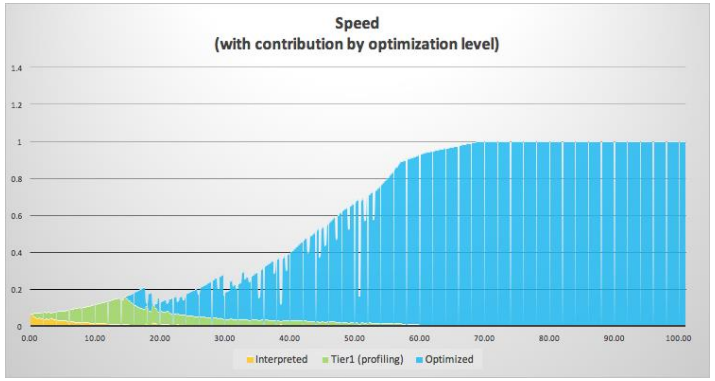


Third run



JVM Performance Graph

First run



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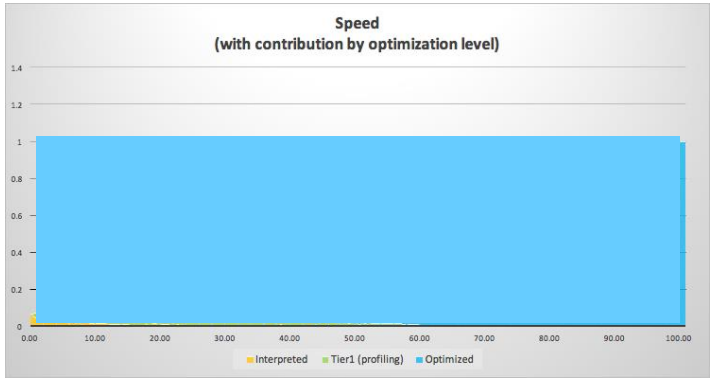

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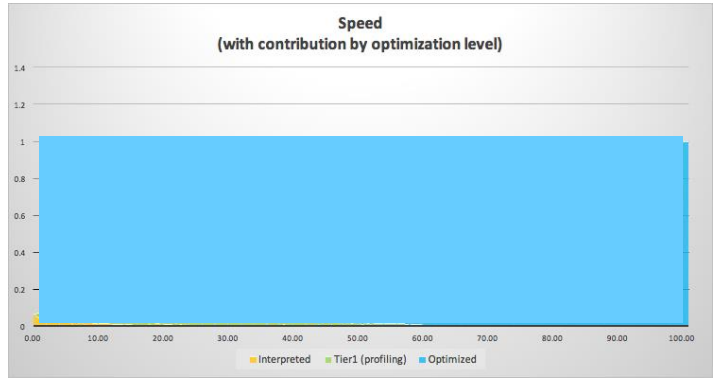

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Solution 1:
Ahead of Time (AOT) Compilation

Compile Java Source Direct to Native Code

- Traditional approach: Ahead of time, static compilation
- No interpreting bytecodes
- No analysis of hotspots
- No runtime compilation of code placing heavy load on CPUs
- Start at full speed, straight away

- This is the Graal native image approach
- Problem solved, right?

Not So Fast

- AOT is, by definition, static
- And code is compiled *before it is run*
- The compiler has no knowledge of how the code will *actually* run
  - Profile guided optimisation has been around for a long time and only helps partially

Speculative Optimisation Example:
Branch Analysis

```
int computeMagnitude(int value) {
  if (value > 9)
    bias = computeBias(value);
  else
    bias = 1;

  return Math.log10(bias + 99);
}
```

Profiling data shows that *value* (so far) has never been greater than 9

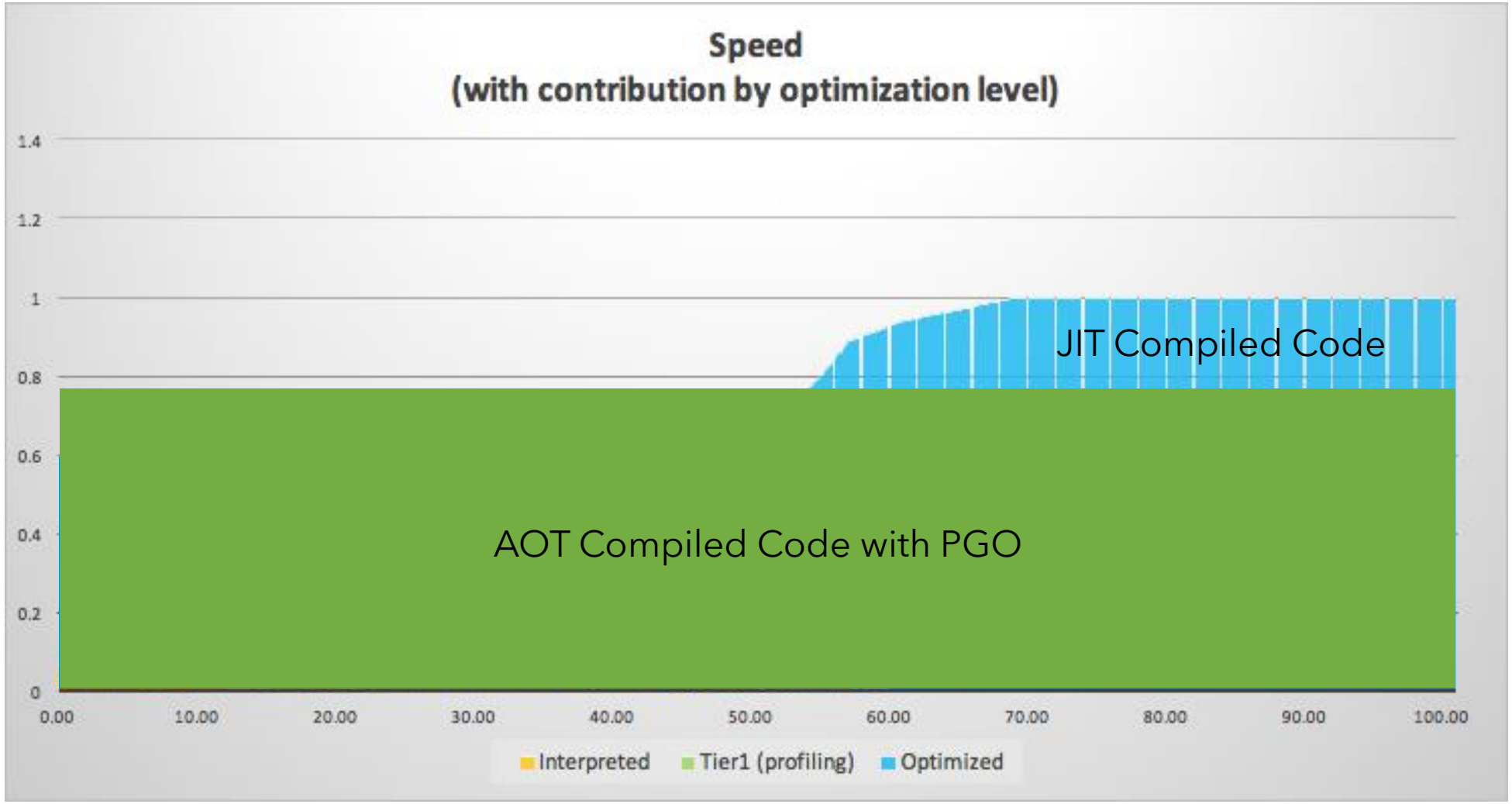
Speculative Optimisation Example:
Branch Analysis

```
int computeMagnitude(int value) {
  if (value > 9)
    uncommonTrap();  // Deoptimise

  return 2;  // Math.log10(100)
}
```

