MEASUREMENT AND VALIDATING ENERGY HARVESTED IN WIRELESS SENSOR NODES

MOHD ADDIE BIN AMIR

This Report Is Submitted In Partial Fulfilment of The Requirements For The Award Of Bachelor Of Degree Electronic Engineering (Telecommunication Electronics) With Honours

Faculty of Electronic Engineering and Computer Engineering Universiti Teknikal Malaysia Melaka

JUNE 2014

UNIVERSTI TEKNIKAL MALAYSIA MELAKA
FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : MEASUREMENT AND VALIDATING ENERGY HARVESTED IN WIRELESS SENSOR NODES

Sesi Pengajian :

1	3	/	1	4

Saya MOHD ADDIE BIN AMIR

mengaku membenarkan Laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (√) :

☐ **SULIT*** *(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

☐ **TERHAD**** **(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☐ **TIDAK TERHAD**

Disahkan oleh:

(TANDATANGAN PENULIS) (COP DAN TANDATANGAN PENYELIA)

"I hereby declare that this report is the result of my own work except for quotes as cited in the references."

Signature: …………………………………………………

Author : MOHD ADDIE BIN AMIR

Date : …………………………………………………

"I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the scope and quality for the award of Bachelor of Electronic Engineering (Telecommunication Electronics) With Honours."

Signature : …………………………………..

Supervisor's Name : ENGR. VIGNESWARA RAO A/L GANNAPATHY

Date : ………………………………….

DEDICATION

To

My Beloved Parents,

En Amir bin Kimin and Hamidah binti Abdul Aziz,

My Brother and Sister,

My kind hearted supervisor,

ENGR. Vigneswara Rao A/L Gannapathy

And all my dearest friends.

ACKNOWLEDGEMENT

First of all, I would like to thank to Allah the Almighty who always beside me guiding and giving me blessing to finish my Project Sarjana Muda II successfully.

My sincere appreciation and gratitude are dedicated to my honourable supervisor, ENGR. Vigneswara Rao A/L Gannapathy for his encouragement, guidance and critics. Without his continued support and interest, this thesis would not have been the same as present here.

I would like to extend my sincere appreciation to all my dearest friend, encouragement and always being beside me in every condition. Not to forget, all students under the same supervisor thanks you for sharing the similar knowledge.

Last but not least, I would like to thank my beloved family especially my loving parents, En Amir bin Kimin and Pn. Hamidah binti Abdul Aziz. Their loves, supports and prayers have given me the strength to finish what I have started. Finally, to everybody that has been involved in my project directly or indirectly, thank you very much.

ABSTRACT

In this research I will research in Performance Analysis Energy Harvested Wireless Sensor Nodes. Wireless sensor technology, which integrates transducers, measurement electronics and wireless communication, has become increasingly vital in structural monitoring applications. Wireless sensor networks are used in scenarios where many sensors need to collect data and exchange with a central base station. These battery powered devices are expected to have a long lifetime as frequent battery replacement is labor intense and in some cases may not be possible due to deployment constraints. Furthermore, in the case of wireless sensor nodes located on structures, it is often advantageous to embed them, which makes an access impossible. Therefore, if a method of obtaining the untapped energy surrounding these sensors was implemented, significant life could be added to the power supply. A smart approach is to adapt the system according to the incoming energy. One of the ways is using green and unlimited source energy with harvesting solution. In this paper, we aim in havested the performance of the energy various applications and validate it on its efficiency, reliability and robustness to overcome the problems faced by the use of batteries. A comparison will be made on the performance that vary from the power consumption, network type, mobility, latency and also data throughput.

CONTENTS

II LITERATURE REVIEW

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Introduction

Energy harvesting is the process by which energy is derived from external sources, example is solar power, thermal energy, wind energy, and kinetic energy captured and stored for small wireless autonomous devices like those used in wearable electronics and wireless sensor networks.

Energy harvesting takes advantage of these sources to provide energy that is renewable and more environmentally friendly than that derived from fossil fuels. It is most often used to generate electricity, but can generate other energy forms as well.

