WIRELESS BIOMEDICAL SENSOR NETWORK FOR HOME-BASED HEALTHCARE MONITORING SYSTEM

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

FEBRUARY 2011

To my beloved parents, brothers, sisters and friends....

ACKNOWLEDGEMENT

In the name of ALLAH The Most Gracious and Most Merciful, my utmost gratitude to Him for giving me strength to complete this thesis. Peace be upon Prophet Muhammad S.A.W, Family as well as His Beloved Friends.

Here, I would like to express my sincere gratitude to my supervisor Dr. Sharifah Hafizah Syed Ariffin for her invaluable advice, guidance as well as support in the effort to accomplish this project. Further appreciation especially to Prof. Dr Norsheila Fisal and Pn Rozeha Rashid for their guidance, help, advice as well as criticisms to increase the quality of this project.

I am also very thankful to all my laboratory mates who have helped me both in my research which included Ariff, Abdul Hadi Fikri, Yaakub Yakubu, Adib, Nurhija, Kashif, Dr Adel, Hamdan, Kal, Abang Arif, Shidan, Nadia, Izzah and the practical training students Faiz, Jia, Ika and Ecah. Not forgetting, i would like to express my appreciation to my family especially Cik Ani bin Mat and Nuurul Afifah Hussin for continuous support and encouragement which contribute to the successful of this project.

ABSTRACT

Wireless Sensor Network (WSN) consists of sensor nodes that interact with each other to collectively monitor environmental or physical conditions at different location for the intended user. One of its potential deployment is for the form of Wireless Biomedical Sensor Network (WBSN) to measure physiological signals. The WBSN applications would allow the medical practitioners to continuously monitor and update the status of a patient from a far. This project focuses on the development of a WBSN platform for home-based healthcare monitoring over WBSN which complies with IEEE 802.15.4 standard and operates in 2.4 GHz ISM (industrial, scientific and medical) band. The initial state of WBSN development is the design of the wireless sensor node called TelG. The main feature of TelG include low power consumption, wearable, flexible and small size. It is then embedded with a self-built operating system called WiseOS to support customized operation. The home-based healthcare monitoring system is able to operate via web-based with the capability multi-hop real-time communication using Lightweight Real-time Load Distribution (LRTLD) routing protocol for device discovery. The system is also capable of displaying patients data which include electrocardiogram (ECG), pulse rate and temperature. The performance of the TelG is tested experimentally and found to be comparable with other sensor nodes in the market. The node can achieve packet reception rate (PRR) above 80% for a distance of up to 6 meters and also for up to 3 hops at different transmission rates. In addition, the LRTLD routing protocol takes less than 1 millisecond to obtain information on the forwarding node. It is also observed that the packet transmission rate does not affect the end-to-end delay if the range of communication is less than 10 m. The WBSN is tested in a real experimental test bed and are able to successfully provide ECG, pulse rate and temperature data for remote monitoring of patient at home from the hospital.

ABSTRAK

Rangkaian Penderia Wayarles (WSN) terdiri daripada nod-nod penderia yang berhubung di antara satu sama lain untuk mengawal persekitaran ataupun keadaan fizikal pada tempat yang berbeza kepada pengguna yang berkenaan. Salah satu penempatan yang berpontensi adalah dalam membentuk rangkaian Penderia Bioperubatan Wayarles (WBSN) untuk mengukur isyarat fisiologi. Aplikasi WBSN membenarkan pengamal perubatan untuk memantau pesakit secara beterusan dan juga dapat mengemaskini keadaan semasa pesakit dari jauh. Projek ini memberi penumpuan kepada pembinaan pelantar WBSN untuk pegawasan kesihatan berpangkalan dari rumah melalui WBSN di mana ia mematuhi piawaian IEEE 802.15.4 dan beoperasi dalam jalur gelombang ISM(industri, sainstifik dan perubatan) 2.4GHz. Peringkat awal pembangunan WBSN ialah reka bentuk nod penderia wayarles yang dinamakan TelG. Ciri-ciri utama TelG adalah termasuk pengunaan kuasa yang rendah, mudah digunakan, fleksibel, dan bersaiz kecil. Ia juga dibenamkan dengan sistem pengendalian binaan diri yang dipanggil WiseOS untuk menyokong penyesuaian operasi. Sistem pengawasan kesihatan berpangkalan rumah mampu beroperasi melalui pangkalan web dengan kebolehan perhubungan lompatan berbilang masa nyata dengan menggunakan protokol laluan Masa Nyata Pengagihan Beban Ringan (LRTLD) untuk pencarian peranti. Sistem juga berkemampuan untuk memaparkan data pesakit termasuk elektrokardiogram (ECG), kadar denyut nadi dan juga suhu. Perestasi TelG telah diuji secara ujikaji dan di dapati setanding dengan nod pengesan yang berada dipasaran. TelG boleh mencapai kadar penerimaan paket (PRR) sehingga 80% untuk jarak sehingga 6 meter bagi jumlah sehingga 3 lompatan pada kadar penghantaran yang berlainan. Tambahan, protokol laluan LRTLD mengambil masa kurang daripada 1 milisaat untuk memperolehi maklumat mengenai nod destinasi. Ia juga menunjukkan bahawa kadar penghantaran paket tidak memberi kesan kepada masa yang diambil dari satu nod ke nod yang lain jika jarak penghantaran adalah kurang daripada 10 meter. WBSN telah pun diuji di dalam ujikaji yang sebenar dan telah berjaya membekalkan ECG, kadar denyutan nadi dan suhu untuk pemantauan pesakit di rumah melalui jarak jauh dari hospital.

