Dynamic Analysis of Application Delivery Network for Leveraging Software Defined Infrastructures

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These slides and a video recording of this presentation are at: 
http://www.cse.wustl.edu/~jain/talks/profile.htm
Overview

1. OpenADN Architecture
2. Need For Profiling OpenADN
3. Profiling Led Optimization of Multi-Cloud Platforms
4. OpenADN Profiling
Multi-Cloud Application Delivery

**New Business Opportunities**: Datacenters on Towers, Internet of Things

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Services in a Cloud of Clouds

OpenADN Platform

OpenADN Resource Driver (OpenStack)  OpenADN Resource Driver (OpenDayLight)  OpenADN Resource Driver (EC2)

Virtual Hosts  Virtual Storage  Virtual Network

Virtual WAN Services

OpenStack  OpenDayLight  EC2

Northbound Interface

Resource Providers

Application Deployment Administrators

Application Architects

Application Service Developers

Services in a Cloud of Clouds
Key aspects of OpenADN Architecture

- Hybrid control – global and local controllers
- Centralized management, distributed data plane
- Application and Network layer services
Need for profiling OpenADN

- OpenADN and other similar platforms tend to be massively distributed and complex software.

- Use of multithreading for concurrent execution makes code difficult to optimize. Simple code reading fails to find potential bottlenecks.

- Profiling isolates hotspots, that consume disproportionate resources, and aids optimization.
Profiling Led Optimization

a) Non-Profiling Based Optimization

Optimization based on intuition, guesswork, reading of code → Sub-optimal code

b) Profiling Based Optimization

Source → Event timing, code instrumentation → Optimization → Optimal Code

Original code → Profiling → Optimization → Resulting code
Profiling Techniques

- **Profiling**: Analyzing program behavior and gathering data to analyze performance of a platform

- **Static**: Analysis of code by reading or model checking

- **Dynamic**:
  - Deterministic: Instrumented code
  - Statistical: Sampling process states
Static Profiling

- **Manual**: Passive checking of control flows and execution states
  - Source Code → Dry run/Reading → Analysis → Results

- **Automatic**: Make model to exhaustively explore inter-leavings
  - Source Code → Scanning/conversion → Intermediate Representation → Analysis → Results

- Computationally expensive for numerous inter-leavings
- Does not give program behavior under execution
- Only gives relative execution times

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Dynamic Profiling

- The system generates information about its execution parameters while it executes. Primarily two ways to do it.
- **Statistical**: sampling of process states – relative
- **Deterministic**: *absolute and precise* measure of events function calls or more fine-grained flow transitions.

- Deterministic profiling has been carried out for OpenADN
Virtual Environment for OpenADN Profiling

- Virtual clouds created:
  - One global controller
  - Two local controllers
  - One name server
  - Hosts – 7 per datacenter
  - Client host – 10000 users

- Levels of profiling
Platform-Level Profiling

Assessment of user CPU time, System CPU time and real time

<table>
<thead>
<tr>
<th>Runs</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
<th>V</th>
<th>Averages</th>
<th>% Run time</th>
</tr>
</thead>
<tbody>
<tr>
<td>User Space</td>
<td>0.53</td>
<td>0.55</td>
<td>0.62</td>
<td>0.6</td>
<td>0.61</td>
<td>0.58</td>
<td>1.65</td>
</tr>
<tr>
<td>System Calls</td>
<td>0.76</td>
<td>0.75</td>
<td>0.65</td>
<td>0.67</td>
<td>0.68</td>
<td>0.7</td>
<td>1.99</td>
</tr>
<tr>
<td>User+System</td>
<td>1.29</td>
<td>1.3</td>
<td>1.27</td>
<td>1.27</td>
<td>1.29</td>
<td>1.28</td>
<td>3.64</td>
</tr>
<tr>
<td>Run time</td>
<td>35.82</td>
<td>35.6</td>
<td>34.65</td>
<td>34.8</td>
<td>35.06</td>
<td>35.19</td>
<td></td>
</tr>
</tbody>
</table>

Comparison of run time and user/kernel time

Time in seconds

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Platform-Level Profiling

Advantages:
- Provides CPU time spent in user and system software.
- It gives total run time which tells us how effectively platform is using computing resources.
- It indicates the possibility of higher load on the CPU because of potentially wasteful activities.

