DESIGN OF ENERGY EFFICIENT EMBEDDED CONTROLLED SENSOR NETWORKS

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by

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CERTIFICATE

This is to certify that the thesis titled **"DESIGN OF ENERGY EFFICIENT EMBEDDED CONTROLLED SENSOR NETWORKS"** is being submitted by Mr. Vaneet Singh to Indian Institute of Technology Delhi for the award of the degree of **Doctor of Philosophy**. This thesis is a record of bona-fide work carried out by him under our guidance and supervision. In our opinion, the thesis has reached the standards fulfilling the requirements of the regulations relating to the degree.

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

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ABSTRACT

Embedded controlled sensor networks are being widely adopted for many applications including very complicated tasks, like control of military operations in remote areas. However, a major concern for embedded controlled sensor network technologies are a short lifetime and high maintenance cost due to limited battery energy. The objective of this thesis is to investigate the feasibility of an energy efficient embedded sensor network. To achieve this goal, novel approaches to implementation of energy efficient embedded controlled sensor network are analyzed and benchmarked. Detailed analysis has led to innovative solutions at micro-controller, routing protocols and the sensors levels.

An Embedded controlled sensor network system, for monitoring of environmental as well as agricultural parameters, has been developed in compliance with IEEE 802.15.4 standard. The sensor array is implemented by interfacing various low power and low cost sensors along with JN5148 microcontroller to form the base node. Sensors are recalibrated using the potentiometer adjustment technique of signal conditioning circuits. The developed ECSN is low cost and energy efficient. It uses available off the shelf components.

For making ECSN more energy efficient, the important parameters are the microcontroller and the routing protocol. An application specific microcontroller dedicated to embedded sensor network has been proposed as a solution. Simulation of the proposed 8 bit microcontroller has been carried out. This is tested for ECSN application related algorithms. The proposed microcontroller is more energy efficient as compared to the existing microcontrollers. An energy efficient clustering algorithm based on average residual energy is proposed. The performance of proposed

clustering scheme is evaluated and compared with existing clustering algorithms. The proposed clustering algorithm is much more energy efficient as compared to existing clustering schemes.

In conclusion, important contributions of the work are summarized. Scope of the further work in this area is finally outlined.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND SYMBOLS

C_{CO_2}	Concentration of CO_2 Gas (ppm)
V_{OUT-CO_2}	Output Voltage of CO_2 sensor Module (Volts)
ADC	Analog to digital Converter
AF	Application Framework
ALU	Arithmetic logic unit
APS	Application Sub layer
ASIC	Application Specific Integrated Circuit
ASK	Amplitude Shift Keying
BEM	Building Energy Management
BPSK	Binary Phase Shift Keying
CDMA	Code Division Multiple Access
CH	Cluster Head
CMOS	Complementary Metal Oxide Semiconductor
CRC	Cyclic redundancy check
CSMA-CA	Carrier Sense Multiple Access-Collision Avoidance
DOE	Department of Energy
DSSS	Direct Sequence Spread Spectrum
DWEHC	Distributed Weight-based Energy-efficient Hierarchical Clustering protocol
ECG	Electrocardiogram
ECSN	Embedded Controlled sensor Network
EECS	Energy Efficient Clustering Scheme
EEHC	Energy efficient heterogeneous clustered
EPA	Environmental Protection Agency

FDMA	Frequency Division Multiple Access
FMP	Final Mean Point
FND	First of the node die
FPGA	Field-Programmable Gate Array
GPIO	General Purpose Input Output
GPR	General purpose register
GTS	Guarantee Time Slots
HDL	Hardware Description Language
HEED	Hybrid. Energy-Efficient Distributed
HND	Half of the node die
IDE	Integrated development environment
IP	Intellectual property
ISM	Industrial, Scientific And Medical
LEACH	Low Energy Adaptive Clustering Hierarchy
LEACH-C	Low Energy Adaptive Clustering Hierarchy- Centralized
MAC	Media Access Control
NRZ	Non return to zero
O-QPSK	Offset-Quadrature Phase Shift Keying
OSI	Open Systems Interconnection
PANEL	Position-based Aggregator Node Election
PC	Personal Computer
RAM	Random Access Memory
RE	Residual Energy
RISC	Reduced instruction set computer
RLE	Reverse Encryption Algorithm
ROM	Read Only Memory

RTC	Real Time Clock
SMAC	Sequential Model-Based Algorithm Configuration
SPI	Serial Peripheral Interface
SPINS	Security Protocols for Sensor Networks
SRAM	Static Random Access memory
TDMA	Time Division Multiple Access
TEA	Tiny Encryption Algorithm
UART	Universal Asynchronous Receiver/Transmitter
ZDO	Zigbee Device Object