An Energy Aware Framework for Virtual Machine Placement in Cloud Federated Data Centres

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FIT4Green seeks energy saving policies for DCs, enhancing the effects inside a federation by an aggressive strategy for reducing the energy consumption in ICT.

- We aim at reducing cost for companies → Strengthening competitive position.
- FIT4Green needs to be DC framework agnostic:
  - Demonstrated in Cloud computing, Traditional computing, Super computing and Networking.
Introduction
Requirements
Framework design
SLA Constraints
Power Objective Model
Heuristics
Experiments on Cloud Test-bed
Scalability Evaluation
Conclusion & Future work
The strategies are ranked through their Energy KPIs.

Introduction

The policies seek to:

Consolidate application/services and turn unused servers off.

★ ★ ★ ★ ★

Relocate application/services to efficient servers

★ ★

The strategies are ranked through their Energy KPIs.
Single allocation

Find the most energy efficient and suitable resource for a new **Workload**.

Global optimization

**Rearrange the resources** in a way that saves maximum amount of energy or carbon emission.
- Flexibility, extensibility
- Deep exploration of the search space

Abstracting out the constraints
SLA constraints flow

Data Centre Operator and CPT

Automatic

Service Level Agreements

Technical SLA

SLA Constraints

CP Engine
## SLA constraints examples

<table>
<thead>
<tr>
<th>Category</th>
<th>Constraint</th>
<th>Approach</th>
<th>LoC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardware</td>
<td>HDD</td>
<td>Choco + ext. Entropy</td>
<td>121+(25)</td>
</tr>
<tr>
<td></td>
<td>CPU Cores</td>
<td>Entropy (‘fence’)</td>
<td>0+(25)</td>
</tr>
<tr>
<td></td>
<td>CPUFreq</td>
<td>Entropy (‘fence’)</td>
<td>0+(25)</td>
</tr>
<tr>
<td></td>
<td>RAM</td>
<td>Choco + ext. Entropy</td>
<td>123+(25)</td>
</tr>
<tr>
<td></td>
<td>GPU Cores</td>
<td>Entropy (‘fence’)</td>
<td>0+(25)</td>
</tr>
<tr>
<td></td>
<td>GPUFreq</td>
<td>Entropy (‘fence’)</td>
<td>0+(47)</td>
</tr>
<tr>
<td></td>
<td>RAID Level</td>
<td>Entropy (‘fence’)</td>
<td>0+(47)</td>
</tr>
<tr>
<td>QoS</td>
<td>Max CPU Load</td>
<td>Choco + ext. Entropy</td>
<td>90+(25)</td>
</tr>
<tr>
<td></td>
<td>Max V Load Per Core</td>
<td>Choco + ext. Entropy</td>
<td>109+(25)</td>
</tr>
<tr>
<td></td>
<td>Max V CPU Per Core</td>
<td>Choco + ext. Entropy</td>
<td>124+(25)</td>
</tr>
<tr>
<td></td>
<td>Bandwidth</td>
<td>Entropy (‘fence’)</td>
<td>0+(49)</td>
</tr>
<tr>
<td></td>
<td>Max VM Per Server</td>
<td>Entropy (‘capacity’)</td>
<td>0+(25)</td>
</tr>
<tr>
<td>Availability</td>
<td>Planned Outages</td>
<td>Choco + ext. Entropy</td>
<td>Future Work</td>
</tr>
<tr>
<td></td>
<td>Availability</td>
<td>Choco + ext. Entropy</td>
<td>Future Work</td>
</tr>
<tr>
<td>Additional Metrics</td>
<td>Dedicated Server</td>
<td>Entropy (‘capacity’)</td>
<td>0 + (25)</td>
</tr>
<tr>
<td></td>
<td>Access</td>
<td>Entropy (‘fence’)</td>
<td>0 + (25)</td>
</tr>
</tbody>
</table>
POWER OBJECTIVE MODEL

Total Reconf. Energy

- Total Instant. Power
  - Power Servers Idle
  - Power VMs
  - Power Network

- Energy Migrations
- Energy On/Off

Reconf Time

Power Calculator
HEURISTICS

Root node: no VM is allocated

First level node: VM1 allocated on S1
First level node: VM2 allocated on S1
First level node: VMx allocated on Sy

Leaf node: all VMs are allocated

At each level: call F4G branching heuristic. If a constraint is broken, backtrack to go up.

At leaf level: note down the solution and the energy saved, then backtrack to find a better solution.
Composable heuristics

- Candidate VM for migration
- Target server for migration
- Candidate Server for extinction

Call the F4G VM selector

Select VM on the least energy efficient server and least loaded server

VM selected

Call the F4G Server selector

Select Server which is the most energy efficient server and most loaded server

Server selected

Call the F4G Server selector

Select Server which is empty and the least energy efficient server

Server selected
Heuritics

To sum up...

Start

Heuristic

A solution is found in search space:

CP Engine

Several solutions are founded starting from the first one:

Re-ranking

The best solution is found:

End
Lab trial resources

- **DC1**: 4 BL 460c blades using VMWare ESX v4.0 native hypervisor, 3 blades for Cluster and Cloud Control
- **DC2**: 3 BL460c blades using VMWare ESX v4.0 native hypervisor, 2 blades for Cluster Control and Power and Monitoring System.

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<table>
<thead>
<tr>
<th></th>
<th>Enclosure 1</th>
<th>Enclosure 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processor model</td>
<td>Intel Xeon E5520</td>
<td>Intel Xeon E5540</td>
</tr>
<tr>
<td>CPU frequency</td>
<td>2.27GHz</td>
<td>2.53GHz</td>
</tr>
<tr>
<td>Cpu &amp; Cores</td>
<td>Dual cpu – Quad core</td>
<td>Dual cpu – Quad core</td>
</tr>
<tr>
<td>RAM</td>
<td>24 GB</td>
<td>24GB</td>
</tr>
</tbody>
</table>
Lab trial Workload

Active SLAs constraints:
- Max vCPU per core = 2
- Min VM Slot = 3
- Max VM Slot = 6
Final test results for the various configurations

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Data Centre 1</th>
<th>Data Centre 2</th>
<th>Energy for Federation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without FIT4Green</td>
<td>6350 Wh</td>
<td>4701 Wh</td>
<td>11051 Wh</td>
</tr>
<tr>
<td>With FIT4Green</td>
<td>5190 Wh</td>
<td>4009 Wh</td>
<td>9199 Wh</td>
</tr>
<tr>
<td>Static Allocation</td>
<td>Saving 16.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With FIT4Green</td>
<td>5068 Wh</td>
<td>3933 Wh</td>
<td>9001 Wh</td>
</tr>
<tr>
<td>Dynamic Allocation</td>
<td>Saving 18.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With FIT4Green</td>
<td>4860 Wh</td>
<td>3785 Wh</td>
<td>8645 Wh</td>
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<tr>
<td>Optimized Policies</td>
<td>Saving 21.7%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#</td>
<td>Configuration</td>
<td>Placement constraints activated</td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>--------------------------------------</td>
<td>---------------------------------</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1 datacenter</td>
<td>none</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1 datacenter with overbooking factor=2</td>
<td>“MaxVCPUPerCore” constraint set on each server</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2 federated datacenters</td>
<td>“Fence” constraint set on each VM</td>
<td></td>
</tr>
</tbody>
</table>
Energy aware resource allocation in datacenters
Flexibility & extensibility
Saves up to 18% in HP experiment
Scalability with parallel processing

Future work:
SLA re-negotiation
Green SLAs
Thanks for your attention

Any Question?