Cloud Language Runtimes on IA - Challenges & Opportunities

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Agenda

Cloud Runtime Usage & Introduction

Cloud Runtime Challenges/Problems

Software/Hardware Optimization

Next Steps/Open Problems/Call To Action
Cloud Runtimes

Usage/Introduction
Cloud Runtime: Usages/Language

Multiple Environments
- IaaS->PaaS->FaaS

Languages
- 4 of top 5 are Runtimes
- 3 are dynamically typed.

Usages
- Function As Service
- WebTier
- Analytics

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https://octoverse.github.com/projects#languages
Cloud Runtime: Web Tier Scale Out Usage

- Each server running a Web Server
- Individual server can run at high utilization (> 90%)
- Each server also running Cloud Runtime
- Scale Out
  - Example: Cluster of Dense Computing Platform with Yosemite v2 (Four 1S servers)
- PHP, Python, Node.js …
- Very different from SPEC benchmarks (Large Scattered Code, JITting, Type Checks, …)
Cloud Runtimes

Challenges/Problems
FaaS JavaScript: Challenges

High CPU bottlenecks ~35-45% stalled
- I-Cache Misses
- I-TLB Misses
- Branch Mispredicts

Problem gets worse for bigger function

<table>
<thead>
<tr>
<th>Anagram</th>
<th>Ghost.js</th>
</tr>
</thead>
<tbody>
<tr>
<td>51% retiring</td>
<td>34% retiring</td>
</tr>
<tr>
<td>1.18% I-TLB misses</td>
<td>6% I-TLB Misses</td>
</tr>
<tr>
<td>1.25% I-$ misses</td>
<td>10% I-$ Misses</td>
</tr>
</tbody>
</table>

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**FaaS JavaScript: Characteristis & Challenges**

**Problem gets worse**
- Bigger Functions
- When multiple functions executing concurrently
- Frontend Stalls increase from **33% to 41%**
- Cycles/work much higher

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WebTier: Characteristics & Challenges

Runtime with High CPU bottlenecks

- Front End Bottlenecks: I-Cache Misses, I-TLB Misses
- Interpreters with high Branch Mispredicts
- Accounting for 50% of Stalls

Long Pathlength

- 10s of millions of instructions executed per request

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Cloud Runtimes
Hardware & Software Optimization
Cloud Runtime: Hardware

Hardware Improvements

- 17% Improvement in Retirement
- 2M Code Pages in shared 2\textsuperscript{nd} level structure
- Larger L2 helps with I$ Misses
  - 40% L2 miss reduction
  - 25% Frontend Improvement

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<table>
<thead>
<tr>
<th>Metric</th>
<th>MediaWiki BDX-D</th>
<th>MediaWiki SKX-D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topdown Frontend bound (%)</td>
<td>43</td>
<td>32</td>
</tr>
<tr>
<td>Topdown Retiring (%)</td>
<td>35</td>
<td>41</td>
</tr>
<tr>
<td>metric_L2 misses per txn (includes code+data+rfo w/ prefetches)</td>
<td>1,139,373</td>
<td>674,635</td>
</tr>
<tr>
<td>RPS</td>
<td>1.0</td>
<td>1.40</td>
</tr>
<tr>
<td>Cores</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>Package Power</td>
<td>70W</td>
<td>85W</td>
</tr>
</tbody>
</table>
Cloud Runtime: Software

Reduce I-TLB misses and cycles by using large pages for code

- Remap a subset of .text segment to 2M pages
- Relies on THP through `madvise`
- Reduce 4K walks and Reduce cycles
  - 30% Reduction in 4K Walks

Benefits longer running workloads

- Ghost.js*: 5%, WebTooling: 3%

Using 2M Pages reduces I-TLB misses 20-30% & improves perf 3-5%

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Reduce I-Cache Misses through Code Layout Optimization

- Intel CPUs have a feature called last branch records (LBR) where the CPU can continuously log branches to a set of model-specific registers (MSRs).
- Profile guided reordering of the static code in .text reduces L1-I, L2, LLC Code Misses.
- 5-7% Performance improvement

**Combining Optimization:**

Cloud Runtime: Software

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Cloud Runtimes

Next Steps,
Open Problems
Call to Action
Next Steps

Intel Focus:

- Continue to optimize Cloud Runtimes
- Collaborate to address Runtime Bottlenecks
- Enhance our Products
- Develop runtime performance optimization blueprint(s)

<table>
<thead>
<tr>
<th>Software</th>
<th>Hardware</th>
</tr>
</thead>
<tbody>
<tr>
<td>2M Pages. Code Layout</td>
<td>Xeon Scalable (Skylake &amp; Beyond)</td>
</tr>
</tbody>
</table>
Open Problems

- Address Frontend problems (I$, I-TLB) in JITs
- Better locality of Native & JIT code
- Better use of SIMD & u-architecture
- Sharing dynamic code across JIT instances
- HW/SW Communication
  - SW Controlled Instruction Fetch
  - SW Control for Indirect Branches
Call to Action

- Diagnose uarch bottlenecks
- Apply known solutions
- Collaborate on Open Problems
- Contact me suresh.srinivas@intel.com

African Proverb: If you want to go fast, go alone. If you want to go far, go together.

Collaborate to Solve these Cloud Runtime problems on Intel Architecture

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Q&A

https://youtu.be/a3e3JBRX1FI
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Cloud Runtime: FaaS

Evolution
- IaaS->PaaS->FaaS
- FaaS business model vs. IaaS business model

Pay for Useful Work (Duration of Execution)
- No effort for server management
- Autoscaling & CSP determines platform for execution

Function
- From 5 lines to multiple megabytes
- Triggered from an event source

JavaScript* (with Node.js*) and Python* are leading FaaS languages

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JavaScript* on Server

- Node.js* is a JavaScript Server runtime built on top of the Chrome* v8 JavaScript engine
- FaaS Function built with Function APIs/Libraries (eg. Alexa-sdk, others)

```javascript
const Alexa = require('alexa-sdk');
const anagrams = require('./anagrams');
var handlers = {
  getAnagrams: function() {... }, ...
};

export.handler = function (event, c, l) {
  var alexa = Alexa.handler(event, c, l);
  alexa.registerHandlers(handlers);
  alexa.execute();
}
```

Node.js* Stack

- Function API's/Libraries (eg alexa-sdk, …)
- Node.js APIs
- Node.js Bindings
- C/C++ AddOns
- V8 JavaScript Engine
- libuv

FaaS Alexa* Anagram Skill
https://github.com/evanchiu/alexa-anagram

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Common Runtime Challenges

- **Runtimes need high performance primitives**
  - Memory & String Operations (memcpy, memchr, …)
  - Compression
  - IA Encoder/Decoder
  - Several rely on system (glibc: In 2019 people are still using glibc 2.17 from 2014)
- **Runtimes need tooling and common infrastructure**
  - LBR Samples decorated to IR
  - Processor-Trace -> JIT
- **Runtimes Libraries don’t expose optimized native**
  - JavaScript/PHP dont expose IA optimized libs