A Wireless Sensor Network (WSN) consists of spatially distributed sensor nodes which monitors environmental conditions such as temperature, humidity, sound or pressure, etc.
Recently there is increasing need to design Wireless Sensor Network systems that support applications with intensive monitoring and control activities. This application class often has significant data collection and processing requirements, requiring increased levels of energy consumption as compared to other WSN applications. Further, many deeply embedded WSN systems with these data collection and processing requirements are expected to operate without manual battery recharging for several decades, and therefore require energy harvesting techniques. For this class of systems, there are currently few effective approaches that balance careful energy management with high performance communication and computation requirements.

My dissertation addresses the above problem. Specifically, I propose a set of algorithms and control methods for energy management in performance-sensitive WSN systems, and harvesting-aware rate allocation for application utility maximization. First I formally define the problem of energy harvesting-aware energy management as two optimization problems, one for individual sensor nodes and another for multi-hop sensor networks. I propose energy management algorithm to solve both problems optimally and efficiently. These solutions combine two energy saving techniques, Dynamic Voltage Scaling (DVS), and Dynamic Modulation Scaling (DMS), alongside with energy harvesting techniques. I then address a harvesting aware rate allocation problem with the objective of utility maximization. The problem is solved with an optimal centralized algorithm and a distributed algorithm.

I conducted extensive simulation-based experiments to evaluate the effectiveness of my proposed algorithms. Specifically I developed simulation software using TOSSIM, the standard WSN simulator, and EPANET, a public domain, water distribution system modeling program. This software simulates in high fidelity the computation and communication activities of WSN nodes, and considers a variety of network setups, energy harvesting profiles (solar and water), and application scenarios, etc. My algorithms are implemented within this simulation environment and compared against a series of rival algorithms under various experimental setups. Extensive simulation results demonstrate the significant advantage of my algorithms over the rival algorithms.