REDUCING GRID ENERGY CONSUMPTION THROUGH CHOICE OF RESOURCE ALLOCATION METHOD

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INTRODUCTION

- Introduction
- Background
- Resource allocation
- What we are doing
- Description
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- Analysis
- Concluding remarks
- Future work
INTRODUCTION

This research looks at:

- The use of simple auctions
- Allocating resources in grids and clusters
- Pilot environment
- Scale up to a Grid Environment
BACKGROUND

- Energy saving in Grid computing
  - Uncoordinated methods
    - Voltage and frequency scaling (VFS)
    - Dynamic voltage and frequency scaling (DVFS)
    - Dynamic power management (DPM)
  - Coordinated methods
    - Unbalancing
    - Coordinated VFS
    - Variable on / Variable off (VOVO)
BACKGROUND – RESOURCE ALLOCATION

- There has been substantial recent work on conserving energy in grid computing through resource allocation including:
  - Heterogeneous nature of geographically dispersed data centers (Patel et al.; Shah and Krishnan)
  - Game theoretical approach to power-aware resource packing (Zomaya et al.)
BACKGROUND – AUCTIONS

- Historically auctions have been used to allocate resources
- There are many auctions in use today including
  - English auction (First price ascending)
  - Dutch auction (First price descending)
  - Continuous double auction
  - Vickrey auction (Second price, sealed bid)
GRID RESOURCE ALLOCATION

- What do we mean by Grid?
  - Multi-institutional
  - Cluster of clusters

- What type of application?
  - Computationally intensive / low data
  - Prime number search
WHAT WE ARE DOING

- Using conventional economic resource allocation mechanisms (auctions) to reduce energy consumption.
- Different auctions have different attributes relating to speed and efficiency of allocation.
- We are looking at the efficiency of the allocations in relation to the conservation of grid energy over a variety of workflows.
DESCRIPTION OF RESOURCE ALLOCATION MECHANISMS

- Batch auction
- Continuous random allocation (CRA)
- Pre processed Batch auction (PPBA)
DESCRIPTION OF RESOURCE ALLOCATION MECHANISMS - BATCH

○ The batch auction
  • Requests to resources that they provide a bid,
  • Waits until resources respond,
  • Sorts the resources based on their bid
  • Assigns incoming tasks to resources

○ Will always allocate to the most efficient available resource

Note: All bids are based on the node’s power/performance ratio.
DESCRIPTION OF RESOURCE ALLOCATION MECHANISMS - CRA

- Allocates to first available node
- Cannot guarantee efficiency
- Will allocate quickly
DESCRIPTION OF RESOURCE ALLOCATION MECHANISMS - PPBA

- Stores history
- Allocates on historical data, then asks.
RESEARCH QUESTION

- Will altering the resource allocation mechanism affect the allocation of resources in a way that alters the total energy used in the execution of tasks?

(In this paper we did not discuss execution time due to space constraints)
EXPERIMENT DESIGN AND APPROACH

• Three (3) workflows
  • First on a pilot environment
  • Then on a small grid

• The workflows consist of known tasks, to ensure repeatability

• Tasks are allocated interactively
LIMITATIONS

We have attempted to limit the impact of external forces on our experiments and as such:

- We have exclusive access to the resources
- The tasks are all homogenous
- The software setup of each node is identical

We also assume:

- Nodes cannot be switched off or to a low power state
- Accounting of energy starts from the submission of the first task to the first node until the completion of the last task.
THE TASK

- A modified prime number search script
- Represents processor intensive but data light tasks
WORKFLOWS

- Workflow 1 consists of 100 small tasks
- Workflow 2, 100 medium tasks
- Workflow 3, 50 large tasks
- In each workflow the tasks are submitted at equal intervals over a period of ten minutes
## PILOT ENVIRONMENT

<table>
<thead>
<tr>
<th>Node</th>
<th>$W_{\text{max}}$</th>
<th>$W_{\text{min}}$</th>
<th>$F_i$</th>
<th>$T_i$</th>
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<td>42</td>
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<td>52.3</td>
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<tr>
<td>4</td>
<td>63</td>
<td>55</td>
<td>286.3</td>
<td>27.6</td>
</tr>
<tr>
<td>5</td>
<td>79</td>
<td>72</td>
<td>318.2</td>
<td>24.8</td>
</tr>
<tr>
<td>6</td>
<td>80</td>
<td>70</td>
<td>317.7</td>
<td>24.2</td>
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GRID ENVIRONMENT

