HY559
Infrastructure Technologies for Large-Scale Service-Oriented Systems

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Cloud brokering

• Scheduling of resources across multi-clouds
  – Price
  – Performance
  – Constraints: configuration, load balancing, etc.

• Uniform management interfaces across clouds
  – OCCI
  – Amazon
  – jClouds, libcloud, deltacloud, etc.
Cloud brokering mechanisms
Cloud scheduling algorithms

- \( n \) VMs \( v_1, \ldots, v_n \)
- \( m \) Clouds \( c_1, \ldots, c_m \)
- \( l \) VM types \( IT_1, \ldots, IT_l \); performance of \( IT_j \): \( C_j \)
- Hourly price of a VM: \( P_{jk} \)
- Objective functions:

\[
\text{Maximize } TIC = \sum_{i=1}^{l} C_j \left( \sum_{i=1}^{n} \sum_{k=1}^{m} x_{ijk} \right)
\]

Up to maximum \( TIP = \sum_{j=1}^{l} \sum_{k=1}^{m} P_{jk} \left( \sum_{i=1}^{n} x_{ijk} \right) \)
Constraints

- VM hardware configuration constraints
  \[ x_{i1k} = 0, \ldots, x_{i\text{min}_{ik}} = 0 \]
  \[ x_{i\text{max}_{ik}} = 0, \ldots, x_{ilk} = 0 \]

- Maximum number of VMs of certain type
  \[ IT \min_j \leq \sum_{i=1}^{n} \sum_{k=1}^{m} x_{ijk} \leq IT \max_j \]

- Load balancing constraints
  \[ LOC_{\text{min}} \leq (\sum_{i=1}^{n} \sum_{j=1}^{l} x_{ijk}) / n \leq LOC_{\text{max}}, \quad 1 \leq k \leq m \]

- Each VM can be of one type and placed in one Cloud

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Tools and complexity

• Modeling language
  – AMPL

• Solver
  – CPLEX (0-1 integer programming)

• Version of Generalized Assignment Problem (GAP)
  – NP-hard
  – Load-balancing constraints drastically reduce solution space
  – Approximations can be used to further speed up solutions
Experimental environment

User job requests → SGE Master

Local infrastructure

OpenVPN tunnels

Cloud

small  xlarge

EC2-US

large  large  large

EC2-EU

small  medium

EH
# Experimental environment (2)

## Hardware metrics and prices for instance types.

<table>
<thead>
<tr>
<th>Instance type</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
<th>xlarge</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU (# cores)</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>CPU (Ghz/core)</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Memory (GB)</td>
<td>1.7</td>
<td>3.5</td>
<td>7.5</td>
<td>15</td>
</tr>
<tr>
<td>Disk (GB)</td>
<td>160</td>
<td>300</td>
<td>850</td>
<td>1700</td>
</tr>
<tr>
<td>Computing capacity</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Provider instance type type prices ($/h)</th>
<th>EC2-US</th>
<th>N/A</th>
<th>EC2-EU</th>
<th>N/A</th>
<th>EH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.1</td>
<td>0.11</td>
<td>0.44</td>
<td>0.88</td>
<td>0.71</td>
</tr>
</tbody>
</table>
Benchmarking results of NGB ED size B for each instance type and cloud.

<table>
<thead>
<tr>
<th>Instance type</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
<th>xlarge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average benchmark execution time (s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC2-US</td>
<td>980 ± 71</td>
<td>N/A</td>
<td>616 ± 61</td>
<td>697 ± 13</td>
</tr>
<tr>
<td>EC2-EU</td>
<td>961 ± 12</td>
<td>N/A</td>
<td>513 ± 9</td>
<td>689 ± 13</td>
</tr>
<tr>
<td>EH</td>
<td>697 ± 5</td>
<td>694 ± 9</td>
<td>611 ± 18</td>
<td>N/A</td>
</tr>
<tr>
<td>Throughput normalized against EC2-US small</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC2-US</td>
<td>1</td>
<td>N/A</td>
<td>3.2</td>
<td>5.6</td>
</tr>
<tr>
<td>EC2-EU</td>
<td>1.01</td>
<td>N/A</td>
<td>3.81</td>
<td>5.67</td>
</tr>
<tr>
<td>EH</td>
<td>1.4</td>
<td>1.4</td>
<td>3.2</td>
<td>N/A</td>
</tr>
<tr>
<td>Hourly price normalized against throughput</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EC2-US</td>
<td>0.1</td>
<td>N/A</td>
<td>0.125</td>
<td>0.143</td>
</tr>
<tr>
<td>EC2-EU</td>
<td>0.109</td>
<td>N/A</td>
<td>0.115</td>
<td>0.155</td>
</tr>
<tr>
<td>EH</td>
<td>0.113</td>
<td>0.223</td>
<td>0.222</td>
<td>N/A</td>
</tr>
</tbody>
</table>
Evaluation

• Study TIC (total infrastructure capacity) vs.
  – TIP (total infrastructure price) for various constraints
  – Various degrees of load balancing

• Solve for 16 VMs using both
  – Compute unit metric stated by Cloud providers
  – Measured benchmark performance
  – Maximum TIP constraint varies from $1.6 to $14.6
  – $1.6 (cheapest) corresponds to 16 m1.small VMs in EC2-US
  – $14.6 (most expensive) allows any placement

• Study three load balancing scenarios
  – Minimum % of VMs to be placed in each Cloud, 0%, 10%, 20% (dispersion)
Price/performance results for various load balancing and budget constraints
Optimal allocation of VMs
Load balancing min 0% per Cloud

Number of instances

Price ($/h)

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Optimal allocation of VMs
Load balancing min 10% per Cloud

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Optimal allocation of VMs
Load balancing min 20% per Cloud
Pricing schemes

• Metering (hardware metrics billing is based on)
  – Amazon offers fixed size VMs with predefined prices
  – ElasticHosts allows users to customize hardware settings and adjusts price accordingly
  – GoGrid [43], memory & network transfers and storage are main billing metrics

• Billing interval
  – Amazon offers hourly (pay-per-use) prices
    • Discounts for one and three year subscriptions
    • Spot prices
  – ElasticHosts uses hourly rates, but offers discounts to users who sign up for at least a month at a time (need funds for min 2 weeks of continuous use).
  – GoGrid also offers discounts in a prepaid scheme with monthly or longer charges. Selection of suitable subscription period is a non-trivial task

• Significant decrease in the hourly prices of VMs over time