

Energy-Efficient Self-Adaptation applied to Cloud Applications

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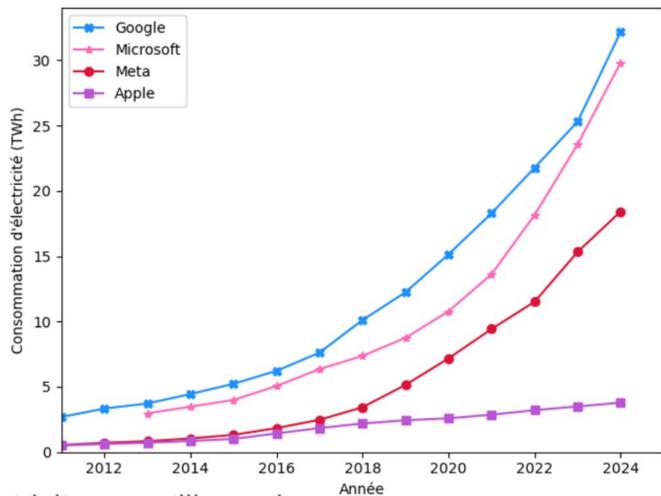
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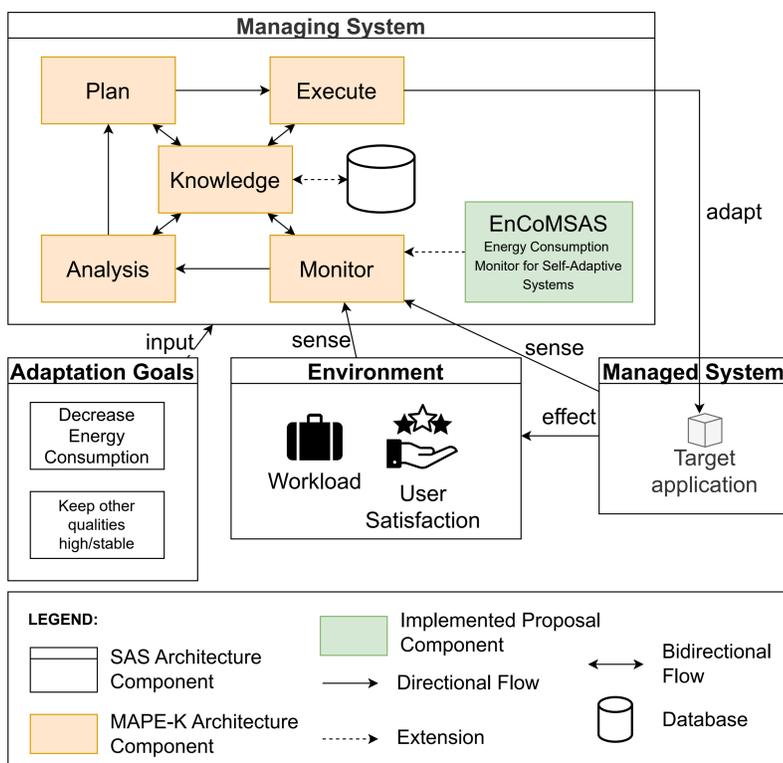
Context - Growing electricity demand by data centers



"Power limits in data centers: what can we expect from improving energy efficiency and refreshing servers?", Pablo Leboulanger, Anne-Cécile Orgerie, IEEE International Conference on Cloud Engineering, 2025, pp.1-12.

As datacenter energy consumption continues to rise, Self-Adaptive Cloud Systems (SACS) can help mitigate their environmental impact by reconfiguring cloud applications. However, existing literature rarely treats energy consumption as a primary concern, focusing instead on CPU and memory usage.

Energy-Efficient Self-Adaptive Cloud Architecture



Based on the MAPE-K [1] architecture, we extend each component to integrate energy efficiency as main goal:

- Monitor (EnCoMSAS [2]) measures energy consumption of Cloud applications
- Analysis integrates AI means to understand the situations in which we have to adapt.
- Plan calculates a new adaptation plan to reduce, or at least stabilize, the energy consumption.
- Execute implements the actuators that execute adaptation plans.

Research Questions for evaluating EnCoMSAS

RQ1: Is the energy consumption calculated by EnCoMSAS coherent w.r.t other metrics (i.e. CPU usage, memory consumption)?

