Energy savings for servers parks

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E2GC2
Octobre 2009

Large scale systems

- Provide computing resources to large scale groups of users or services
- Geographically distributed
- Hardware either heterogeneous or homogeneous
- Heterogeneous usage

Large scale systems

Energy point of view

- Electricity cost of a cluster for 1 year is the same scale as its price
- Electricity consumption impact on environment is important
- Possible to reduce this energy consumption at several levels
  - Infrastructure around the hardware
  - Hardware
  - Software (compilation, algorithmic)
  - Middleware

Task placement
Metric

Introduction of a new metric: *yield*

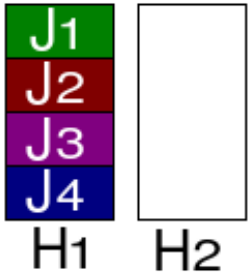
$$Y_{ij} = \sum_{j=1}^{H} (\frac{\alpha_{ij}}{\alpha_i})$$

H : number of hosts
α_i : fraction of the CPU the job *i* requested
α_{ij} : fraction of the CPU of the host *j* actually allocated to job *i*
Model the job yield, its satisfaction rate.

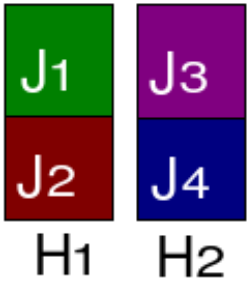
Resource Allocation Using Virtual Clusters, Mark Stillwell, David Schanzenbach, Frédéric Vivien, Henri Casanova, *in 9th IEEE International Symposium on Cluster Computing and the Grid, CCGrid'09*

Example

Lets take 2 hosts and 4 jobs requesting each 60% of CPU resources ($\alpha_i = 0.6$).



$$Y_{ij} = \frac{0.25}{0.6} \approx 0.42$$



$$Y_{ij} = \frac{0.5}{0.6} \approx 0.83$$

Task placement
Initial algorithm

Objectif : maximize the minimum *yield*

1. Apply an algorithm that takes a yield as an objective and computes a placement.
2. Iterate this algorithm to find the optimal yield.

Placement limits

- This approach allows to switch off hosts as a collateral effect.
- Does not take into account hosts heterogeneity.
- Does not take into account the energy required to compute the placement.

$\Rightarrow$ **Energy has to be taken into account globally.**

Taking into account energy: hypotheses

(H1) Hosts are heterogeneous energy wise, but provide the same computing resources.

(H2) An host consumes C^{min} watts when idle and C^{max} when fully loaded.

(H3) $\delta C_{ij} = \alpha_{ij} \times f(j)$ linear, $f(j) = (C^{max} - C^{min})$.

(H4) Infinite jobs.

(H5) No migration.

Formula

Metric redefinition to take into account energy consideration.

$$YE_{ij} = \frac{(Y_{ij})^{1-k}}{(E_{ij})^{k}}$$

$$= \frac{\left[\sum_{j=1}^{H}\left(\frac{\alpha_{ij}}{\alpha_i}\right)\right]^{1-k}}{\left[\lambda(C_j^{max} - C_j^{min}) \times \alpha_{ij} + (1-\lambda)\left[A_j(1 - \sum_{i'=1,i'\neq i}^{J}(\alpha_{i'j}))\right]\right]^{k}}$$

With $0 \leq \lambda \leq 1$ and $0 \leq k \leq 1$.

Properties
Placement

(P1) Favors an energy efficient host.

$$\frac{\left[\sum_{j=1}^{H}\left(\frac{\alpha_{ij}}{\alpha_i}\right)\right]^{1-k}}{\left[\lambda(C_j^{max} - C_j^{min}) \times \alpha_{ij} + (1-\lambda)\left[A_j(1 - \sum_{i'=1,i'\neq i}^{J}(\alpha_{i'j}))\right]\right]^k}$$

With $0 \leq \lambda \leq 1$ and $0 \leq k \leq 1$.