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LIST OF ABBREVIATIONS

ADC	-	Analog to Digital Converter
AODV	-	Ad hoc On Demand Distance Vector
API	-	Application Programming Interface
BAN	-	Body Area Network
CCU	-	Central Control Unit
COTS	-	commercial off-the-shelf
CSMA	-	Channel Sense Multiple Access
ECG/EKG	-	Electrocardiogram
EEG	-	Electroencephalography
EEPROM	-	Electrically Erasable Programmable Read-Only Memory
EMG	-	Electromyography
EMTs	-	Emergency Medical Technician
GBR	-	Gradient-Based Routing
GHz	-	Gigahertz
GPSR	-	Greedy Perimeter Stateless Routing
HHMC	-	Hospital Health Monitoring Center
HHMD	-	Hospital Health Monitoring Center
HTML	-	Hyper Text Markup Language
ISM	-	The industrial, scientific and medical radio bands
ISP	-	In System Programming
kbps	-	kilobit per second
KHz	-	Kilohertz
LED	-	Light-Emitting Diode
LRTLD	-	Lightweight Real-Time Load Distribution
LTRT	-	Least Total-Route Temperature
MAC	-	Medium Access Control
MASN	-	Medical Ad hoc Sensor Network
MCE	-	Mass Casual Event

MHz	-	Megahertz
MICS	-	Medical Implant Communication Service
MTU	-	Maximum Transmission Unit
NIBP	-	Non-Invasive Blood Pressure
OF	-	Optimal Forwarding
OS	-	Operating System
OSI	-	Open System Interconnection
PC	-	Personal Computer
PDA	-	Personal Digital Assistance
PHP	-	Hypertext Preprocessor
PRR	-	Packet Reception Rate
QoS	-	Quality of Service
RAM	-	Random Access Memory
ROM	-	Read-Only Memory
RSSI	-	Received Signal Strength Indicator
RTC	-	Real-Time Clock
RTLD	-	Real-Time Load Distribution
SMS	-	Short Message Service
SNR	-	Signal Noise to Ratio
SPIN	-	Sensor Protocol for Information via Negotiation
SpO2	-	Saturation of Peripheral Oxygen
TCP/IP	-	Transmission Control Protocol/Internet Protocol
TinyADMR	-	Tiny Adaptive Demand-Driven Multicast Routing
TQFP	-	Thin Quad Flat Pack
TRG	-	Telematic Research Groups
UART	-	Asynchronous Receiver/Transmitter
WBSN	-	Wireless Biomedical Sensor Network
WiseOS	-	Wise Operating System
WSN	-	Wireless Sensor Network

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LIST OF SYMBOL

t_a	-	Arrival time
t_t	-	Transmission time
P_r	-	Receive power
G_r	-	Receive antenna gain
G_t	-	Transmit antenna gain
R	-	Distance between antenna
V_{batt}	-	Maximum battery voltage
$V_{Mbat}t$	-	Available battery voltage
P_t	-	Power transmit
S_r	-	Receiver sensitivity
PL(d)	-	Path loss model
V_{in}	-	Voltage input
V_{ref}	-	Voltage reference
d	-	Distance

LIST APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview

Throughout this decade, Wireless Sensor Network (WSN) has achieved successful technology, as in WSN applications, node platform manufacturing, embedded operation system development and network protocol. In the node platform manufacturing, integrated circuit technologies enable the development of low-cost, low power and multifunctional sensor node that are small in size. WSN technology also increases the robustness, fault tolerance, efficiency and flexibility of the developed embedded operating system and network protocol. WSN composed of a large number of sensor nodes and multi-hop networking capability that are densely deployed for a wide variety of applications such as smart buildings, interactive user interfaces; environment control and highly suitable for monitoring in military and biomedical applications.

