Introduction to the Special Section on Adaptive Power Management for Energy and Temperature-Aware Computing Systems

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To maintain a sustained growth of modern IT technology, it is important to curb the energy usage and carbon emission of existing IT facilities. In addition to the environmental impact, excessive power consumption also increases die temperature, reduces system reliability, and cuts the battery lifetime. Effective power and thermal management helps relieve the power and temperature bottlenecks of today's VLSI design, enabling sustained high-performance operations with desired reliability levels. Due to the changing workload, PVT (process, voltage and temperature) variations, and aging effect, the power and thermal characteristics of a computing system vary over time. A robust power management system should be able to work on different types of hardware with variable workloads. The ability to adapt to the environment and workload changes is the key to maintaining the efficiency of power management.

This special section of the ACM TODAES journal presents some of the recent research on adaptive power and thermal management. Seven articles were selected, tackling the power management problem from different aspects. Two of the articles focus on designing hardware architectures that facilitate the runtime resource discovery and DVFS (dynamic voltage and frequency scaling), while the other five focus on runtime management schemes. Based on the objectives of the optimization problems, these five articles can further be divided into two categories, power management and thermal management. Based on the target devices of runtime management, the articles can be categorized into power/thermal management of microprocessors and management of memory/storage systems. Integrating these categories, we arrange the articles into four groups.

The first group of articles present novel architectures that enable adaptive power management. The first article ("Hierarchical Power Management for Adaptive Tightly-Coupled Processor Arrays" by Lari et al.) presents a many-core architecture that allows runtime resource discovery and power gating with a detailed power model. The second article ("Design of Energy-Efficient Adaptable Throughput Systems at Near/Sub-Threshold Voltage" by Sri Vastav et al.) discusses the design of voltage scaling and power-gating circuitry in multicore processors to handle the impact of process variations during runtime power management.

The next group of articles focus on developing runtime power/resource management that adapts to the changing environment. The first article ("A Self-Tuning Design Methodology for Power-Efficient Multicore Systems" by Sun et al.) ranks the competitiveness of different cores based on their temperature, error rate, and aging effect. The tasks of mapping and voltage frequency selection are determined accordingly. The following article ("Improving Performance per Watt of Asymmetric Multicore Processors via Online Program Phase Classification and Adaptive Core Morphing" by Rodrigues et al.) proposes architectures to detect program phases that differ in their resource

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requirements. The proposed technique then dynamically manages cores to adapt to the phase changes.

The third group of articles present adaptive thermal management using advanced control and machine learning techniques. The first article ("Online Thermal Control Methods for Multiprocessor Systems" by Zanini et al.) applies model predictive control to achieve efficient thermal management and studies optimal control strategies. The second article in this group ("Thermal Prediction and Adaptive Control through Workload Phase Detection" by Cochran and Reda) proposes novel classification techniques for workload phase detection to enhance the accuracy of temperature prediction under dynamic workload changes.

The last article ("Hybrid Nonvolatile Disk Cache for Energy-Efficient and High-Performance Systems" by Shi et al.) proposes to add PCM (phase change memory) to NAND flash as disk cache. The goal is to improve performance and also the lifetime of flash memory.

We hope you enjoy reading these seven articles and that they provide stimulus for future research.