Properties
Consolidation

(P2) Favors an already loaded host.

$$\frac{\left[\sum_{j=1}^{H}\left(\frac{\alpha_{ij}}{\alpha_i}\right)\right]^{1-k}}{\left[\lambda(C_j^{max} - C_j^{min}) \times \alpha_{ij} + (1-\lambda)\left[A_j(1 - \sum_{i'=1, i' \neq i}^{J}(\alpha_{i'j}))\right]\right]^k}$$

With $0 \leq \lambda \leq 1$ and $0 \leq k \leq 1$
and $A_j = C^{min}$

Properties
Tradeoff

(P3) Tradeoff between energy savings and performance (k)

(P4) Tradeoff between Placement and consolidation (λ)

$$\frac{\left[\sum_{j=1}^{H}\left(\frac{\alpha_{ij}}{\alpha_i}\right)\right]^{1-k}}{\left[\lambda(C_j^{max} - C_j^{min}) \times \alpha_{ij} + (1-\lambda)(A_j(1 - \sum_{i'=1, i' \neq i}^{J}(\alpha_{i'j})))\right]^{k}}$$

With $0 \leq \lambda \leq 1$ and $0 \leq k \leq 1$.

YE Implementation

2 other differences with the base algorithm:

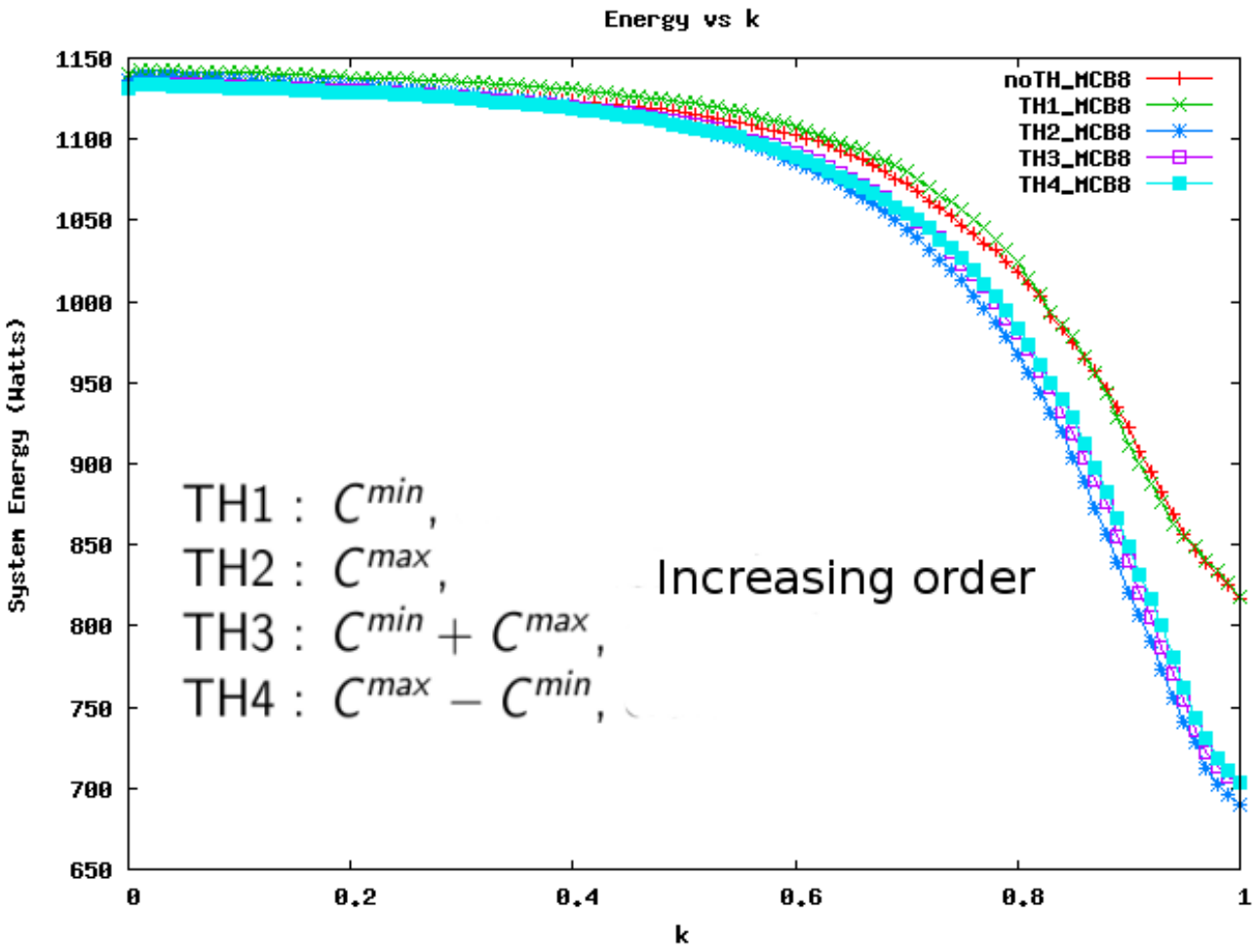
- New dichotomy bounds:

$$YE_{sup} = \frac{\left[min\{\frac{H}{\sum_{i=1}^{J}(\alpha_i)},1\}\right]^{1-k}}{min_j\{(1-\lambda)\times A_i+\lambda\times min\{1,\sum_{i=1}^{J}(\alpha_i)\}\times(C_j^{max}-C_j^{min})\}^k}$$

