An Experimental Study on the Energy-Saving Potential of IaaS-PaaS Co-Design

Mar Callau-Zori, Lavinia Samoila, Anne-Cécile Orgerie and Guillaume Pierre
Roadmap

1.Motivation
2.Potential of IaaS-PaaS co-design
3.Experimental study
4.Conclusions and future work
Roadmap

1. Motivation
   ◦ Growing concern about energy-consumptions in data centers
   ◦ Cloud computing is a green technology?

2. Potential of IaaS-PaaS co-design

3. Experimental study

4. Conclusions and future work
Growing concern about energy-consumption in data centers

US. data centers = 2xNYC households

Google consumes <1% of electricity used by data centers worldwide

- Carbon emission equivalent to:
  - 113 x Earth
  - Mars
Is Cloud Computing a Green Technology?

By moving **86 million** U.S. office workers to the cloud, we would use up to **87%** less energy. That's enough to power **Los Angeles** for 1 year.
Cloud computing

- The cloud has several layers:
  - **Platform** layer facilitates deployment of applications
  - **Infrastructure** layer handles the platform virtualization environment
  - We target services which require (at least) platform + infrastructure
Related work

IaaS:
- scheduling and consolidation combined with turn off idle servers
- dynamic voltage frequency scaling

Overall energy of the Cloud:
- Better utilization of available energy:
  - moving services or scheduling jobs to increase renewable energy
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Counter-productive case
Counter-productive case

- Stopping VMs depends on load (PaaS)
Counter-productive case

- IaaS has decided VM migration
Counter-productive case

Migration wastes 65.58J
Energy-saving potential in IaaS-PaaS co-desing

- IaaS-PaaS co-desing:
  - Layers exchange information
  - Layers coordinate their actions

- We focus on VM management operations
- We demonstrate the potential by an experimental study
Roadmap

1. Motivation
2. Potential of IaaS-PaaS co-design
3. Experimental study
   - Stationary scenario
   - VM start-up
   - VM migration
4. Conclusions and future work
Experimental setup

- Grid’5000 test-bed (taurus)
  - 12-cores Xeon E5-2630@2.3GHz
- (IaaS) Openstack
- (PaaS) MySQL+Apache
- TPC-W benchmark

- Metrics:
  - power (W)
  - throughput (WIPS=Web Interaction Per Second)
Stationary scenario: experiment setup

number of VMs
Stationary scenario: throughput results

![Graph showing linear scalability with number of VMs and throughput (WIPS)]
Stationary scenario: throughput results

- Small energy overhead, small throughput degradation
Stationary scenario: throughput / energy

- A small degradation in throughput can generate energy savings
Stationary scenario: conclusion

- An energy-efficient system should determine VM placement
  - IaaS-PaaS cooperation is required because:
    - IaaS layer allocates VMs
    - PaaS layer can decide the allowed throughput degradation
VM start-up: experiment setup
VM start-up : throughput results

![Bar chart showing energy (W) and throughput (WIPS) for different numbers of VMs.](image)
VM start-up : energy results

- Starting up a VM is not energy-neutral
VM startup: conclusion

- An energy-efficient system should guarantee a minimum lifetime after creation.
- IaaS-PaaS cooperation is required because:
  - IaaS layer starts VMs
  - PaaS layer is able to predict VM lifetime from workload
VM migration

- Energy-consumption / throughput can fluctuate in both hosts
- Thoughput is specially impacted in migrated VM

- Both hosts have the same number of non-migrated VMs
VM migration: an example

Energy in both hosts:

Throughput of migrated VM:
VM migration: experiment setup

**Diagram:**
- **src** and **dst** represent source and destination systems.
- The diagram shows the energy consumption (W) and throughput (WIPS).
- The diagram includes labels for static VMs (st. = static = non-migrated).

**Graph:**
- Energy consumption (W) ranges from 0 to 350.
- Throughput (WIPS) ranges from 0 to 70.

**Legend:**
- **ener. bef.** (energy before migration)
- **ener. mig.** (energy after migration)
- **thr. bef.** (throughput before migration)
- **thr. mig.** (throughput after migration)

**Data Points:**
- #st.VMs: 1, #st. VMs: 2, #st. VMs: 4, #st. VMs: 6, #st. VMs: 8, #st. VMs: 9

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The diagram illustrates the energy consumption and throughput for different numbers of static VMs before and after migration. The energy and throughput metrics are visualized for both source (src) and destination (dst) systems.
VM migration: throughput results

-28%  -24%  -24%  -26%  -27%  -29%

energy (W)

#st.VMs: 1  #st.VMs: 2  #st.VMs: 4  #st.VMs: 6  #st.VMs: 8  #st.VMs: 9
VM migration: energy results

2.05% 1.87% 1.55% 2.69% 1.38% 1.83%

#st.VMs:1 #st.VMs:2 #st.VMs:4 #st.VMs:6 #st.VMs:8 #st.VMs:9
VM migration: conclusion

- An energy-efficient system should consider throughput degradation
- IaaS-PaaS cooperation is required because:
  - IaaS layer migrates VMs
  - PaaS layer can determine when a throughput degradation is less important
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Conclusion and future work

Experiments has shown the potential of co-design to save energy:

- Avoiding counter-productive actions
  - E.g. guaranteeing a lifetime after VM startup
- Coordinating choices by information exchanges
  - E.g. deciding VMs placement

- Design an energy/performance-aware IaaS-PaaS API