Economic regulation for multi tenant infrastructures

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PhD defense
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Outline

Shared computational infrastructures
• Tragedy of the commons
• PlanetLab as case study
• Computational markets
• What is missing?

Main contributions
• Problem
• Approach
• Results
Contributions

Model and analysis of a large scale infrastructure


External regulation entity to improve load balancing


Resource provider as regulator to improve energy efficiency


User self-regulation for energy efficiency and dynamic allocation

Where is the problem?
The “Tragedy of the Commons”

The benefits of exploitation of a finite resource are perceived by individuals while the costs are shared by the group.
Shared computational infrastructures
Case study: Planetlab

Consumption vs Contribution

Cumulative Load of nodes

* Data from Codeen Host Status 03-08-2008
Computational markets as a solution

State of the art
Computational Markets

Users
Applications

Selfish utility optimizing

Computational
Economy

Market equilibrium
Match demand and supply

Resource
Providers

Selfish profit optimizing
Computational markets as a solution

Good at matching demand and supply

Effectively summarize information through prices

User-oriented priorities when demand exceeds supply
Gaps on current research

Mainly focused on utility optimization
- User efficiency
- Profit optimizing

Lack of control over externalities
- Multiple system-wide objectives

What about …
- Load balancing
- Energy-efficiency
Problem statement

How to incorporate multiple system-wide objectives into computational markets?
How do we approach the problem?

Contributions
External entity

Regulation

User self-regulation

Resource provider

[P2] [Ch 6]
Problem
Overexploitation of resources

Overloaded
High dispersion

Load
Mar-28 Apr-04 Apr-11 Apr-18

Relative frequency of nodes

PlanetLab - overload
PlanetLab - idle
Target load $N \sim (\mu, \sigma)$

Overloaded zone
Idle zone

Load Probability $P(L < x)$
Regulative Taxes

Algorithm 6.1 Pricing tax regulation algorithm

Require: $\tau \leftarrow$ target load
Require: $S \leftarrow \{\forall j \in R(\text{load}_j, \text{tax}_j)\}$ ▷ Set of resource info

uniformity $\leftarrow \frac{\min \text{load}_j}{\max \text{load}_j}$

$\beta \leftarrow 1.0 - \text{uniformity}$

for all $(\text{load}_j, \text{tax}_j) \in S$ do

$\Delta_{\text{tax},j} \leftarrow \left(\frac{\text{load}_j}{\tau} - 1\right) \times \beta$

$\text{tax}_j^{t+1} \leftarrow \text{tax}_j^t + \Delta_{\text{tax},j}$

end for
## Regulative Taxes

<table>
<thead>
<tr>
<th>Tax</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>0</td>
<td>16</td>
</tr>
<tr>
<td>0</td>
<td>6</td>
</tr>
</tbody>
</table>

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Regulative Taxes

<table>
<thead>
<tr>
<th>Tax</th>
<th>0 +4+2</th>
<th>0 +2+0</th>
<th>0 -2-1</th>
</tr>
</thead>
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end for
Some results

Better load balance

Same efficiency

Small loss on fairness

Utility uniformity

Global regulation
Price anticipating
Social optimum

Number of users

Efficiency

Number of users

Envy Freeness

Number of users
Conclusions

Resource hot spots may be present

- Need a mechanism to internalize this problem into the market
- Influence users’ choice

Resource taxes through 3rd party regulation entity

- Suitable in decentralized scenarios with no central control

Improves load balancing at the cost of fairness

- Same efficiency
- Utility uniformity and Envy-freeness reduced
Sharing model
Proportional share in datacenters

\[
x_i = \frac{\sum_{j=1}^{m} x_j}{m}
\]

\[
x_1 = 1
\]
\[
x_2 = 2
\]
\[
x_3 = 1
\]
Problem
Increasing energy costs

\[ f_e(s) = \sigma_e + \mu_e s^\alpha \]

Good for *Energy Proportionality* → Still high idle power!
Problem
Increasing energy costs

Given a specific user demand, how many resources should the resource provider shut down without reducing the QoS?
Let users optimize utility...

Proportional share model of competition

\[
\max U_i(x_1, \ldots, x_m) = \sum_{j=1}^{m} q_{ij} \frac{x_{ij}}{x_{ij} + y_j}
\]

subject to

\[
\sum_{j=1}^{m} x_{ij} \leq X_i
\]

\[
\frac{x_{ij}}{x_{ij} + y_j} \geq \phi_i \in (0, 1]
\]

\[
|S| \geq \tau_i
\]
...and provider optimize profit
by minimizing energy related costs

Revenue – cost model

\[
\max \quad P(q_1, \ldots, q_m) = \sum_{j=1}^{m} (q_j \sum_{i=1}^{n} x_{ij}) - \sum_{j=1}^{m} q_j c_j
\]

subject to

\[\forall_i |S_i| \geq \tau_i\]

Every user is satisfied

Node state
(on/off)

Price paid
by users

Cost of
resource
How to solve it?

Stackelberg game

How many resources to shutdown?

Resource Provider
Leader / Resource supply Regulator

Selfish users
Followers

Given $k$ available resources, is every user satisfied?
How to solve it?
Stackelberg game

User demand

Optimal # of resources found!

Shutdown remaining resources

Sorted by power consumption (ascending)
Some results

![Graph showing some results](image)

![Graph showing some results](image)
Conclusions

Significant costs related to energy consumption

- Idle power usage of IT equipment becomes a key factor

Resource provider in control of resource supply

- Stackelberg model of competition
- Suitable when resource provider has full control over supply

Upper bound on energy savings

- Minimize *switched on* machines while *satisfying* users’ requirements
Fair share/Capacity scheduler

Hadoop

Pool of resources (time slots in Hadoop)

1/n

1/n

1/n

1/n

“Fixed” resource allocation

Spare resources
Dynamic shares market

Spare resources that can:
- Be shutdown
- Reused by others

Pool of resources (time slots in Hadoop)

Capacity saving
Dynamic shares market

If competition -> Proportional share

Savings proportional to Time and share not used

Allow more than fair share if enough credits

No credits -> default to fair share
Some results

[Graphs showing comparisons between different energy-saving strategies: Optimum, Cooperative, Fair Share. Each graph displays Satisfaction and Cluster Usage against Users.]

[Graph showing Satisfaction against % Followers, with lines for Followers, No Followers, and Mean.]
Conclusions

Issues we address

- No control over share guarantees
- Lack of dynamic and elastic resource allocation
- No notion of energy-related costs

Provide incentives for user self-regulation

- Decentralize decision making

Dynamic and energy-aware resource allocation

- Incentive compatible
Wrapping up

Conclusions and Future work
Conclusions

How to incorporate multiple system-wide objectives into computational markets?

Diagram:
- External entity
- Regulation
  - User self-regulation
  - Resource provider
- Choice
  - Regulation
  - Capacity distribution
  - Resource supply
Future work

What about other system-wide metrics?

- Reward the social benefit of executions
- Control monopolies on federated infrastructures

Explore these mechanisms on real deployments

- Are they feasible?
- Easy of use?
- Need for computer-aided decision making?
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