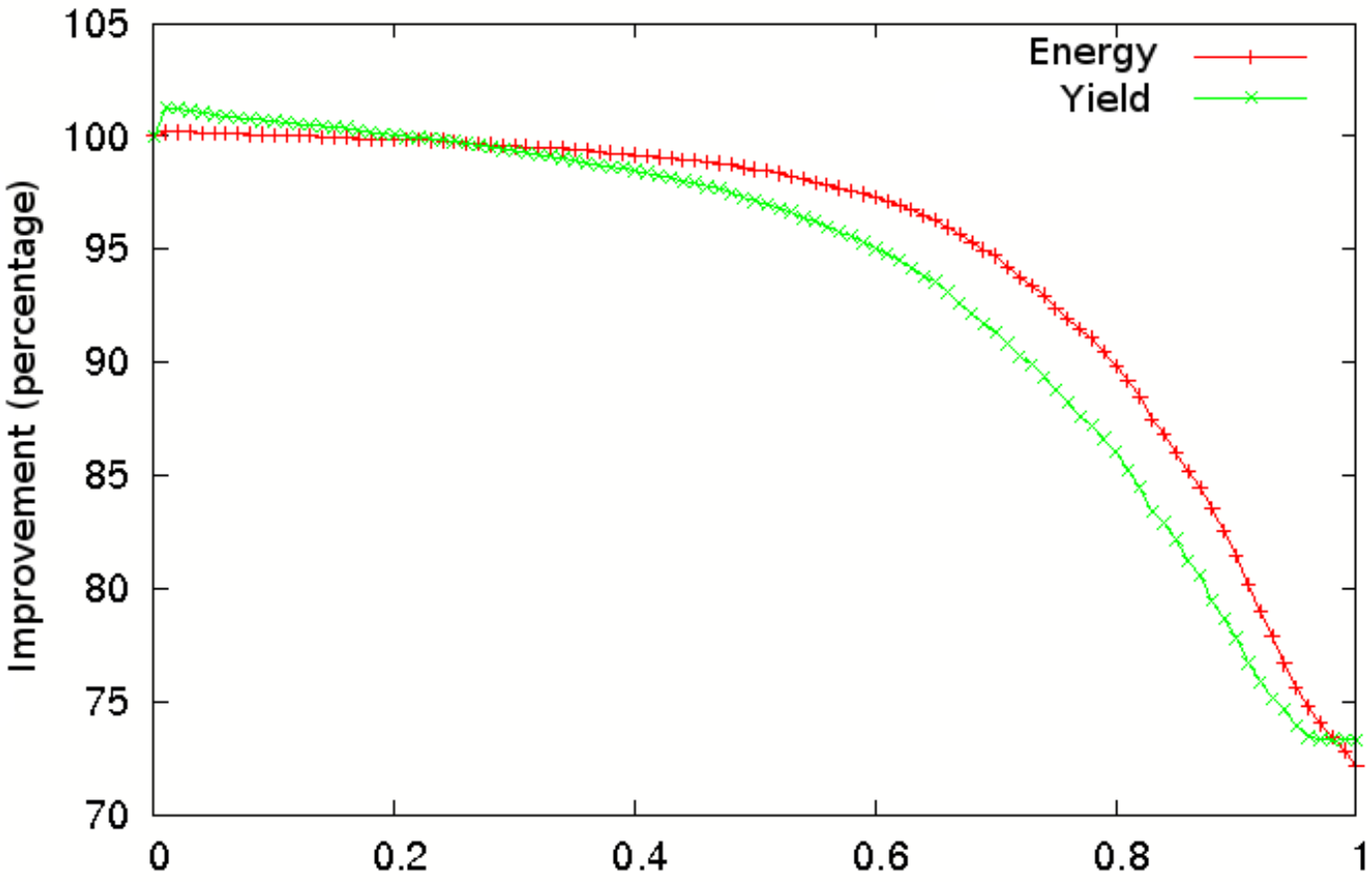
- Sort of the hosts at the algorithm beginning to place on the best hosts firsts:
  - TH1 : C^{min}, increasing;
  - TH2 : C^{max}, increasing;
  - TH3 : $C^{min} + C^{max}$, increasing;
  - TH4 : $C^{max} - C^{min}$, increasing;

- Same methodology as defined in Stillwell and al (to allow comparison).
- Small problem instances: 4 hosts, 1440 simulations.
- Campaign of more than a million simulations.
- Experimentation done on the french Grid'5000 platform.