Energy harvesters provide a very small amount of power for low-energy electronics. While the input fuel to some large-scale generation costs money (oil, coal, etc.), the energy source for energy harvesters is present as ambient background and is free. For example, temperature gradients exist from the operation of a combustion engine and in urban areas; there is a large amount of electromagnetic energy in the environment because of radio and television broadcasting.

Ambient energy is in many different forms such as thermal, chemical, electrical, and mechanical. To make use of energy harvesting one or more of these energy fields must be present in the environment of interest, and there must be a suitable transducer to convert the energy.

Off-grid energy is an energy harvesting is used where another supply of energy is not available. Harvesters cost money, so it only makes sense to use them when it is too expensive or physically impossible to use other energy sources such as grid electricity or batteries.

Selection of harvested energy also depends on the place where the sensor is to be placed. It should match the energy that is easily available and ongoing.

Wireless sensor networks [1] are an exciting new area of research. They belong to the class of ad-hoc networks, where the individual nodes have limited sensing, computation, communication and energy. The large scale of such networks prohibits human intervention for network maintenance. One of the very scarce resources for these types of networks is energy. These networks are expected to have a long lifetime.

Wireless sensor networks (WSNs) have attracted a great research interest in recent years. Since wireless sensor nodes can provide information from previously inaccessible locations and from previously unachievable number of locations, many new application areas are emerging, such as environmental sensing, structural monitoring and human body monitoring. Although wireless sensor nodes are easy to deploy, the lack of physical connection means they must have their own energy supply. Because batteries have limited lifetime and are environmentally hazardous, it has become widely agreed that energy harvesters are needed for long-lasting sensor nodes. The idea is to use energy harvester to capture small amounts of energy from the environment and use the generated energy to power the nodes in wireless sensor networks.

1.2 Objective

The objectives of this project are:

1) To investigate the efficiency, reliability and robustness of energy harvested WSN.
2) To evaluate the performance of energy harvested WSN in term of power consumption, latency and throughput.
3) To validate the performance of energy harvested WSN in real environment.

1.3 Scope of work

This project involves developing a comparison between using battery and energy harvested in wireless sensor nodes. The analysis and measurement will developed based on efficiency, reliability and robustness. The software Dolphin View will use as an interface to measure the performance of wireless sensor nodes.

1.4 Problem statement

Wireless sensor nodes are easy to deploy, the lack of physical connection means they must have their own energy supply. Because batteries have limited lifetime and are environmentally hazardous, it has become widely agreed that energy harvesters are needed for long-lasting sensor nodes.

Performance measurement is including power consumption, time response, network mobility and throughput.

1.5 Summary

Energy harvesting has many methods and resources that can be taken to be converted into electric energy. Energy output from each source is different. The selection of resources to be energy to wireless sensor nodes is also becoming a problem. This is because the wireless sensor nodes are placed all over the place up to the point that we cannot accomplish for maintenance and so on.

In the transmit and receive system, the system needs enough power to transmit information to the receiver. If the power supplied is not enough, then there will be loses the signal being transmitted. Throughput received by the receiver will be reduced as a result loses the transmitter. Thus the energy has to be improved to overcome this problem.

Efficient solar energy harvester for low-power wireless sensor nodes is proposed in this paper. In the proposed harvester, maximum power point tracking (MPPT) is achieved by using the constant voltage detection principle . Implementation MPPT control circuit is carried out using the discrete analog components. This is to reduce energy use in electronic circuits. The experimental results obtained from polycrystalline solar panel 45 mm × 76 mm in a laboratory setting to show harvest of 400 mW average powers under 1 sun solar insolation. The proposed harvester is used to power the battery which then feeds the sensor nodes.

Harvester systems provide overall efficiency of about 93 %. The harvesting of solar energy is also tested with a crossbow wireless sensor node (WSN) for monitoring the temperature of the external environment real field. Harvesters could extend the lifetime of wireless sensor nodes to the almost infinite while the battery -powered WSN become inactive after 150 hours of operation.