Assume that, based on profiling, *value* will continue to be less than 10

JVM Performance



When To Use AOT

- Ephemeral microservices
  - Startup and warmup time is more important than overall speed
  - Garbage collection is usually a non-issue
- Resource constrained services
  - E.g. 2 vcore container
  - JIT compilation will significantly reduce throughput during warmup

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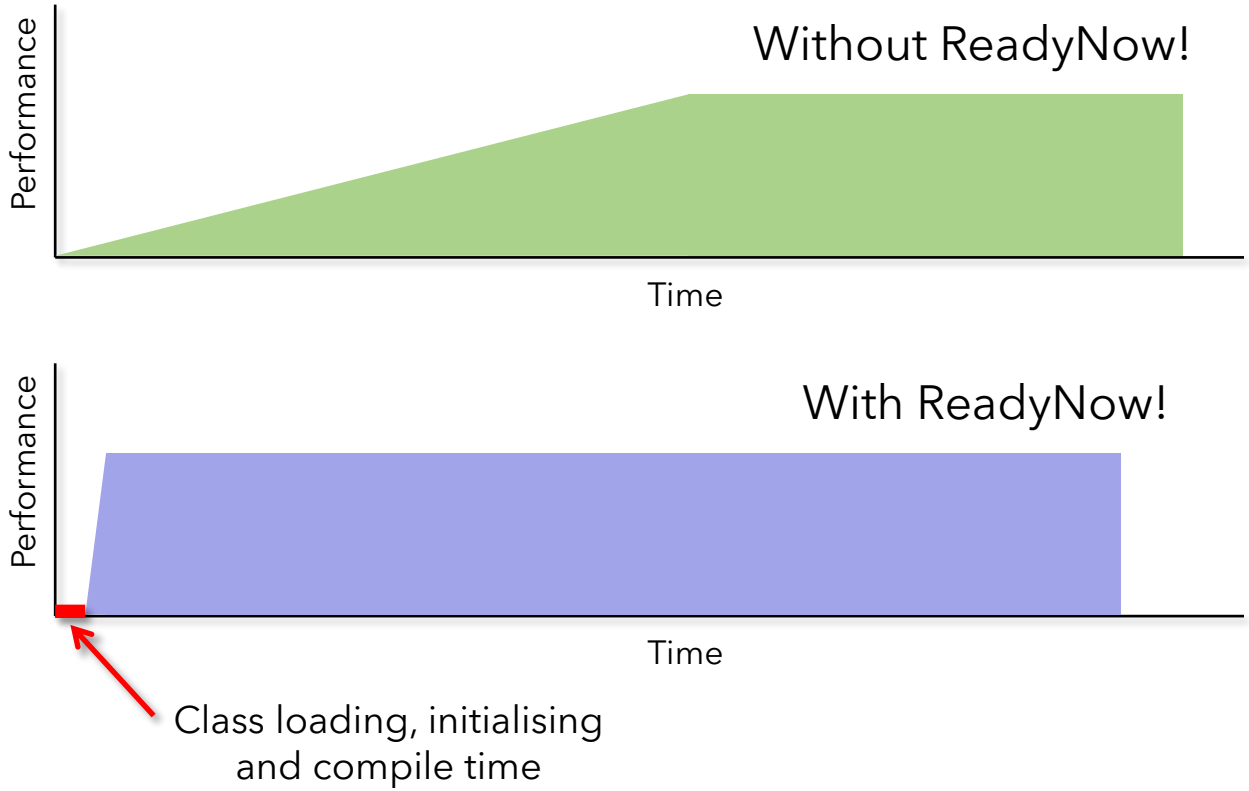
Solution 2:
Store JIT Compilation Data

Azul Prime ReadyNow

- Run the application until its warmed up
- Take a profile
  - All currently loaded classes
  - All currently initialised classes
  - JIT profiling data
  - Deoptimisations that occurred
  - A copy of all compiled code
- Restart application
  - Load and initialise all required classes
  - Load code or compile methods
  - All before `main()`

