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Energy-Discounted Computing and Supercapacitor Energy Buffering for Resource-Constrained Systems

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The past decade has witnessed an enormous growth and popularity of off-the-grid computer systems. From smartphones to field-deployed systems, self-contained computing devices that can operate anytime and anywhere have unleashed a wave of change in the society.

One of the biggest constraints of these systems is the limited energy buffering capacity. Comparing to the rapid advancement in the semiconductor industry, there has only been tepid improvement in the device energy buffering capacity over the years. Thus energy management and optimization techniques are vital to extend the usefulness of these systems in practice. As technology evolves, however, the emergence of new hardware platform, application usage pattern and energy buffering mechanism have rendered the existing techniques inadequate. In this dissertation, we study new techniques that capitalize on this technology trend to improve energy management for resource constrained systems.

First, we introduce energy discounted computing that is specifically tailored for multicore processors on smartphones. Multicore processors are not energy proportional: the first running CPU core that activates shared resources incurs much higher power cost than each additional core does. By non-work-conserving scheduling, we exploit energy-discounted co-run opportunities to process best-effort smartphone tasks that involve no direct user interaction, improving energy efficiency without impacting user experience.

Second, we take a user-centric approach to develop application-transparent execution con- text for mobile operating systems that reflects the criticality of current execution on user inter- activity. This interactive context enables differential resource scheduling for improved system interactivity and energy efficiency.

Finally, we construct a supercapacitor-sustained data-intensive field system that aims for continuous operation. The system leverages the voltage-to-stored-energy relationship in capacitors to enable precise energy buffer modeling. We demonstrate that the precise supercapacitor energy model allows model-driven system adaptation for optimal and stable operation quality- of-service.