Therefore, the ability of the project to study and measure the wireless sensor node using harvested energy as its power source. This project focuses primarily designed to perform energy harvesting wireless sensor nodes with multiple applications and verify the efficiency, reliability and dependability. The uses of the potential that can be tested for lead are industrial control, home automation, environmental sensing and health monitoring. Performance measurement tool is in terms of power consumption, type of network, mobility, latency and data processing. A comparison between the two sources used for development.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In recent years, there has been an increasing need for apply energy harvesting in wireless sensor nodes (WSN). Energy harvesting methods such as RF powered systems, solar powered system, wind powered system, motional energy harvesting system, thermoelectric powered system, and piezoelectric conversion system can be used to harvest energy from a controlled or ambient environment, to power wireless sensor nodes or store the energy in capacitor or batteries for later use. These harvesting method support wide range of application and also can be used to increase lifetime of wireless sensor nodes. The advantages of energy harvesting application are that reduce or eliminate the dependency of wireless sensor nodes on batteries and power source while prolonging their lifetimes or the time between charging of wireless device. Energy harvesting approaches are mostly used in micro-power application as wireless sensor network, biomedical implants and radio frequency identification. These systems are often very small size and require little power to operate.

This dissertation covers energy harvesting power interface circuit, used to directly power us wireless sensor nodes and charge the capacitor. A general block diagram of a power harvesting is shown in figure 2.1.

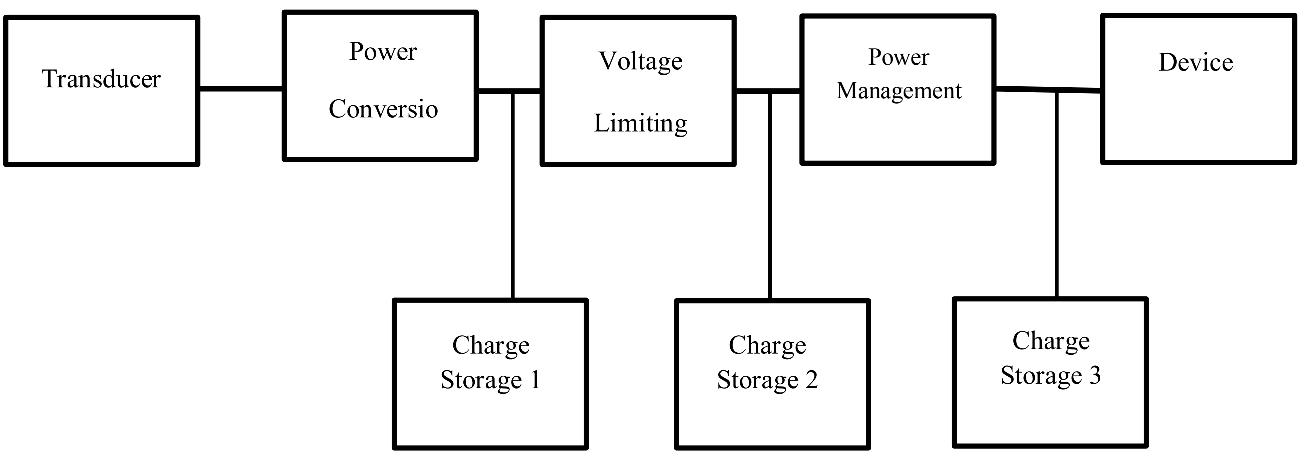

Figure 2.1 General block diagram of an energy harvesting system

For a general energy harvesting system, there must be a transducer that harvest energy and convert it into electric power. The transducer can be an antenna, a piezoelectric device, a solar cell, a fuel cell, a wind turbine, and many other forms. The electric power available at the output of the transducer can be in the form direct current or alternating current and can vary depending on the mode of energy harvesting. A power conversion interface circuit is required to convert the energy to a usable form for storage or may pass to a voltage regulation circuit.

The power conversion circuit may be in the form of rectifier or a DC to DC voltage converter. For certain power conversion interface circuit, impedance matching or maximum power tracking is required to ensure maximum power transmit for between the power source and power harvester. The charge storage device in this case can be capacitor, a battery or any other charge storage element.

2.2 Related Work

Researchers solved performance energy harvested in Wireless Sensor Nodes by proposing measurement in energy consumption, energy management and network function.