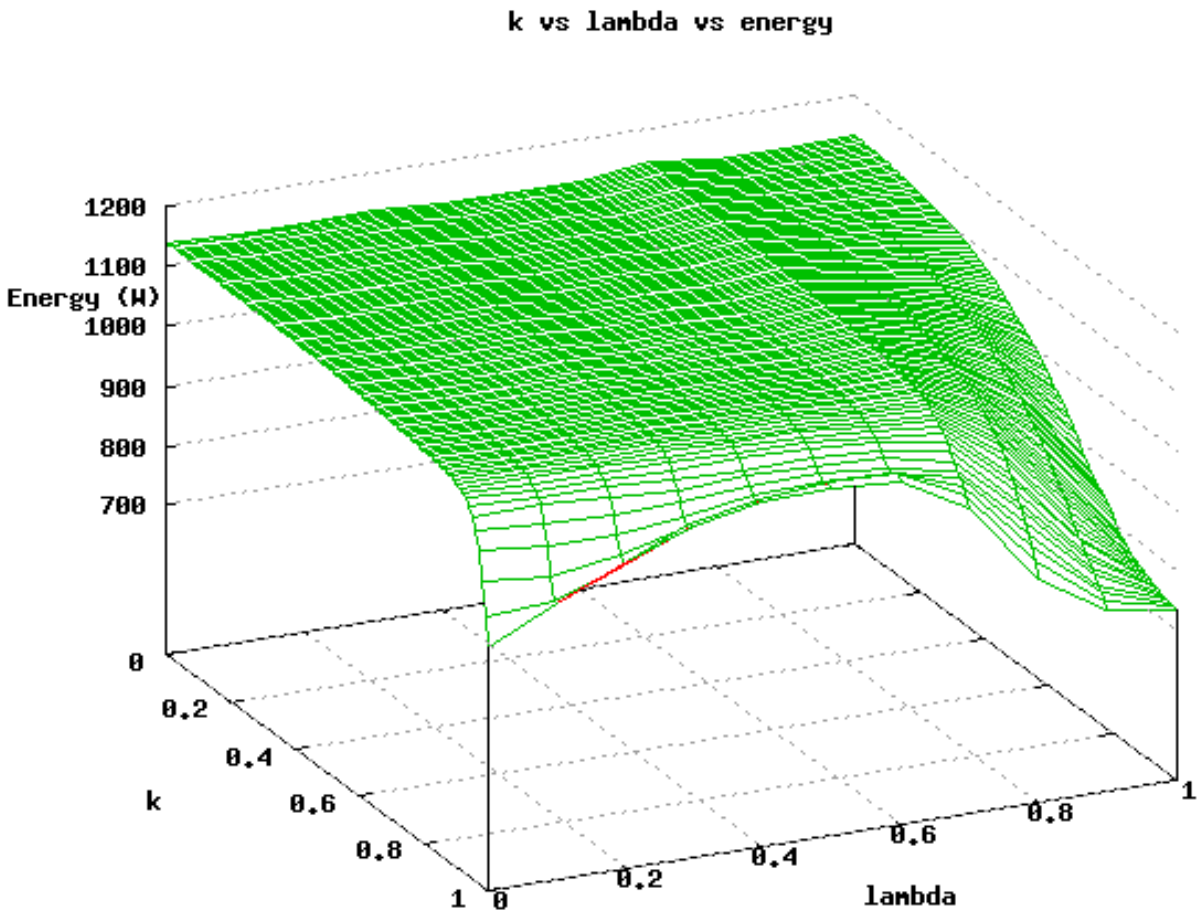
Influence of the hosts sorts on the energy consumption



