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Editorial: Energy Constraints and Lifetime Performance in Wireless Sensor Networks

Wireless sensor networks have been undergoing a revolution that promises to have a significant impact throughout society, one that could quite possibly dwarf previous milestones in the information revolution. These networks consist of battery-powered nodes that are endowed with a multitude of sensing modalities. The demand for these networks is spurred by numerous applications that require in-situ, unattended, high-precision, real-time observation over a vast area. Such networks are more than simply the next step in the evolution of the personal computer or the Internet. Instead, wireless sensor networks operate under a set of unique constraints and requirements that demand more than merely incremental improvements in, or modifications of, traditional technologies. In particular, although there have been significant improvements in processor design and computing, advances in battery technology still lag behind, making energy resource the ultimate bottleneck in wireless sensor networking.

The purpose of this issue is to disseminate state-of-the-art approaches and novel techniques that will advance basic knowledge and understanding of wireless sensor networks. The eight papers selected for publication address various aspects of energy constraints and lifetime performance in wireless sensor and ad hoc networks.

The first paper in this issue by Duarte-Melo, Liu, and Misra, “An Efficient and Robust Computational Framework for Studying Lifetime and Information Capacity in Sensor Networks” presents a modeling methodology with the aim of reducing the time needed for determining the expected information capacity of a data-gathering wireless sensor network. This computational tool could be used in scenarios where the exact node locations are not determined in advance, but are instead a sample realization of an underlying probabilistic node distribution strategy. The authors also develop a robust version of the linear program formulation that can be applied to different network layouts that are perturbations of one another, rather than just to a specific deployment.

Following this, the paper by Deng, Han, Heinzelman, and Varshney on the “Scheduling Sleeping Nodes in High Density Cluster-based Sensor Networks” studies the problem of how a cluster head selects sensor nodes to put to sleep without compromising the sensing coverage capability of the cluster. The authors propose a Linear Distance-based Scheduling (LDS) scheme that selects a sensor node to sleep with high probability when it is farther away from the cluster head. Through analysis and simulation, the authors show that the LDS scheme can save energy with negligible loss in sensing coverage area and outperforms the conventional Randomized Scheduling (RS) scheme.

Next, Wu, Gao, Li, and Xiao analyzes the problem of estimating redundant sensing areas among neighboring wireless sensors in their paper “Lightweight Deployment-Aware Scheduling for Wireless Sensor Networks.” The authors present simple formula to estimate the probability that a sensor is completely redundant and to estimate the average partial redundancy. Based on this analysis, the authors propose a lightweight deployment-aware scheduling scheme to turn off redundant sensors. Simulation results show that the scheme can reduce network energy consumption while meeting desired performance requirement.

In the next paper on “Maximizing Lifetime for Data Aggregation in Wireless Sensor Networks,” Xue, Cui and Nahrstedt model the problem of maximizing network lifetime as a concurrent multi-commodity flow problem. Following the Garg-Konemann algorithm for multi-commodity flow, the authors present a tree-based approximation algorithm that addresses the unique traffic characteristics of data aggregation and achieves faster running time. Using this algorithm, the authors further study the impact of multiple data sinks on the lifetime of sensor networks.

In their paper “On Node Lifetime Problem for Energy-Constrained Wireless Sensor Networks,” Hou, Shi, and Sherali study the so-called Lexicographic Max-Min (LMM) node lifetime problem, which not only maximizes the lifetime until the first node fails, but also maximizes the lifetimes for all the nodes in the network. The authors propose an efficient computational technique based on parametric analysis in linear programming and show that this approach is much more computational efficient than an state-of-the-art computational technique in the literature. The authors also present a simple polynomial-time algorithm to calculate the flow routing schedule such that the LMM-optimal node lifetime objective can be achieved.

The paper on “Maximizing Network Lifetime of Broadcasting Over Wireless Stationary Ad Hoc Networks” by Kang and Poovendran investigates the problem of maximizing the network lifetime of a single broadcast session over stationary wireless ad hoc networks. Using a graph theoretic approach, the authors propose a polynomial-time near-optimal heuristic solution to minimize the maximum (MinMax) transmission power under static routing. Built upon this result, the authors propose to dynamically adjust broadcast routing topology to further improve network lifetime performance.

Agarwal, Cho, Gao, and Wu investigate the problem of minimizing the total energy consumed in broadcasting data in their paper on "Energy Efficient Broadcast in Wireless Ad Hoc Networks with Hitch-hiking." The authors propose to take advantage of the physical layer design that facilitates the combining of partial information to obtain complete information. This idea is referred to as "hitch-hiking" since partial signals are analogous to cars passing on the road carrying messages as hitch-hikers and delivering them to their destinations at no extra cost. The authors study the scenarios when the transmission power level of the nodes in the network is fixed and when it can vary. For both scenarios, the authors propose heuristic algorithms based on the idea of hitch-hiking and show that they can reduce the energy cost of broadcast.

The final paper of this issue by Song, Wang, Li, and Frieder, addresses how to achieve power spanner, planar, and degree bounded properties for unicast in wireless ad hoc networks. In their paper on "Localized Algorithms for Energy Efficient Topology in Wireless Ad Hoc Networks," the authors propose two localized algorithms that can construct energy efficient routing structures, where each node has a bounded degree and the structures are plannar. Using both theoretical and simulation results, the authors show that the resulting topology structures are more efficient and easier to construct than other known structures used in wireless ad hoc networks; the power assignment based on the new structures has low energy cost and small interference at each wireless node.

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