ReadyNow Startup Time



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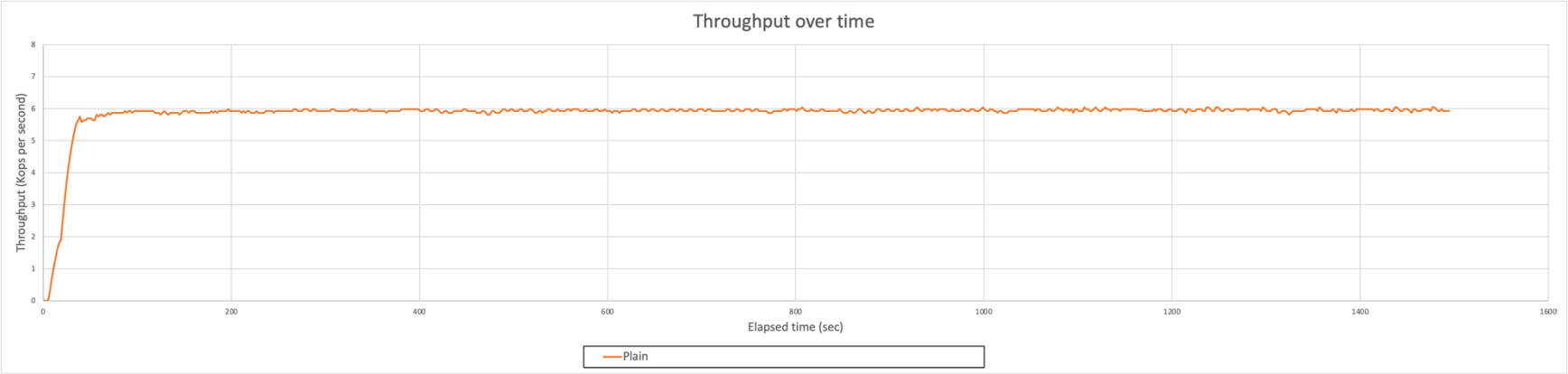
Solution 3:
Decouple The JIT Compiler

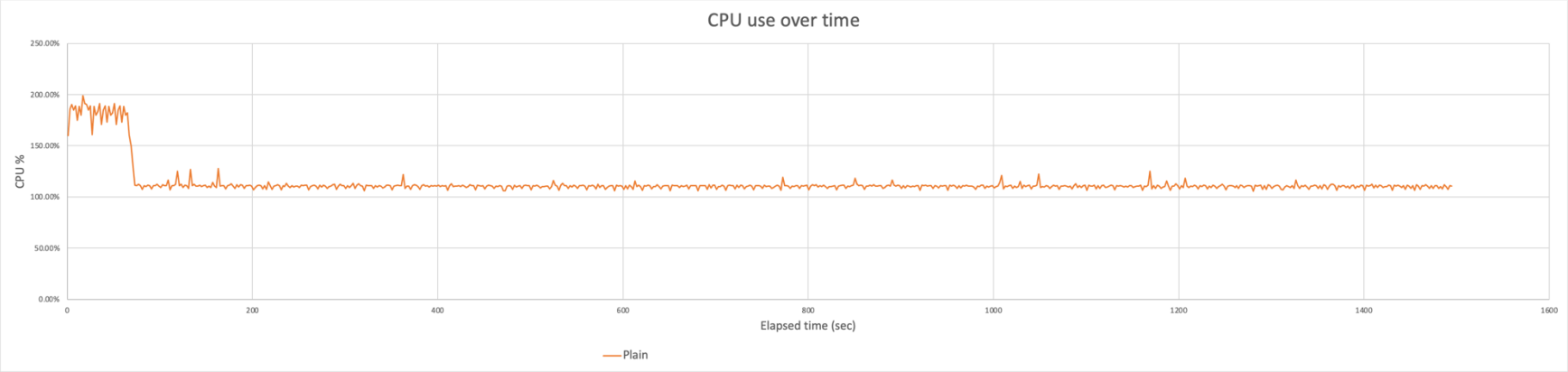
JIT Compilation Has Cost

- JIT is CPU intensive
  - The work has to be done concurrently with the application workload
- Better optimisations deliver better performance (throughput)
  - But require more time, compute power and memory
- This is fine if we have a powerful machine
  - E.g. 64 vcores and 64GB RAM
- Less powerful environments can be problematic
  - E.g. 2vcore container with 2GB RAM
  - Heavily optimised JIT can become prohibitive by degrading throughput
  - Even resul in OOM errors
- Often we end up with a compromise