Figure 1.1 shows the various WSN applications. WSN applications can be classified into two types including tracking application and monitoring application [1]. Tracking application refers to tracking the location of an animal, human, vehicle or object. Example of existing WSN tracking application is the Real-time Indoor Localization for Emergency Responder by Delft University, and ZebraNet [2]. In the monitoring application, the wireless sensor node has been used to monitor the activity or behaviour, of as animals, human beings, environment and weather. The existing application that has been successful implemented are in the Cyclops [3], WSN in a petroleum facility [4] and paddy field monitoring [5].

The implementation of WSN technology in the healthcare application called Wireless Biomedical Sensor Network (WBSN) application has stimulated great interest in the development of healthcare monitoring application such as smart home health monitoring [6], smart ward [7] and athletic performance monitoring [8]. This WBSN provides the healthcare application more flexibility, reliable, efficient, low cost, reduced time, secured and power efficient. The WBSN application would allow the medical practitioners to continuously monitor and update the status of the patient from a far.

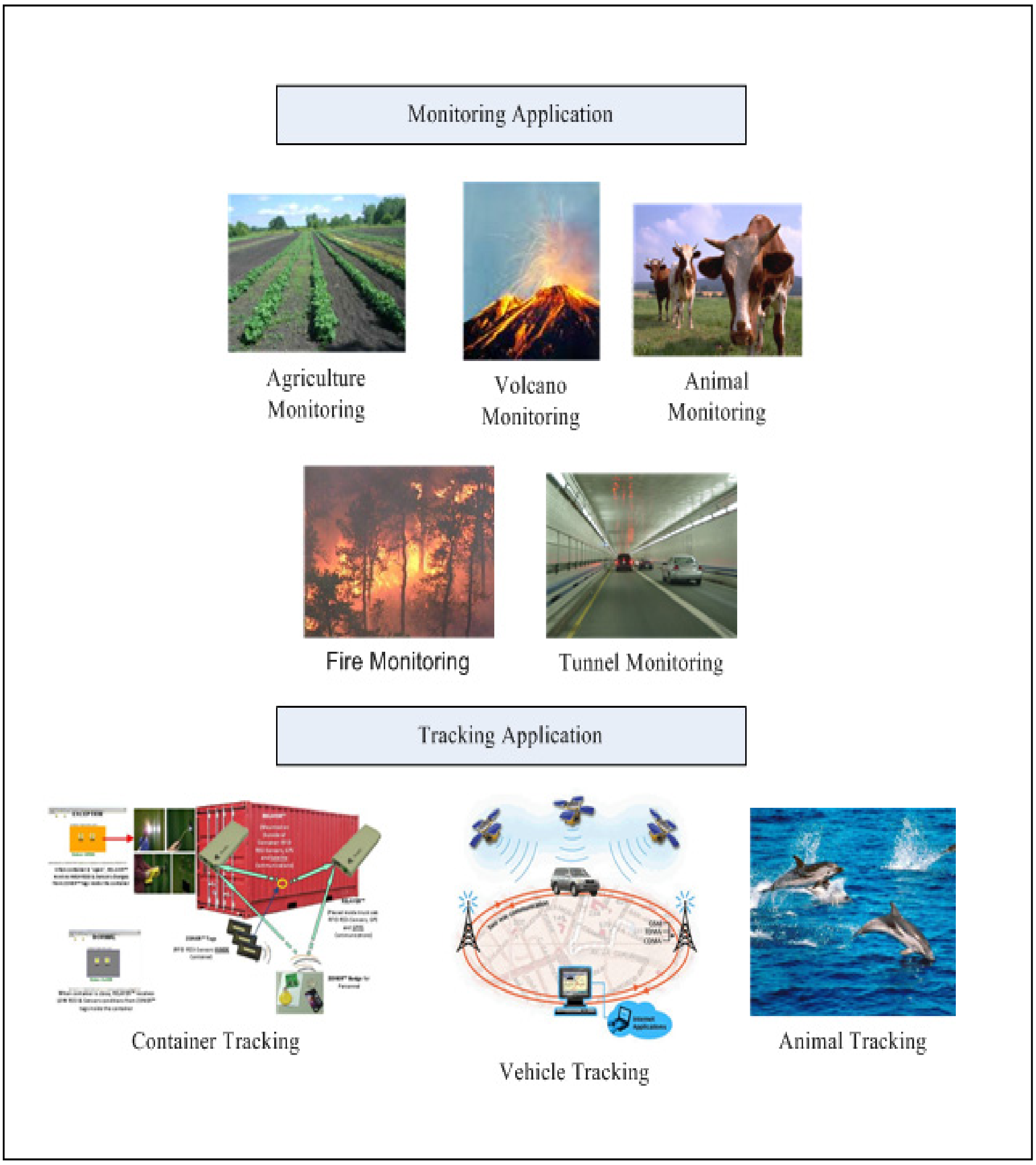

Figure 1.1 WSN application

1.2 Problem Statement

The need to effectively design systems which are relatively cheap, scalable, biologically compatible and energy efficient for health monitoring application is very crucial. There has been an explosive growth in demand for WBSN in home healthcare system due to increase in population and technological advancement. Sensor devices can be used to capture continuous, real-time vital signs from a large number of patients, relaying the data to handheld computers carried by emergency medical technicians (EMTs), physicians, and nurses.

Wearable sensor nodes can store patient's data such as identification, history, and treatments supplementing the use of back-end storage systems and paper charts. In a mass casualty event (MCE), sensor networks can greatly improve the ability of first responders to triage and treat multiple patients equipped with wearable wireless monitors. This has revolutionalized the medical and health industry by providing systems which are highly sophisticated and can be used to constantly monitor and observed patients. Hence, this will reduce the health care cost and allow doctors to remotely access information about their patient. More importantly, diseases can be detected in their early stage and diagnose immediately by medical doctors.

It is challenging to meet up with low power, security, delay and throughput requirements due to time-varying changing wireless environment. Several existing biomedical devices also do not support the patient mobility since they are wired. For medical applications, wireless biomedical system should be reliable and secured in order to ensure effective communication. Medical field has been one of the mission critical applications which require high precision and accuracy, mobility and good coverage. This ultimately requires more reliable and robust design to properly monitor and diagnose patient via WBSN.

In order to effectively transport medical data over WBSN, there is a dramatic need to design energy efficient, economically affordable, flexible, user and environmental friendly WBSN. This project focuses on the development of the WBSN to enhance the available service provider in order to support the medical applications. This project concentrates on the development of the hardware and software development for wireless biomedical application.

