Delivering Energy Proportionality with Non Energy-Proportional Systems – Optimizing the Ensemble

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2006: $4.5 Billion
“The cost of power and cooling is likely to exceed that of hardware…”

- Luiz Barosso, Google
“In the data center, power and cooling costs more than the IT equipment it supports.”

- Christian L. Belady, Microsoft
Energy-Proportional Computing

Consume energy in proportion to the amount of work performed.

[Barosso07]

![Graph showing linear relationship between power and utilization.](graph.png)
Energy Proportionality requires “significant improvements in the energy usage profile of every system component”

Power Breakdown for a Busy “Medium” Server

Source: Leigh07, PhD Dissertation
Use Software to achieve Proportionality

• Leverage multiple servers + virtualization
• Use optimization to make the ensemble approximate a theoretical energy-proportional system

• Tradeoff: Software Complexity for Power Savings
Two Case Studies

- Ensemble: Blade Enclosure
  - Server Power
  - Cooling Power
The graph shows a comparison of power consumption under different utilization conditions. The x-axis represents the average enclosure utilization (in %), and the y-axis represents the power consumption (in W).

Three lines are plotted:
- Blue line: No DVFS
- Red line: DVFS
- Green line: DVFS + Off

As the average enclosure utilization increases, the power consumption increases for all three scenarios. The DVFS + Off scenario shows a higher power consumption compared to No DVFS and DVFS at lower utilization values, but it becomes more efficient at higher utilization levels.

The graph indicates that DVFS can help manage power efficiently, especially at high utilization levels, but it might require additional management if combined with the off feature.
Two Case Studies

- Ensemble: Blade Enclosure
  - Server Power
  - Cooling Power
Power Model: Single Fan

- Measured Fan Power
- Fan Power Model
Caveat Emptor

- CPU heterogeneity in data centers
- Locally-attached storage
- Reliability
  - Hardware
  - Applications
Conclusion

• Treat ensemble as the computational unit
• Optimize to approximate energy proportionality

• Apply to other non-proportional components
  – Network, Storage, CRACs, Power Supplies