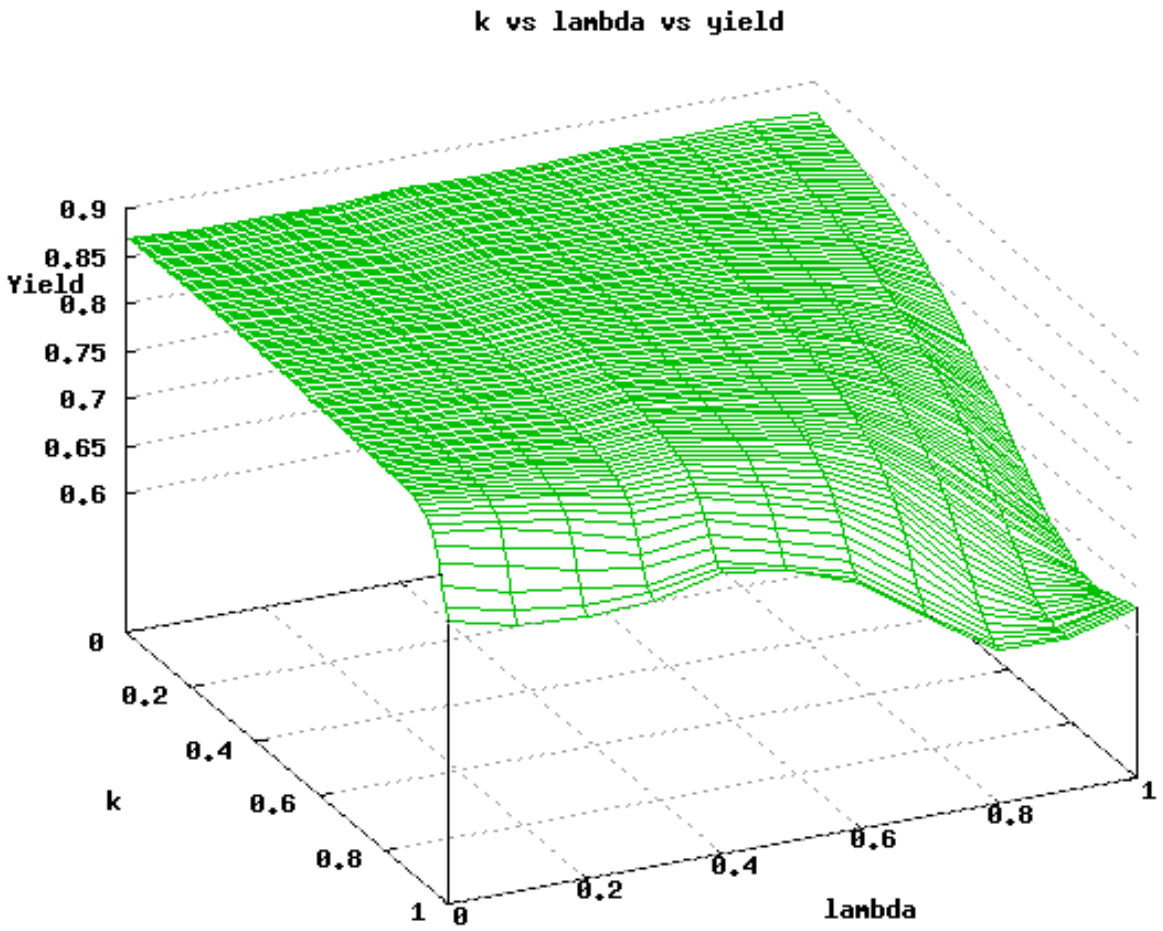
Improvement of the energy consumption and reduction of the yield



Energy consumption in function of λ and k



Yield in function of λ and k



Current state:

- Definition of a placement metric *energy-aware*
- Metric validation using simulation

Perspectives

Short-term:

- Job sorts *energy-aware*
- Model of the optimal placement with energy/performance constraint

Mean-term:

- Remove some hypotheses: performance homogeneity and infinite jobs
- Job migration
- Overhead estimation
- Heuristic comparison

Long-term:

- Autonomous system of energy management

Questions

Questions?

Task placement

Initial algorithm

Objective : maximize the minimum *yield*

1. Fix a value Y of the aimed *yield*;
2. For each jobs, deduce from Y new CPU requirements to guaranty jobs attain this objective;
3. Sort jobs into two lists;
4. Place jobs using *multi capacity bin-packing*;
5. Restart 1, 2, 3 and 4 by doing a dichotomy on Y to find the optimal Y.

Several jobs sorts:

- MCB4: max(mémoire,CPU), increasing;
- MCB8: max(mémoire,CPU), decreasing.