Speed and CPU Usage Over Time

- 2 Vcore container





Speed and CPU Usage Over Time

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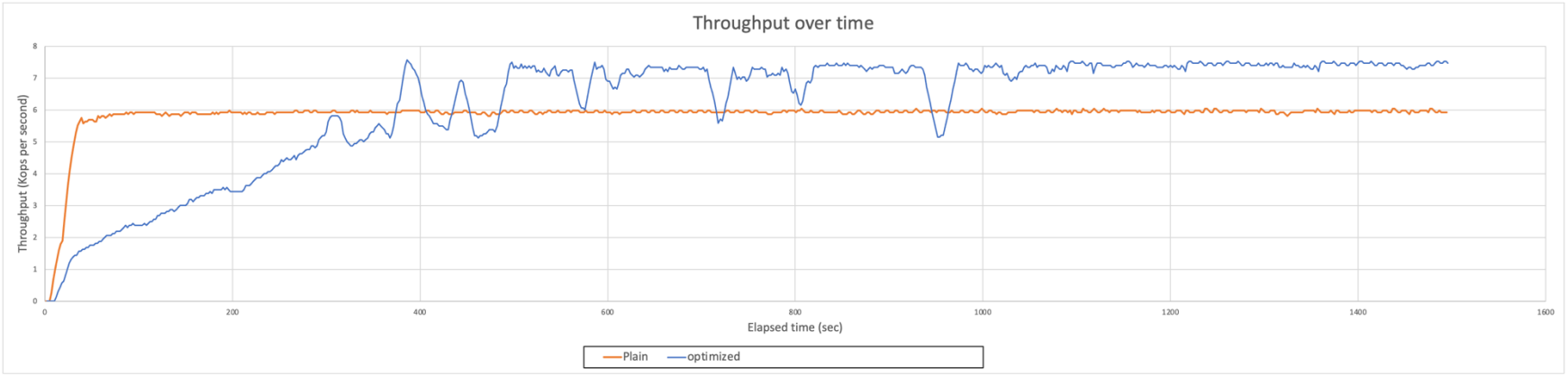
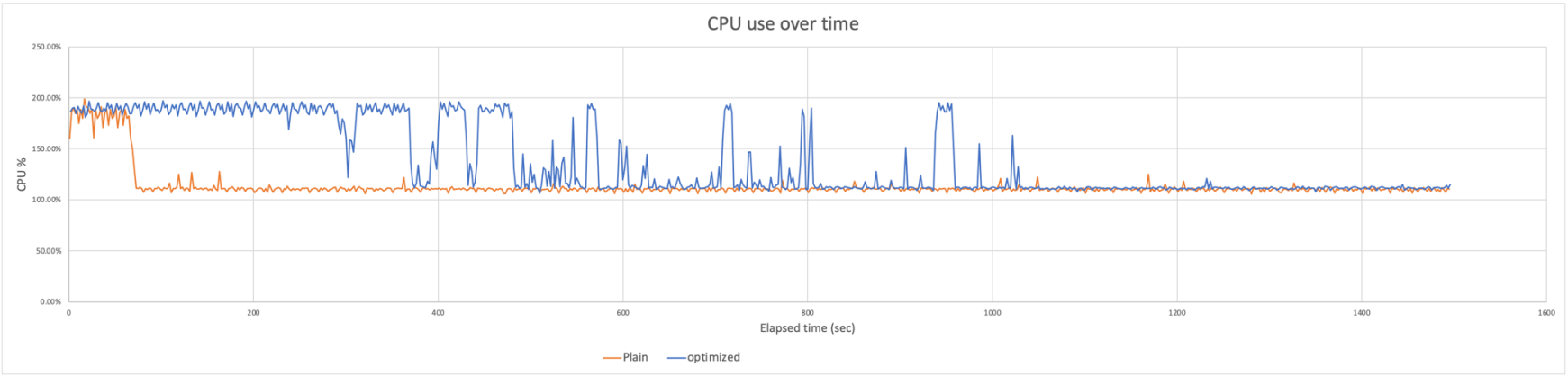
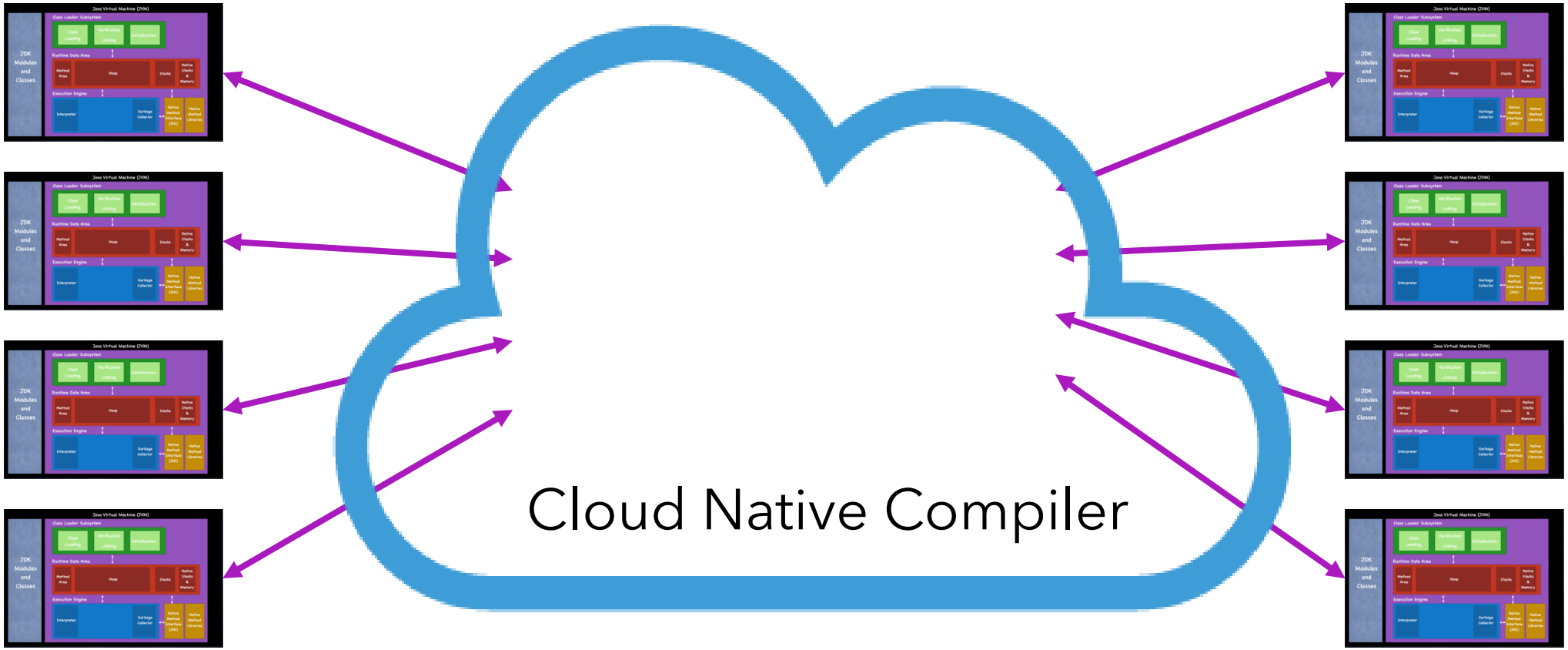