<table>
<thead>
<tr>
<th>Cluster</th>
<th>$W_{max}$</th>
<th>$W_{min}$</th>
<th>$F_i$</th>
<th>$T_i$</th>
<th>nodes</th>
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<td>61</td>
<td>235.3</td>
<td>44.2</td>
<td>16</td>
</tr>
<tr>
<td>B</td>
<td>80</td>
<td>70</td>
<td>317.7</td>
<td>24.2</td>
<td>11</td>
</tr>
<tr>
<td>C</td>
<td>63</td>
<td>55</td>
<td>286.3</td>
<td>27.6</td>
<td>4</td>
</tr>
</tbody>
</table>

Note: the clusters within the grid are of different sizes and vintage.
## RESULTS - PILOT

Note: each test was performed ten (10) times; the values above are means

<table>
<thead>
<tr>
<th>Test</th>
<th>Workflow</th>
<th>Mechanism</th>
<th>Mean energy usage (KJ)</th>
<th>Energy difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 (small)</td>
<td>Batch</td>
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<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1 (small)</td>
<td>CRA</td>
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<td>-2.2</td>
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<tr>
<td>3</td>
<td>1 (small)</td>
<td>PPBA</td>
<td>190</td>
<td>0.2</td>
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<tr>
<td>4</td>
<td>2 (medium)</td>
<td>Batch</td>
<td>364</td>
<td>0</td>
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<tr>
<td>5</td>
<td>2 (medium)</td>
<td>CRA</td>
<td>443</td>
<td>21.8</td>
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<td>PPBA</td>
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<td>1.9</td>
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**RESULTS - GRID**

<table>
<thead>
<tr>
<th>Test</th>
<th>Workflow</th>
<th>Mechanism</th>
<th>Mean energy usage (KJ)</th>
<th>Energy difference</th>
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</thead>
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<tr>
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<td>PPBA</td>
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<tr>
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<td>Batch</td>
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<td>0</td>
</tr>
<tr>
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<td>2 (medium)</td>
<td>CRA</td>
<td>1049</td>
<td>19.6</td>
</tr>
<tr>
<td>6</td>
<td>2 (medium)</td>
<td>PPBA</td>
<td>917</td>
<td>4.6</td>
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<tr>
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<td>3 (large)</td>
<td>Batch</td>
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<td>0</td>
</tr>
<tr>
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<td>3 (large)</td>
<td>CRA</td>
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<tr>
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<td>3 (large)</td>
<td>PPBA</td>
<td>1035</td>
<td>-13.6</td>
</tr>
</tbody>
</table>
ANALYSIS OF RESULTS - PILOT

In workflow one

- There was a significant difference in energy consumption
  - CRA and PPBA
  - CRA and batch
- No significant difference between batch and the PPBA
ANALYSIS OF RESULTS – PILOT

- Workflow one
- Small tasks
- CRA uses the least energy
ANALYSIS OF RESULTS – PILOT

- In workflow two there was a significant difference in the energy used by each pair of mechanisms.
- In workflow three there was significant difference between the CRA and batch mechanisms, and between the CRA and PPBA mechanisms, but not between the batch and PPBA mechanisms.
ANALYSIS OF RESULTS - GRID

- In workflow one there was a significant difference in the energy consumption depending on the resource allocation mechanism chosen.
- The PPBA and batch mechanisms were not significantly different from each other.
- There were significant differences between the CRA and batch mechanisms and between the CRA and PPBA.
ANALYSIS OF RESULTS - GRID

- In workflow two the only significant difference in energy consumption was between the CRA and batch mechanisms.
ANALYSIS OF RESULTS - GRID

- In workflow three the CRA was significantly different from both the batch and the PPBA which were not significantly different from each other.
- However, the energy difference suggests that PPBA might be performing better than batch when processing this workflow, more tests are needed.
ANALYSIS OF RESULTS

- The results of the pilot and grid studies were similar.
- The grid results showed more variance:
  - Greater number of nodes
  - External factors
  - Minor heterogeneity of homogeneous nodes
  - Latency
ANALYSIS OF RESULTS

- Why did the CRA auction outperform the others in workflow one?
  - The tasks finished in a fraction of a second on any node
  - The master node (node of submission)
CONCLUDING REMARKS

- These results reveal that altering the resource allocation mechanism can significantly alter the energy used in the execution of tasks.

- The results show that the differing characteristics of these simple auctions may be useful in the conservation of energy.
FUTURE WORK

- Simulate a number of different auctions
- Under what circumstances one auction perform better than another auction.
ANY QUESTIONS?