Shortcoming:
- If run time is much higher than the total time for user and system calls, it does not tell what is taking this time.
Function Level Profiling

Gives cumulative execution time of various user, system & library functions (including sub-function calls)

Extract of a function level profile run
Analysis of Function Level Profile

Advantages:

- The function level profiling gives cumulative times in the functions of OpenADN modules like GC, LC, hosts etc.
- It confirmed that certain functions like polling (φMQ library function) and Python sleep functions take unduly long part of the run time.

Shortcomings:

- Does not tell which modules to look into to locate problems?
- Does not give fine-grain profiling down to the statements level. So statements causing problems cannot be pin-pointed.
Statement-Level Profiling

- It introduces special code or hooks (e.g. in Python) to record the execution time for each statement.

<table>
<thead>
<tr>
<th>Line #</th>
<th>Hits</th>
<th>Time</th>
<th>Per Hit</th>
<th>%Time</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>273</td>
<td>1</td>
<td>24689</td>
<td>24689.0</td>
<td>0.0</td>
<td>simNetwork.start_client_host()</td>
</tr>
<tr>
<td>274</td>
<td>1</td>
<td>1499</td>
<td>1499.0</td>
<td>0.0</td>
<td>print (&quot;---------------\n&quot;)</td>
</tr>
<tr>
<td>275</td>
<td>1</td>
<td>1301</td>
<td>1301.0</td>
<td>0.0</td>
<td>print (&quot;checkpoint 5...after client host&quot;)</td>
</tr>
<tr>
<td>276</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>#start the monitoring</td>
</tr>
<tr>
<td>277</td>
<td>1</td>
<td>17</td>
<td>17.0</td>
<td>0.0</td>
<td>endTime = time() + _runTime</td>
</tr>
<tr>
<td>278</td>
<td>102526</td>
<td>481979</td>
<td>4.7</td>
<td>0.2</td>
<td>while time() &lt; endTime:</td>
</tr>
<tr>
<td>279</td>
<td>102526</td>
<td>208269149</td>
<td>2031.4</td>
<td>87.2</td>
<td>readable = poller.poll(1)</td>
</tr>
<tr>
<td>280</td>
<td>102810</td>
<td>495496</td>
<td>4.8</td>
<td>0.2</td>
<td>for fd, _mask in readable:</td>
</tr>
<tr>
<td>281</td>
<td>285</td>
<td>1032</td>
<td>3.6</td>
<td>0.0</td>
<td>node = Node.outToNode[ fd ]</td>
</tr>
<tr>
<td>282</td>
<td>285</td>
<td>11422</td>
<td>40.1</td>
<td>0.0</td>
<td>outString = node.monitor().strip()</td>
</tr>
</tbody>
</table>

Time in seconds

A sample clip of Statement-level profiling
Statement-Level Profiling (Cont)

- Shows that sleep and polling functions dominate execution times.
- Some modules like Global Controller and Name server are inactive most of the time (so they can share resources!)
- Checking ports for inter-process messages (polling) takes up 87.2% of the entire simulation time
- Optimization of the code may lead to reduced virtual resource demand and operational expense.
Observations

Top-Level Profiling

A large component of non-user, non-kernel time that could be explained by I/O waits. Some part of this time could be spent unproductively using up resources and contributing to energy consumption.

Function level Profiling

Functions that have potential hot spots.

Statement-Level Profiling

On complete platform allows interplay of threads and reveals the parts of the functions that could be helped with optimization efforts.
Summary

1. OpenADN is a platform for managing and controlling resources across multiple clouds.

2. Profiling is useful for optimization as follows:
   
a. Critically examine the time spent in I/O waits and take remedial measures wherever possible

b. Examine the use of sleep statements and fine-tune their durations

c. Examine the use of heartbeat and ways to make it efficient

d. Optimize the time taken to dynamically create and destroy virtual resources
Conclusions
Summary

1. OpenADN is a platform for managing and controlling resources across multiple clouds.

2. Multi-cloud management systems need to have their performance optimized.

3. Hotspots lead to increased resource requirement and higher operational expenses.

4. Increasingly fine grained profiling of platform behavior provides useful data for optimization.