And Made It A Cloud-Based Resource



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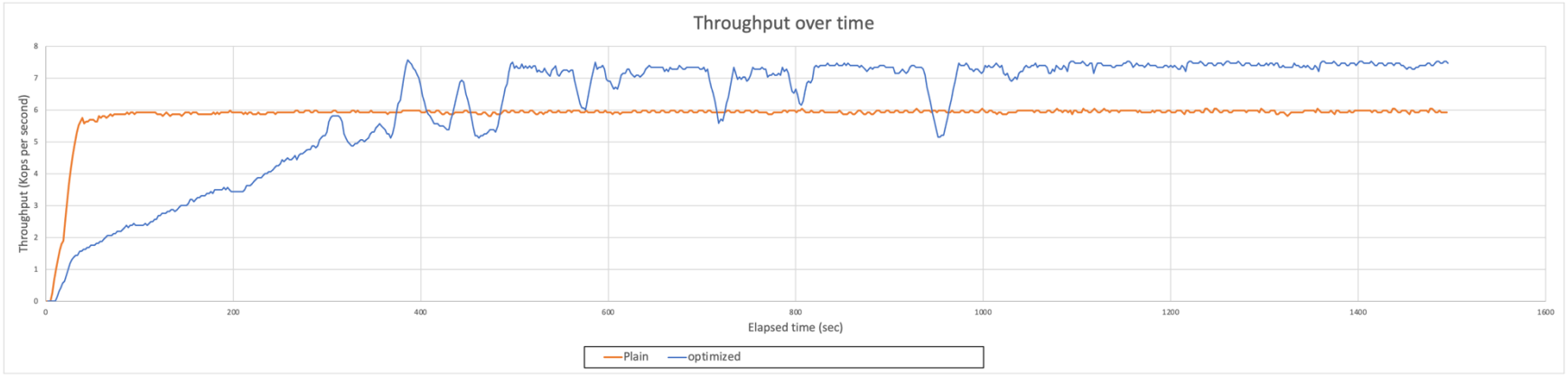

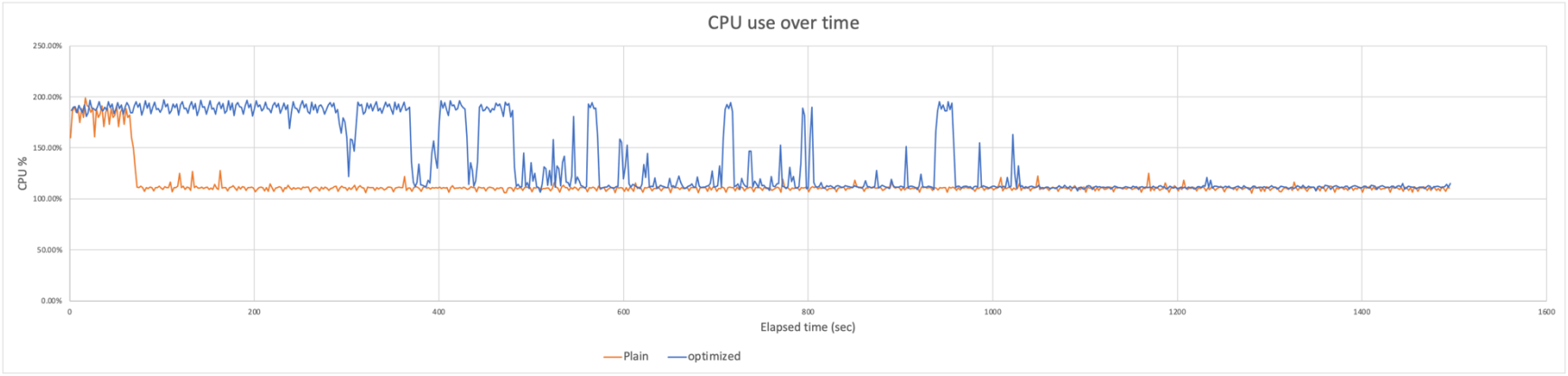

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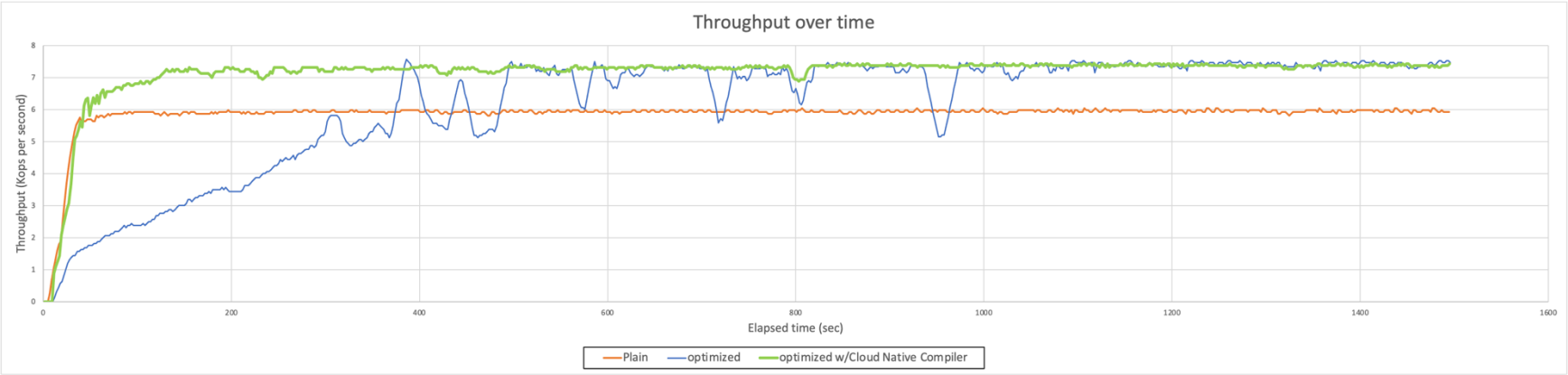

