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# **A testbed implementation of energy efficient wireless sensor network routing protocols**

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**Dissertation submitted in fulfilment of the requirements for the degree  
*Magister in Computer and Electronic Engineering* at the  
Potchefstroom campus of the North-West University**

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**November 2013**

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# Declaration

I, Joubert Krige hereby declare that the dissertation entitled “A testbed implementation of energy efficient wireless sensor network routing protocols ” is my own original work and has not already been submitted to any other university or institution for examination.

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Signed on the 15th day of November 2013 at Potchefstroom.

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## Acknowledgements

I would like to thank my study leaders, Leenta Grobler and Henri Marais, for their advice, guidance and encouragement.

I would also like to thank Telkom SA for their financial support.

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## Abstract

Wireless Sensor Networks (WSNs) consist of Sensor Nodes (SNs) spatially removed from one another, that can monitor a variety of environmental conditions. SNs then collaboratively communicate the collected information to a central location, by passing along the data in a multi-hop fashion. SN energy resources are limited and energy monitoring and preservation in WSNs are therefore very important. Since multi-hop communication takes place, the routing protocol used may have a significant effect on the balanced use and preservation of energy in the WSN.

A significant amount of research has been performed on energy efficient routing in WSNs, but the majority of these studies were only implemented in simulation. The simulation engines used to perform these studies do not take into account all of the relevant environmental factors affecting energy efficiency. In order to comment on the feasibility of a routing protocol meant to improve the energy efficiency of a WSN, it is important to test the routing scheme in a realistic environment.

In this study, a SN specifically designed to be used in an energy consumption ascertaining WSN testbed was developed. This SN has a unique set of features which makes it ideal for this application. Each SN is capable of recording its own power consumption. The design also features a lithium battery charging circuit which improves the reusability of the SN. Each node has a detachable sensor module and transceiver module which enables the researcher to conduct experiments using various transceivers and sensors. Twenty of these SNs were then used to form an energy consumption ascertaining WSN testbed.

This testbed was used to compare the energy consumption of a Minimum Total Transmission Power Routing (MTTPR) scheme to a shortest hop path routing scheme. The results show that each SN's transmission power setting dependant efficiency has a significant effect on the overall performance of the MTTPR scheme. The MTTPR scheme might in some cases use more energy than a shortest hop path routing scheme because the transmission power setting dependant efficiency of the transceiver is not

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taken into account. The MTTPR scheme as well as other similar routing schemes can be improved by taking the transceiver efficiency at different transmission power settings into account. Simulation environments used to evaluate these routing schemes can also be improved by considering the transceiver efficiency at different transmission power settings.

**Keywords:** *Energy Aware Routing, Energy Efficient, Sensor Node, Testbed, Wireless Sensor Network, Minimum Total Transmission Power Routing*

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# List of Acronyms

**AODV** Ad Hoc On-Demand Distance Vector

**AFE** Analog Front End

**API** Application Programming Interface

**AS** Autonomous System

**CCA** Clear Channel Assessment

**CCL** Command and Control Scripting Language

**CMMBCR** Conditional Max-Min Battery Capacity Routing

**CSMA-CA** Carrier Sense Multiple Access with Collision Avoidance

**DSN** Data Sequence Number

**ED** Energy Detect

**EIRP** Equivalent Isotropically Radiated Power

**ETSI** European Telecommunications Standards Institute

**ETX** Expected Transmission Count

**FCS** Frame Check Sequence

**FPGA** Field-Programmable Gate Array

**GPIO** General-Purpose Input/Output

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**GTS** Guaranteed Time Slot

**GUI** Graphical User Interface

**I2C** Inter-Integrated Circuit

**IOS** International Organization for Standardization

**ISM** Industrial, Scientific and Medical

**LEACH** Low Energy Adaptive Clustering Hierarchy

**LED** Light-Emitting Diode

**IETF** Internet Engineering Task Force

**LDO** Low-Dropout Regulator

**LQI** Link Quality Indicator

**LR-WPAN** Low-Rate Wireless Personal Area Network

**MAC** Medium Access Control

**MANET** Mobile Ad Hoc Network

**MBCR** Minimal-Battery Cost Routing

**MiMAC** Microchip Wireless (MiWi) Media Access Controller

**MLME** MAC Sublayer Management Entity

**MMBCR** Min-Max Battery Cost Routing

**MPDU** MAC Protocol Data Unit

**MPR** multipoint relay

**MTTCP** Minimum Total TransCeiving Power

**MTTP** Minimum Total Transmission Power

**MTTPR** Minimum Total Transmission Power Routing

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**MTRTP** Minimum Total Reliable Transmission Power

**OSI** Open Systems Interconnection

**OLSR** Optimized Link State Routing

**SN** Sensor Node

**OS** Operating System

**OSPF** Open Shortest Path First

**OSR** Oversampling Ratio

**P2P** Point to Point

**PAN** Personal Area Network

**PCB** Printed Circuit Board

**PHY** Physical Layer

**PLL** Phase-Locked Loop

**PLME** Physical Layer Management Entity

**PPDU** PHY Protocol Data Unit

**RIP** Routing Information Protocol

**ROLL** Routing Over Low Power and Lossy Networks

**RTCC** Real-Time Clock and Calendar

**SAP** Service Access Point

**SCS** Statistical Consultation Service

**SPCO** Single Pole Changeover

**SPI** Serial Peripheral Interface

**TDMA** Time Division Multiple Access

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**TEEN** Threshold Sensitive Energy Efficient Sensor Network Protocol

**TWIST** TKN Wireless Indoor Sensor network Testbed

**USART** Universal Synchronous/Asynchronous Receiver/Transmitter

**WSN** Wireless Sensor Network

**ZC** ZigBee Coordinator

**ZED** ZigBee End Device

**ZR** ZigBee Router

# List of Symbols

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$I$	Current
$d$	Distance
$E$	Energy
$f$	Frequency
$G$	Gain
$P$	Power
$R$	Resistance
$c$	Speed of light
$t$	Time
$V$	Voltage
$\lambda$	Wavelength