Bayllocator: A proactive system to predict server utilization and dynamically allocate memory resources using Bayesian networks and ballooning

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Motivation

- Consolidation of virtual machines is the norm
- Most systems are idle most of the time, so we can overcommit resources
- However, when they need to do their job, they need their resources
  - ... and could benefit if others don’t need theirs
- Reactive resource allocation may not be fast enough
  - The allocation mechanism is sometimes slow in itself
Problem statement and approach

To get a flexible approach on improving utilization efficiency of hardware resources in a single hypervisor running virtual machines

Approach:

* A proactive system to predict server load using Bayesian networks, and dynamically allocate resources on virtual machines running on a single hypervisor to provide more efficient utilization of the physical hardware

* Currently only focused on dynamic memory allocation using ballooning
Ballooning

- A kernel module is loaded into the kernel of the VM
- It can be controlled from the hypervisor to allocate or release memory
- The VM will therefore believe to have the same amount of memory, but have some of it locked
Bayllocator will ... 

- Assume an over-provisioned environment
- Make a prediction of how much memory each VM needs + a defined percentage
- Ensure that a VM’s min/max values are not violated
- Avoid Hypervisor swapping
- Distribute excessive memory fairly to all VMs
- Claim memory fairly
Prediction Algorithm

• Memory consumption is divided into categories
  
  • Each category spans 100MB, e.g. 400_500MB

• Given the input of: VM, weekday, time interval and current consumption, a probability is calculated for all categories

• Each probability is multiplied with a number representing the category

• In our case: 400_500MB -> 450MB * P(400_500MB)
Simple example

1. Calculate new probabilities using Bayesian network
$ QueryNet .R TestServer1.dat FMU \>
> Monday h07 m55_59 mem_100_200

mem_100_200, 0.148  
mem_200_300, 0.306  
mem_300_400, 0.492  
mem_400_500, 0.054

2. Use probabilities to calculate memory demand
  150 · 0.148 = 22.2  
  250 · 0.306 = 76.5  
  350 · 0.492 = 172.2  
  450 · 0.054 = 24.3  
  22.2 + 76.5 + 172.2 + 24.3 = 295.2 MB
The redistribution of wealth

- There may not be enough memory to meet all the predicted allocations

- *Fair* - Large VM’s will need more memory, but should be expected to share more too

- In practice, use a percentage rather than memory values when awarding / claiming memory
Experimental setup

- Both generated data and replays of real data
- Single KVM hypervisor with several VM’s
- Special script mimicked workloads inside the VM
- Collected usage data into a DB and wrote a prototype using R and Perl
Results - Simulated data

Performance on Server 1
(Apache PHP Script Execution)

Seconds to Complete Job

<table>
<thead>
<tr>
<th>Friday 00:00:00</th>
<th>Monday 00:00:00</th>
<th>Thursday 00:00:00</th>
<th>Sunday 00:00:00</th>
<th>Wednesday 00:00:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ballooning Disabled</td>
<td>Ballooning Enabled</td>
<td>Ballooning Disabled</td>
<td>Ballooning Enabled</td>
<td>Ballooning Disabled</td>
</tr>
</tbody>
</table>
Results - Real-life replay

Predictions start

Predictions start
Results - Learning periods and accuracy

- The more observed data, the better the accuracy of the predictions
- A fundamental difficulty with using historical data is that you need historical data
  - High-quality historical data is hard to come by
  - Often times underlying trends or gaps pollute the data
Discussion

• A virtual machine will never get less memory than has ever been observed on it*

• “Why not choose the category with the highest probability, instead of calculating the sum?”

• “What is the training time?”

• “Why use only temporal parameters?”

• “Can I run it and expand on the bayesian network myself?”

• Bayllocator is not about reactive, flashmob-mitigation
Future work

- Weight-lifting for servers: If we knew the signs of a flashmob, we could train the model for it.
- Investigate the outer limits of ballooning under extreme circumstances
- Comparison with memory de-duplication
- Combining Bayllocator with reactive behavior
Thank you!

Questions?