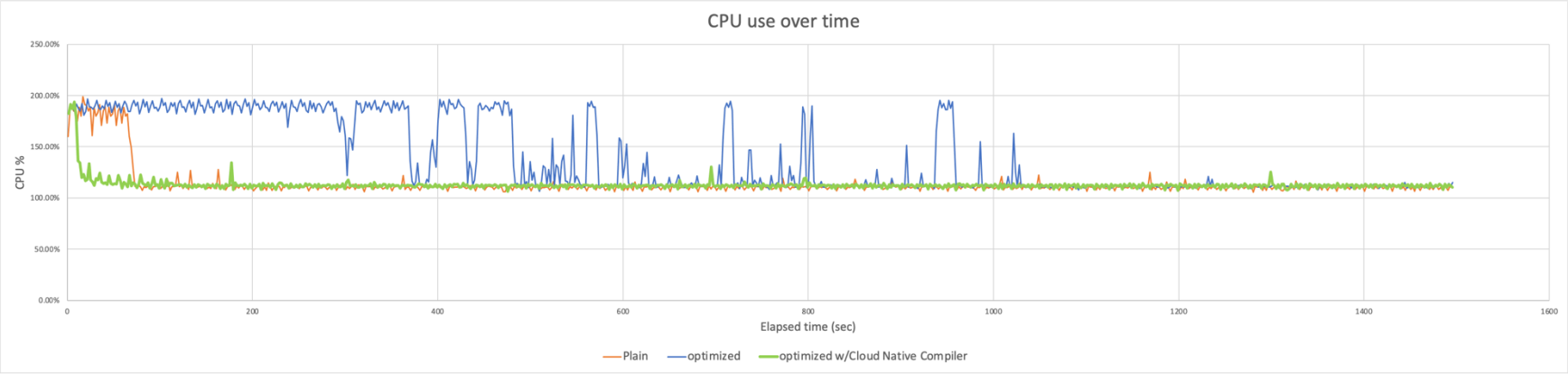

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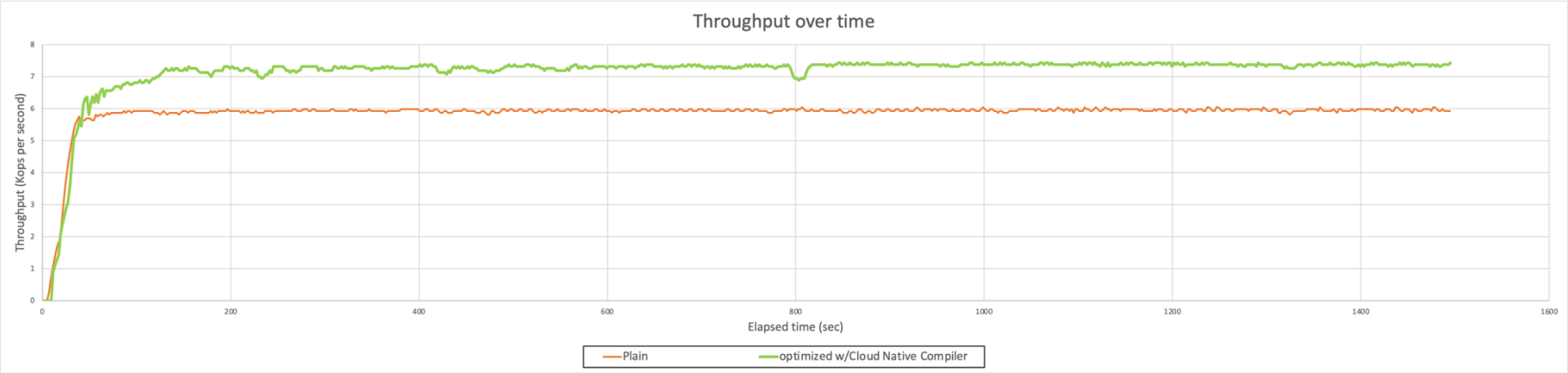

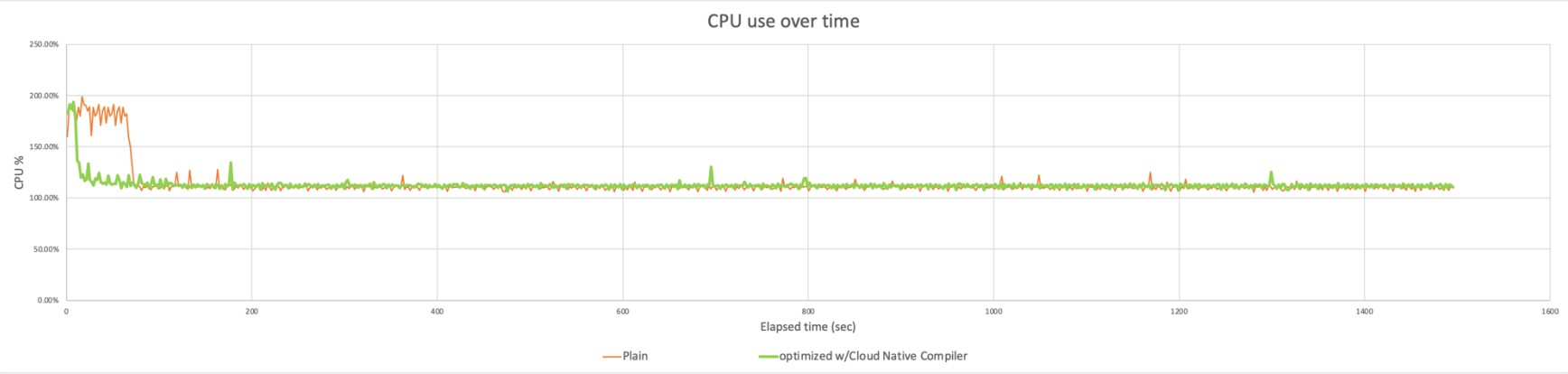

Isn't This Just Shifting The Cost?

