# Distributed Energy Management for Virtual Machines

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Virtualization technology has regained considerable attention in the design of modern operating systems. At the very same time, with the ever increasing power dissipation of today's computer systems, energy management is becoming a crucial aspect as well. However, current approaches to energy management are based on legacy operating systems, which have full knowledge of and full control over the underlying hardware; the modular nature of modern virtual machine environments renders such approaches insufficient.

This paper presents a novel framework for energy management in modular, multi-layered operating systems. The framework provides a unified power model, and mechanisms for energy-centric profiling resource allotments; it supports extensible energy policies at different software layers. For demonstration, we have developed a prototype for virtual machine based server systems. A host-level subsystem controls machine-wide energy constraints and enforces them among all guest OSes and service components. It is complemented by an energy-aware guest operating system capable of application-specific energy management, which relies on effective virtualization of physical energy effects provided by the host-level subsystem.

Our prototype currently supports management of CPU and disk devices. Experiments show that energy budgets can effectively be stipulated, both for energy-aware and -unaware guest OSes. Guest-level control enables fine-grain distribution of energy among competing tasks. In contrast, host-level control enforces the budgets reliably and independent of the guest's particular capabilities. Our energy management does not cause more than a small, single-digit performance degradation.