Dissertations

Software Techniques to Reduce the Energy Consumption of Low-Power Devices at the Limits of Digital Abstractions

Mastooreh Salajegheh, *University of Massachusetts - Amherst*

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First Advisor

Kevin Fu

Second Advisor

Deepak Ganesan

Third Advisor

Erik Learned-Miller

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Abstract

My thesis explores the effectiveness of software techniques that bend digital abstractions in order to allow embedded systems to do more with less energy. Recent years have witnessed a proliferation of low-power embedded devices with power ranges of few milliwatts to microwatts. The capabilities and size of the embedded systems continue to improve dramatically; however, improvements in battery density and energy harvesting have failed to mimic a Moore's law. Thus, energy remains a formidable bottleneck for low-power embedded systems.

Instead of trying to create hardware with ideal energy proportionality, my dissertation evaluates how to use unconventional and probabilistic computing that bends traditional abstractions and interfaces in order to reduce energy consumption while protecting program semantics. My thesis considers four methods that unleash energy otherwise squandered on communication, storage, time keeping, or sensing: 1) CCCP, which provides an energy-efficient storage alternative to local non-volatile storage by relying on cryptographic backscatter radio communication, 2) Half-Wits, which reduces energy consumption by 30% by allowing operation of embedded systems at below-spec supply voltages and implementing NOR flash memory error recovery in firmware rather than strictly in hardware, 3) TARDIS, which exploits the decay properties of SRAM to estimate the duration of a power failure ranging from seconds to several hours depending on hardware parameters, and 4) Nonsensors, which allow operation of analog to digital converters at low voltages without any hardware modifications to the existing circuitry.