

# Design Study of Energy-Efficient Routing Protocol for Wireless Sensor Networks

by

**Lifang Lu**

B.S., Northwestern Polytechnical University

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Lifang Lu

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# Abstract

Recent advances in wireless sensor networks have led to an emergence of many routing protocols. Limited battery capacity of sensor nodes makes energy efficiency a major and challenge problem in wireless sensor networks. Thus, the routing protocols for wireless sensor networks must be energy efficient in order to maximise the network lifetime.

In this thesis, we developed a centralised clustering, energy-efficient routing protocol for wireless sensor networks. Our protocol consists of a cluster head selection algorithm, a cluster formation scheme and a routing algorithm for the data transmission between cluster heads and the base station. The cluster head selection algorithm is performed by the base station using global information of the network. This algorithm aiming at choosing cluster heads that ensure both the intra-cluster data transmission and inter-cluster data transmission are energy-efficient. The cluster formation scheme is accomplished by exchanging messages between non-cluster-head nodes and the cluster head to ensure a balanced energy load among cluster heads. The routing algorithm is based on the optimal transmission range for the data transmission between cluster heads and the base station using multi-hop.

The performance of our routing protocol is evaluated by comparing with three existing routing protocols on a simulation platform. The simulation results show that our protocol can achieve better performance in terms of energy efficiency and network lifetime. Because of the centralised algorithm and multi-hop routing, there is a small communication overhead and transmission delay when using our protocol. Since our protocol can save energy and prolong network lifetime, it is well suited for applications where energy and network lifetime are the primary considerations and small overhead and time delay can be tolerated.

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# Statement of Originality

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

I give consent to this copy of the thesis, when deposited in the University Library, being available for loan and photocopying.

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Date

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# List of Symbols

$E_{elec}$	per bit energy dissipation for running the transceiver circuitry .	25
$\epsilon_{fs}$	amplifier parameter for free space propagation model . . . . .	25
$\epsilon_{tg}$	amplifier parameter for two-ray ground propagation model . .	25
$d_0$	cross-over distance . . . . .	25
$N$	number of nodes in the network . . . . .	28
$N(v)$	number of neighbours of node $v$ . . . . .	28
$dist(v, v')$	distance between node $v$ and node $v'$ . . . . .	28
$R_c$	intra-cluster transmission range . . . . .	28
$\Delta v$	degree-difference of node $v$ . . . . .	28
$\delta$	ideal number of nodes for a cluster to accommodate . . . . .	28
$d_v$	sum of square distance between node $v$ and its neighbours . . .	28
$D(v, BS)$	distance between node $v$ and the base station (BS) . . . . .	28
$E_v$	residual energy of node $v$ . . . . .	28
$W_v$	combined weight of node $v$ . . . . .	28
$w_1, w_2,$ and $w_3$	weighting factors . . . . .	28
$E_{ini}$	initial energy of node . . . . .	28
$A$	area of network field . . . . .	33
$\rho(x, y)$	node distribution in the network . . . . .	33

## LIST OF SYMBOLS

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$k$	energy loss exponent . . . . .	38
$E_{Tx}$	energy dissipation of the transmitter . . . . .	38
$E_{Rx}$	energy dissipation of the receiver . . . . .	38
$R$	inter-cluster transmission range . . . . .	38
$D$	distance between a node and the base station . . . . .	38
$R_{opt}$	optimal inter-cluster transmission range . . . . .	39
$O_A$	ideal relay point . . . . .	40
$(x_a, y_a)$	coordinators of Head A . . . . .	40
$(x_{BS}, y_{BS})$	coordinators of the base station . . . . .	40
$(x_o, y_o)$	coordinators of point $O_A$ . . . . .	40
$S_A$	search region for Head A . . . . .	41
$r_A$	radius of search region for Head A . . . . .	41
$n_A$	next-hop node of Head A . . . . .	41
$f(B)$	relay factor of Node $B$ . . . . .	41
$E_{dir}$	energy dissipation of direct transmission . . . . .	44
$E_{mh}$	total energy dissipation for multi-hop routing . . . . .	45
$\bar{M}$	average number of cluster members . . . . .	59
$\sigma_{load}^2$	variance of cluster member . . . . .	59
$\sigma_{energy}^2$	variance of energy dissipation of cluster head . . . . .	59