- Well, Yes…
- But we are shifting it to a much more efficient place
- When a JVM optimizes locally, it must carry dedicated resources to do so
- When outsourced to a Cloud Native Compiler
  - The resources are shared and reused
  - The resources can be elastic

- Compiled code can be cached
  - The JIT now effectively has a memory across runs

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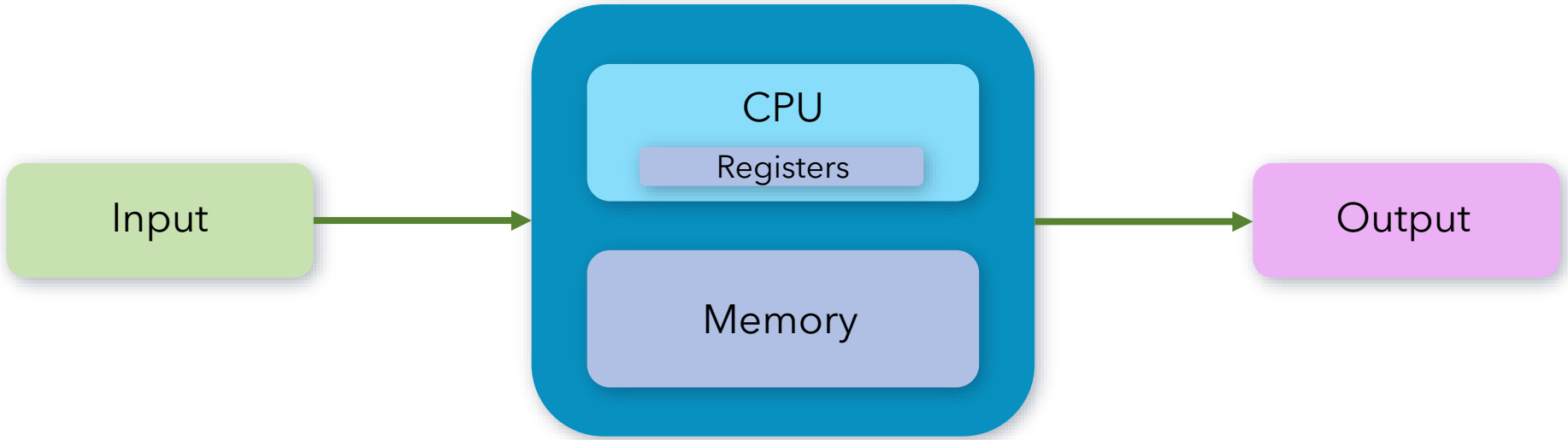
Solution 4:
Save The Whole Application State

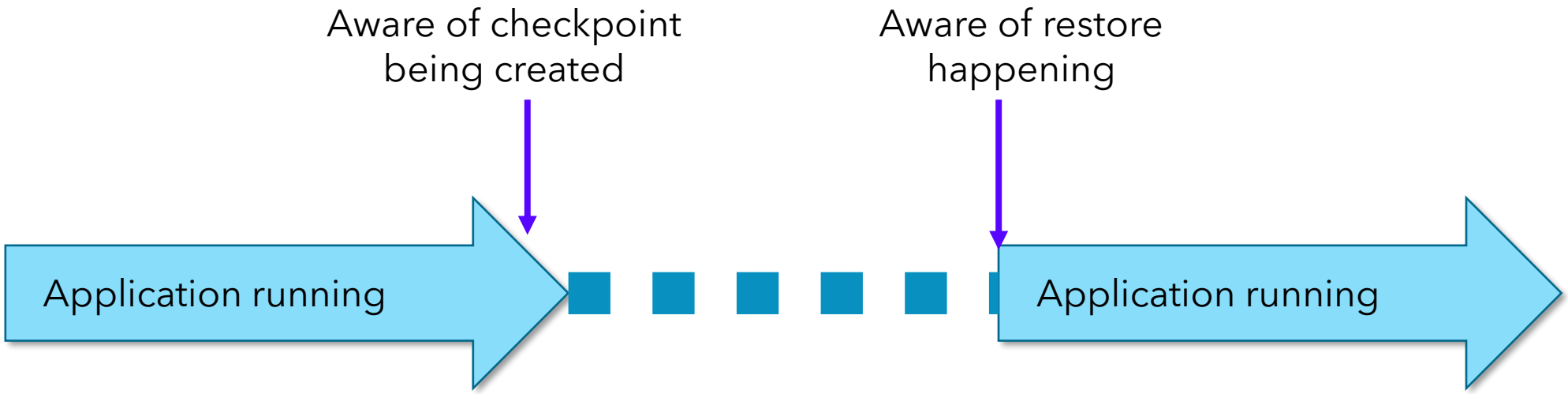
Co-ordinated Resume In Userspace

- Linux project
- Basic idea
  - Freeze a running application
    - Pause program counter
  - Create a snapshot of the applications state (as a set of files)
  - At some later point, use those files to restart the application from the same point
    - Potentially, on a different physical machine



Co-ordinated Restore at Checkpoint (CRaC)

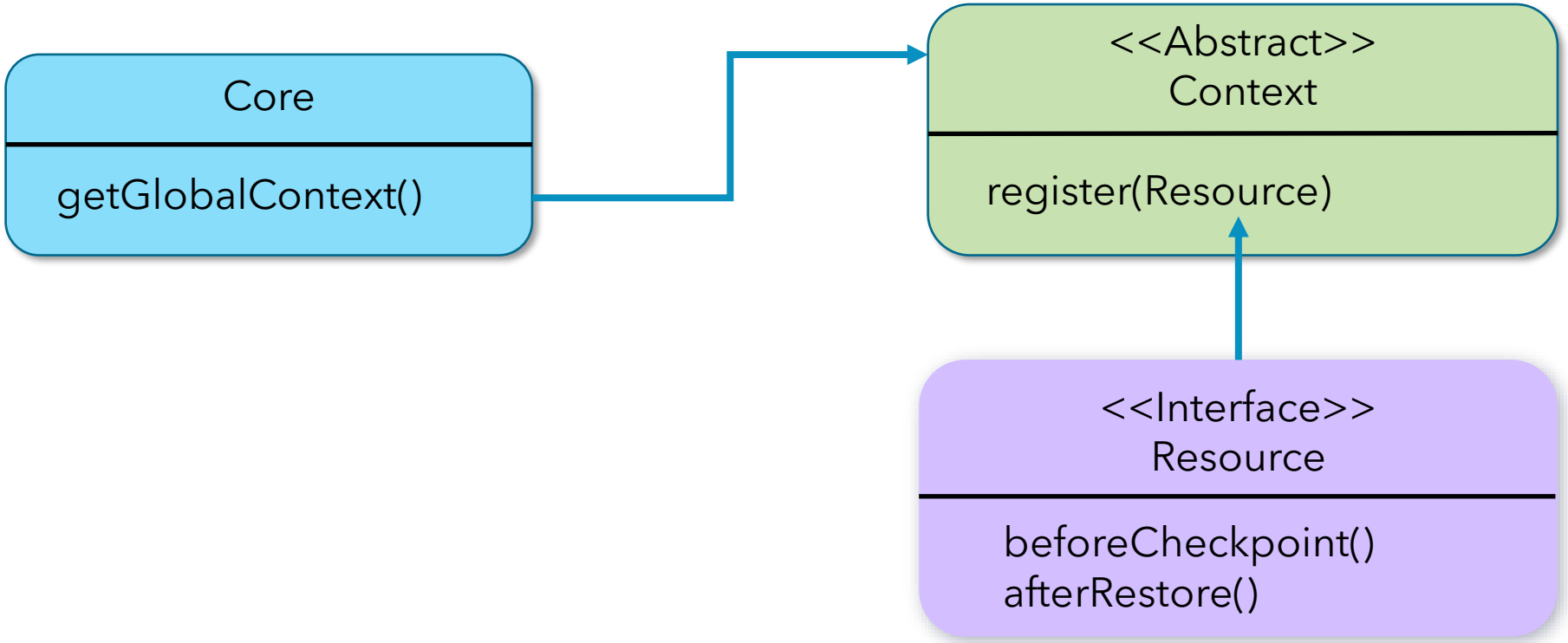
- Let's make the application *aware* it is being checkpointed and restored