To ascertain the stability of WSN functionality at acceptable level during the operation, this paper proposes an incipient performance monitoring algorithm. The proposed algorithm tracks network operation and isolate network nodes afore they have a distorted high impact on network amassed data precision or network lifetime [4]. That purposed algorithm functionality was tested on a Berkeley (Crossbow) Mica2 sensor motes test bed with the 'Surge' multihop application of TinyOS. However, the proposed algorithm has been tested using Multi-hop applications TinyOS 'Surge' run at Berkely Mica2 sensor node testbed. Empirical experiments show VMBA algorithms that detect 100% of the nodes is broken when the number of faulty nodes is 50% or less. There are many aspects to be considered in future to extend this work and improve the algorithm functions, such as examining the effects of mobility sensor nodes to function algorithm.

Without energy, sensor will not work and do not give anything on the network. Therefore, research efforts have been undertaken to develop a protocol that is able to control the energy in this range. However, another effort has been made to replace the harvested energy as an energy source. However, this energy produces only a little energy to cover the sensor is operating. Author discusses research on the challenge to create Wireless Sensor Nodes powered up by energy harvested [5]. There are some important points highlighted as power management, data delivery schemes, Topology and connectivity, energy storage technology and reliable data delivery. However, the author only discussed in theory and not does the actual measurement.

Also, Zaho suggest aggregation -predicated approach to energy map that sends a message recording consequential energy level drops to sink. Though energy consumption is very paramount in WSNs and all affected by the network, several researchers such as show in their analysis that there could be a sharp decline in node and network functions that are not possible to detect by quantifying the voltage level [13]. This decline resulted network instability due to the sudden change of route, and more energy use due to non-optimal route destinations.

2.3 Radio Frequency Energy Harvesting

Other than direct wiring, the most common method of distributing power to embedded electronic though the use radio frequency (RF) radiation. RF power harvesting is most often used in RFID or passive tags to replace the bar code as a new form of data collection. Passive RFID tags are typically used in very short range of less than 3meter. RF powered device are also used in application such as structure monitoring where RF powered device are embedded into a structure making battery replacement impossible without destroying the structure. Some application employing RF powered device require deployment of these device in very large numbers thus, making individual node battery replacement impractical. In RF energy harvesting, the RF harvester energy of propagating RF waves which can be ambient RF waves generated by nearby electronic component such as cellular phone or generated from dedicated RF power source.

For RF power harvesting, the power that can be transmitted by an RF power source is limited by FCC regulation. The power that can be harvested at the harvester is strong function of the distance of the harvester from the power source. In free space, the path loss of the RF signal is given by Friis' equation as

$$Lp = (\frac{4\pi R}{\lambda})^2 \quad (1)$$

Where R is the distance between the power source and power harvester, and λ is the wavelength of the RF signal transmitted from the power source. Figure 2.2 show the free space path loss for RF signal transmission in ultra-high frequency.

In different environments, the path loss of the radiated signal behaves differently than it would behave in free space. With the multipath fading and destructive signal collisions, the propagation signal loss from the power source to the harvester increase.

