Energy Efficiency in Wireless Sensor Networks

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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Abstract

Wireless sensor networks (WSNs), as distributed networks of sensors with the ability to sense, process and communicate, have been increasingly used in various fields including engineering, health and environment, to intelligently monitor remote locations at low cost. Sensors (a.k.a nodes) in such networks are responsible for four major tasks: data aggregation, sending and receiving data, and in-network data processing. This implies that they must effectively utilise their resources, including memory usage, CPU power and, more importantly, energy, to increase their lifetime and productivity. Besides harvesting energy, increasing the lifetime of sensors in the network by decreasing their energy consumption has become one of the main challenges of using WSNs in practical applications. In response to this challenge, over the last few years there have been increasing efforts to minimise energy consumption via new algorithms and techniques in different layers of the WSN, including the hardware layer (i.e., sensing, processing, transmission), network layer (i.e., protocols, routing) and application layer; most of these efforts have focused on specific and separate components of energy dissipation in WSNs. Due to the high integration of these components within a WSN, and therefore their interplay, each component cannot be treated independently without regard for other components; in another words, optimising the energy consumption of one component, e.g. MAC protocols, may increase the energy requirements of other components, such as routing. Therefore, minimising energy in one component may not guarantee optimisation of the overall energy usage of the network.

Unlike most of the current research that focuses on a single aspect of WSNs, we present an Energy Driven Architecture (EDA) as a new architecture for minimising the total energy consumption of WSNs. The architecture identifies generic and essential energy-consuming constituents of the network. EDA as a constituent-based architecture is used to deploy WSNs according to energy dissipation through their constituents. This view of overall energy consumption in WSNs can be applied to optimising and balancing energy consumption and increasing the network lifetime.

Based on the proposed architecture, we introduce a single overall model and propose a feasible formulation to express the overall energy consumption of a generic wireless sensor network application in terms of its energy constituents. The formulation offers a concrete expression for evaluating the performance of a wireless sensor network application, optimising

its constituent's operations, and designing more energy-efficient applications. The ultimate aim is to produce an energy map architecture of a generic WSN application that comprises essential and definable energy constituents and the relationships between these constituents so that one can explore strategies for minimising the overall energy consumption of the application. Our architecture focuses on energy constituents rather than network layers or physical components. Importantly, it allows the identification and mapping of energy-consuming entities in a WSN application to energy constituents of the architecture.

Furthermore, we perform a comprehensive study of all possible tasks of a sensor in its embedded network and propose an energy management model. We categorise these tasks into five energy consuming constituents. The sensor's energy consumption (EC) is modelled based on its energy consuming constituents and their input parameters and tasks. The sensor's EC can thus be reduced by managing and executing efficiently the tasks of its constituents. The proposed approach can be effective for power management, and it also can be used to guide the design of energy efficient wireless sensor networks through network parameterisation and optimisation.

Later, parameters affecting energy consumption in WSNs are extracted. The dependency between these parameters and the average energy consumption of a specific application is then investigated. A few statistical tools are applied for parameter reduction, then random forest regression is employed to model energy consumption per delivered packet with and without parameter reduction to determine the reduction in accuracy due to reduction.

Finally, an energy-efficient dynamic topology management algorithm is proposed based on the EDA model and the prevalent parameters. The performance of the new topology management algorithm, which employs Dijkstra to find energy-efficient lowest cost paths among nodes, is compared to similar topology management algorithms. Extensive simulation tests on randomly simulated WSNs show the potential of the proposed topology management algorithm for identifying the lowest cost paths. The challenges of future research are revealed and their importance is explained.

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List of publications

Journal

1. **N Kamyabpour**, DB Hoang, "Energy Efficient Parametric Topology Management and Routing in Wireless Sensor Networks", *Computer Communications*, elsevier (submitted).

Conference

2. DB Hoang, **N Kamyabpour**, "Energy-Constrained Paths for Optimization of Energy Consumption in Wireless Sensor Networks", *IEEE Fourth International Conference on Networking and Distributed Computing (ICNDC)*, 2013
3. **N Kamyabpour**, DB Hoang, "Statistical Analysis to Extract Prevalent parameters on Overall Energy Consumption of Wireless Sensor Network (WSN)", *IEEE 13th International Conference on Parallel and Distributed Computing, Applications and Technologies (PDCAT)*, 2012
4. DB Hoang, **N Kamyabpour**, "An energy driven architecture for wireless sensor networks", *IEEE 13th International Conference on Parallel and Distributed Computing, Applications and Technologies (PDCAT)*, 2012
5. **N Kamyabpour**, DB Hoang, "A Task Based Sensor-Centric Model for Overall Energy Consumption", *IEEE 12th International Conference on Parallel and Distributed Computing, Applications and Technologies (PDCAT)*, 2011
6. **N Kamyabpour**, DB Hoang, "A hierarchy energy driven architecture for wireless sensor networks", *2010 IEEE 24th International Conference on Advanced Information Networking and Applications Workshops (WAINA)*, 2010
7. **N Kamyabpour**, DB Hoang, "Modeling overall energy consumption in wireless sensor networks", *IEEE 11th International Conference on Parallel and Distributed Computing, Applications and Technologies (PDCAT)*, 2010

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