1.3 Research Objective

The goal of this research to develop a WBSN for home-based healthcare monitoring system. The WBSN will consist of the hardware platform, the operating system, the routing protocol and the application running on it. Hence, main objective in the development of WBSN include:

- To design a wireless sensor node platform for WBSN.
- To embed the wireless sensor node with LRTLD multi-hop routing protocol running in WBSN.
- To develop a home-based healthcare monitoring system prototype on the proposed WBSN

The proposed design of WBSN will be developed and implemented on a real test bed environment.

1.4 Scope of Work

The scope of this research is to design a low cost sensor node application for WBSN. The sensor node design will consists of a processing unit, wireless transceiver module, data logger, and also medical sensor devices called the TelG wireless sensor node. The XBEE module will be used as the wireless module.

Sensor nodes will be embedded with multi-hop routing protocol called Lightweight Real-time Load Distribution (LRTLD) multi-hop routing protocol which provide real-time routing and distributed load balancing. The design and functionality of LRTLD will embedded in the TelG be studied and developed.

Lastly, A home-based healthcare monitoring system, based on hardware and software implementation has been developed and integrated with the TelG wireless sensor node and LRTLD multi-hop routing protocol to relay the data from the patient body to the base station. The TelG at the patient body will be integrated with CSN808 medical sensor called TelG-based CSN808 sensor node. The operation on the system prototype will be investigated in the real test bed implementation.

1.5 Thesis Outline

This thesis consists of six chapters. Chapter 1 serves as an introduction to the thesis. It covers topics such as problem statement, objectives of the research and scope of the project.

Chapter 2 provides the relevant background to understand WSNs and WBSN. The typical WSN architecture will be explained which includes research challenges and routing protocol in the WSN. The existing wireless sensor node and routing protocol in the WBSN application will be explained. The related WBSN application related to the project will also be described.

Chapter 3 describes the design and development of TelG wireless sensor node platform for WBSN application. The design considerations and the designed architecture for the development of the wireless sensor node will also be discussed.

Chapter 4 explains the Lightweight Real-time Load Distribution (LRTLD) multi-hop routing protocol. The design concept and requirement of the proposed multi-hop routing protocol will be explained in this chapter. The proposed multi-hop routing protocol will be embedded into the TelG wireless sensor node and the functionality of the purposed multi-hop routing protocol will be investigated.

Chapter 5 presents the biomedical sensor network prototype for home-healthcare monitoring. The integration between of TelG wireless sensor node platform and CSN808 medical sensor device will be discussed. The implementation of TelG wireless sensor node and the LRTLD multi-hop routing protocol in the home-based healthcare monitoring system will be identified. Lastly the functionality of the system will be verified by real-time testing and practical implementation.