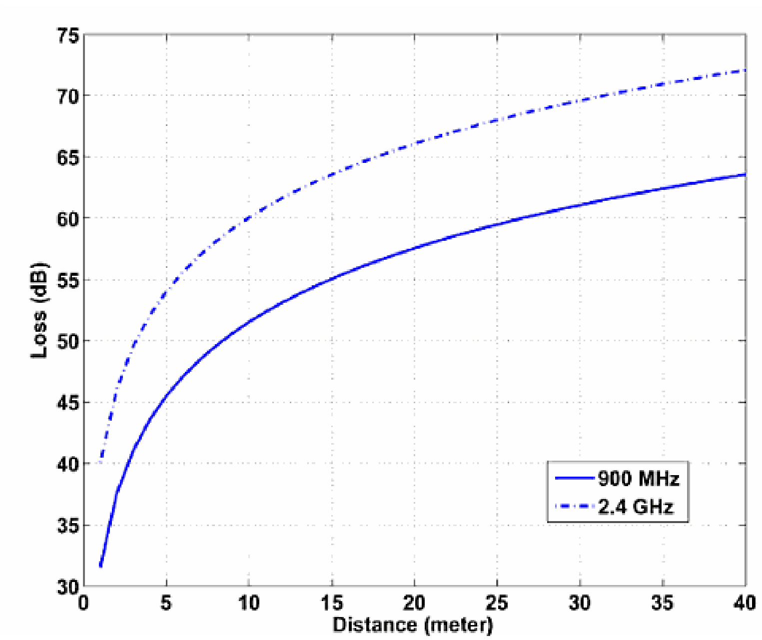

Figure 2.2 Path Loss of RF Signal Transmission in UHF

2.4 Solar Energy Harvesting

Wireless sensor networks for environmental monitoring outside is a class system in which to exploit alternative power sources can significantly increase node autonomy . Energy harvesting techniques can solve a quandary by providing and convert energy from the environment to obviate and fill the energy engendered by a stack buffer battery or super capacitor [6]. Collector’s energy utilizing photovoltaic PV modules minutes have been recently proposed to sanction joint operations WSNs. Unfortunately, low power budget is found to be in vain to implement efficient replenishment of storage.

Under temperature or radiation varying state output characteristics of PV modules is non-linear change. Therefore this quandary is to find the voltage and current in which it should operate for maximum output potential automatically. Efficient photovoltaic energy harvesting system should detect a particular operation is called Maximum Power Point (MPP) [3].

MPPT methods have so far been less down into two groups: sizably large scale PV power systems all generally based on a digital signal processor (DSP) or microcontroller, and scale PV power system minuscule conventional without DSP or any other digital controller. However, with an incremented interest in harvesting technology for wireless sensor networks incipient class MPPT method, fixated on micro-scale PV power systems, has recently emerged. Approach to address the development MPPT technique with several mW power consumption. In fact, the maximum power point tracking using the diminutive size of PV modules practicable only if the potential used by the tracker is substantially lower than the amount of power that had it stolen

This withal leads to quandaries in developing power management software for sensor networks. Adding Energy harvesting vigilant features might require the cognizance of the current available energy and the estimation of the future harvested power to tune the system comportment [5]. Clearly, if there is a cognation between conversion efficiency and energy buffer level, the energy prognostication will require more computing effort and may lose in precision. Ultra-low power systems designed for wearable contrivances and perspicacious materials equipped with photovoltaic harvester are withal presented in. Due to the minuscule size, these architectures are powered with miniaturized batteries and exploit the scavenger only as trickle recharger without any efficacious tracking of the MPP. In a MPPT system that utilizes only a super capacitor as energy reservoir is presented. The microcontroller on the node runs a tracking algorithm and drives a pulse width modulator (PWM) circuit to control the puissance converter. The microcontroller is essential for the MPPT system which leads to the main drawback of this implementation: the MPPT circuit cannot work without microcontroller and exploiting the scavenger on another sensor node requires a revision of the firmware.

To harvest energy from light using high conversion rate PV cells (amorphous silicon), the first known sub-mA level maximum power point tracking (MPPT) architecture was designed and quick charging circuits were developed to effectively and efficiently convert the harvested energy into useable form. An indoor light energy harvesting system is now providing power for the WSN in the ERI (Environment Research Institute) building for several of the motes deployed there.

2.5 Energy Harvesting for Wireless Sensors by Using Piezoelectric Transducers

Piezoelectric energy harvester engenders electricity depending on the amount of energy utilized in compressing or deforming the material, the amount and type of deformation of crystalline materials and the speed or frequency of pressure or vibration to the material. There are more than 200 materials felicitous to the cull of a particular application [5].

As we used piezoelectric transducer Active Fiber Composite because they are lightweight and flexible and therefore they can be utilized on curved structures. In order to consummate the wireless sensors that exploit energy harvesting, the entire system must be considered. The puissance utilized by all system components (sensors, conditioners, processors, data storage, and data transmission) must be compatible with the strategy of harvesting energy and puissance. Obviously, reducing the puissance required to accumulate and transmit data to match lower demand on resources. Consequently, reducing power consumption is a consequential goal to maximize power generation. For our SHM applications utilizing wireless sensor networks with a