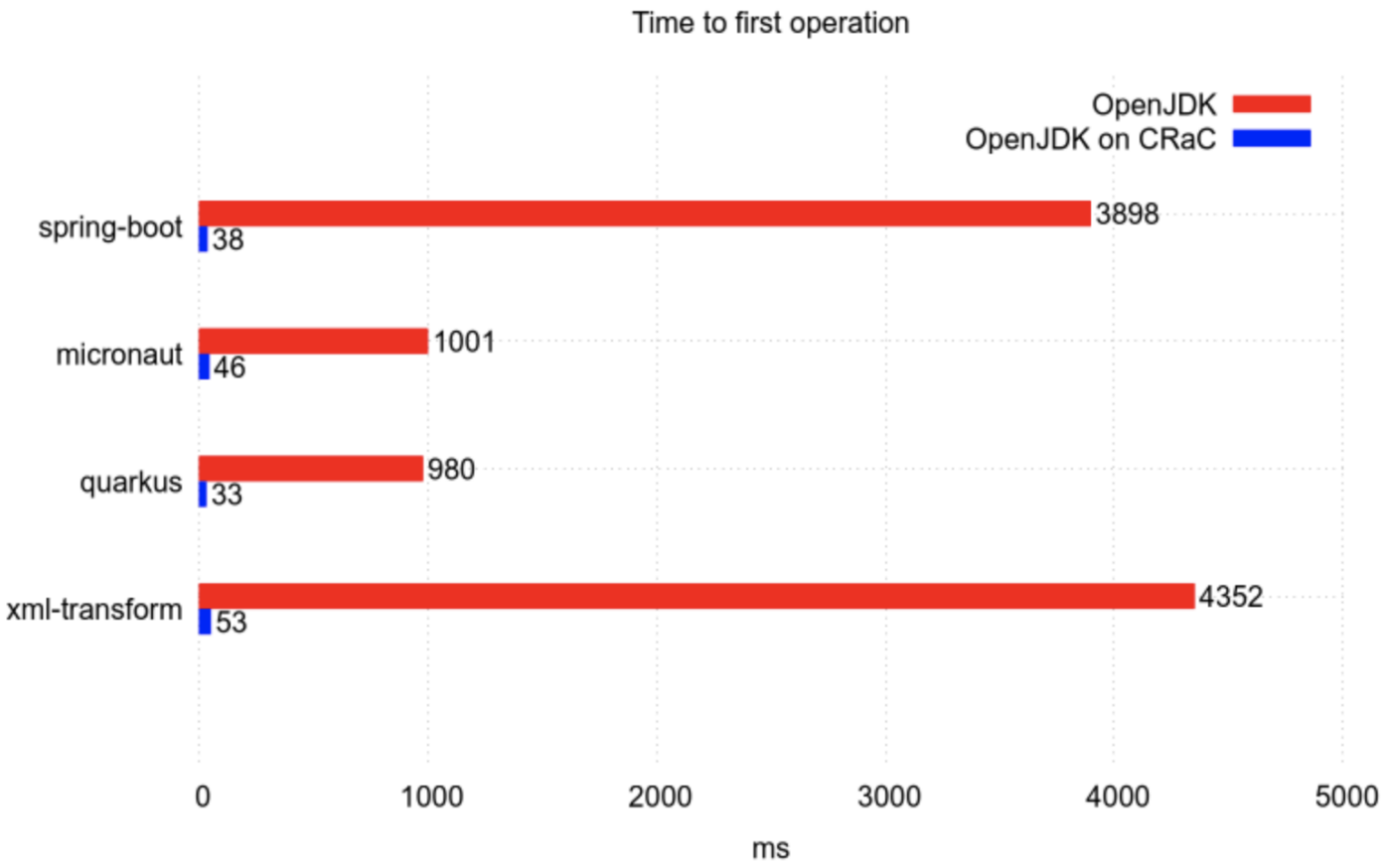
- CRaC also enforces more restrictions on a checkpointed application
  - No open files or sockets
  - Checkpoint will be aborted if any are found

Using CRaC API

- `Resource` objects need to be registered with a `Context` so that they can receive notifications
- There is a global `Context` accessible via the static `getGlobalContext()` method of the `Core` class



Does It Work? POC Results



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Summary

Solving The JVM Warmup Problem

- No one solution will fit all situations
- AOT is good for fast startup/small footprint in ephemeral services
- ReadyNow provides memory of JIT across runs
- Cloud Native Compiler offloads JIT workload
- CRaC restarts an application from a known point
- Project Leyden is looking at approaches that include those above as well as other ideas

Thank You.

Simon Ritter, Deputy CTO

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