RQ2: Does EnCoMSAS enable the analysis of the impact of variants of Adaptable TeaStore on its energy consumption?

RQ3: Does EnCoMSAS enable the analysis of runtime adaptations of Adaptable TeaStore?

RQ4: How does EnCoMSAS impact the energy consumption of the entire Adaptable TeaStore ecosystem?

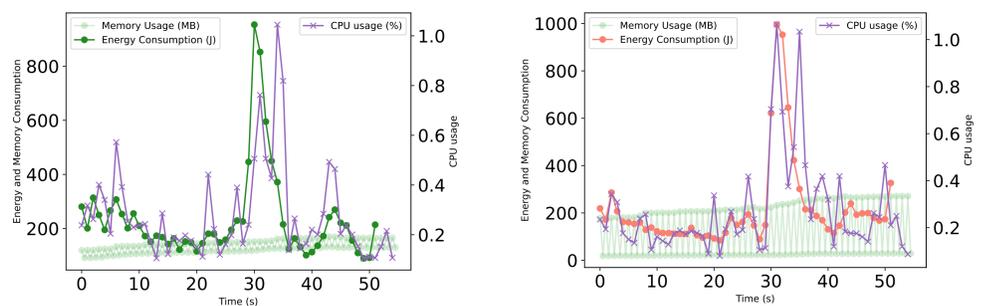
Case Study of Adaptable TeaStore

Monitoring the energy consumption to allow improvements in the energy efficiency of cloud applications, providing adaptations.



RQ1: Energy Consumption vs CPU Usage vs Memory Consumption

Answer: Energy consumption is directly correlated with CPU usage, but not with memory consumption.



RQ2: Different Recommender Algorithms impact on Energy Consumption

Answer: Energy consumption depends not only on algorithmic complexity but also on hardware configuration.

RQ3: Analysis of runtime adaptations on Energy Consumption

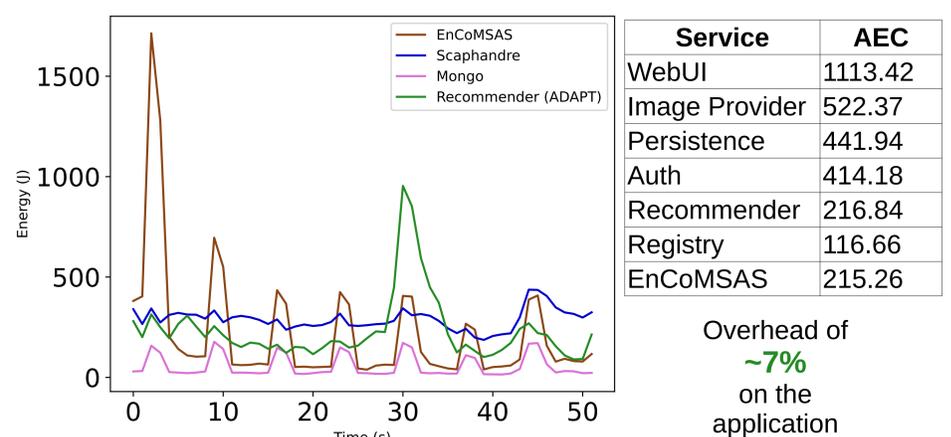
Answer: Each variant presents a different energy consumption distribution.

VARIANT	AEC	RSEC	%DEC	p-value
ADAPT	56.29	0.48	-	-
NOADAPT	45.87	0.50	-18	0.009

Where: AEC = average of energy consumption (EC in Joule unit), RSEC = relative standard deviation of EC, DEC = difference of EC vs Base, p-value= p-value of Wilcoxon test.

RQ4: Impact of EnCoMSAS on Energy Consumption

Answer: EnCoMSAS introduces a low overhead in energy consumption, compared to the entire set of TeaStore application microservices.



References

[1] Autonomic Computing et al. An architectural blueprint for autonomic computing. IBM White Paper, 31(2006):1-6, 2006.

[2] Henrique De Medeiros, Denisse Muñante, Sophie Chabridon, César Perdigão Batista, and Denis Conan. Adaptable teastore with energy consumption awareness: A case study. In Giuseppe De Palma and Saverio Giallorenzo, editors, Post-proceedings of the Workshop on Adaptable Cloud Architectures (WACA 2025), 2025

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