ENERGY AWARE CROSS-LAYER OPTIMIZATION STRATEGIES IN WIRELESS NETWORKS

By

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to the

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To

My loving Parents

Certificate

This is to certify that the dissertation titled "**Energy aware cross-layer optimization strategies in wireless networks**" being submitted by Bighnaraj Panigrahi to the Department of Electrical Engineering, Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy, is a record of bonafide research work carried out by him under our guidance and supervision. In our opinion, the dissertation has reached the standards fulfilling the requirements of the regulations relating to the degree.

The results contained in this dissertation have not been submitted to any other university or institute for the award of any degree or diploma.

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Abstract

This dissertation contributes toward the design of new cross-layer protocols for emerging wireless networks based on an objective of energy optimization. Many wireless network applications like wireless sensor networks (WSN) and wireless ad hoc networks are usually autonomous distributed systems that are infrastructure-less, fully distributed and multihop in nature.

The dissertation begins by investigating some fundamental energy aware lifetime maximizing forwarding protocols based on fixed transmission power control (FPC). We show how the selection of a proper nexthop forwarding neighbor in a multihop packet transmission can contribute significantly in increasing the lifetime and performance gain of the WSN. Via simple probabilistic analysis we prove the intuition behind the optimum forwarding node selection for network lifetime maximization. We model the lifetime maximization of a sensor network as an optimization problem and compare the practical protocol-dependent network lifetime with the theoretical upper bound. We propose three variants of distributed and stateless forwarding strategies for wireless sensor networks, namely, greedy minimum energy consumption forwarding protocol (GMFP), lifetime maximizing GMFP (LM-GMFP), and variance minimizing GMFP (VAR-GMFP) which aim at maximizing the network lifetime while achieving a high forwarding success rate.

We then study the impact of interference and variable transmission power control (VPC) on the energy optimization, lifetime of the network, and other cross-layer performances. The advantage of using VPC has a twofold. First, it can reduce overall transmission power in the network, therefore increasing the energy savings of wireless devices that are typically energy limited. Second, it can increase the traffic carrying capacity of these wireless networks in comparisons to existing systems that are based on FPC. We make a number of fundamental contributions. We throughly study and propose mathematical models for the interference and VPC for wireless networks and study their effect on the energy conservation and lifetime of wireless networks.

In a study that laid an important basis of transmission power control implementation in sensor motes, effective energy saving per successful frame transmission with VPC strategies as well as with FPC, we verify the effect of transmission power control, and link layer frame size on the energy savings in a WSN. We investigate the energy saving performance of two automatic transmission power control strategies, namely binary ACK (acknowledgment) based and receiver's signal quality information based approaches, on a Crossbow MICA2 platform operating at 915 MHz. We also investigate the effect of link layer frame size on the energy saving performance in sensor nodes. We show that, although there is energy saving per transmitted frame with power control, the effective energy saving with TPC per successful payload unit is achieved only up to certain transmitter-receiver distance. With variable sized frame transmissions we further demonstrate that the detrimental effect of large frame size – in terms of increased energy consumption – is only apparent at very high inter-nodal distance.

In the final part of the dissertation we investigate the feasibility of supporting the energy conservation and other traditional QoS (e.g., bandwidth or throughput assurances) performances in a network that is based on VPC. Specifically, we study impact of interference and VPC on energy consumption and throughput and study its implementation for wireless networks using IEEE 802.11 and alternative VPC based multiple access schemes. We show limitations of FPC based MAC protocols and proposed two variants of advanced power control MAC protocols with significantly improved performance than existing protocols.

Appropriate simulation models for the proposed protocols are designed using NS-2.31 network simulator and MATLAB-7.1. Through extensive simulations we demonstrate that the proposed protocols outperform the existing energy-aware protocols. Being light-weight, the proposed algorithms can be easily retrofitted at the software level in the already-deployed field sensor nodes.

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