DEPLOYMENT OF WIRELESS SENSOR NETWORK (WSN) IN AGRICULTURAL ENVIRONMENT IN NORTHERN MALAYSIA

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by

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LIST OF ABBREVIATIONS

WSN	Wireless Sensor Network
RF	Radio Frequency
FLASH	Fast Low-Latency Access with Seamless Handoff
IEEE	Institute of Electrical and Electronic Engineering
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network
Kbps	Kilo Bit Per Second
CCP	Coverage Configuration Protocol
ASCENT	Adaptive Self-Configuring Sensor Networks Topologies
OGDC	Optimal Geographical Density Control
KCCS	K-neighbors Constrained Coverage Strategy
RIS	Random Independent Scheduling
LEACH	Low Energy Adaptive Clustering Hierarchy
PILOT	Pre-defined, Intelligent, Lightweight Topology management
QoS	Quality of Service
FSL	Free Space Loss
KHz	Kilohertz
MHz	Megahertz
GHz	Gigahertz
MED	Modified Exponential Decay
MA	Maximum Attenuation
NZG	Non-Zero Gradient
ITU-R	International Telecommunications Union – Radio communications
RET	Radiative Energy Transfer
Tx	Transmit
Rx	Receive
T	Temperature
P	Pressure
H	Relative Humidity

RSSI	Received Signal Strength Indicator
dB	Decibel
dBi	Decibel with reference to isotropic antenna
dBm	Decibel with reference to 1 mW
LOS	Line of sight
NLOS	Non line of sight
UNIMAP	Universiti Malaysia Perlis
ISM	Industrial, Scientific and Medical
RMSE	Root Mean Square Error
WMN	Wireless Mesh Network
MAC	Medium Access Control

Perlaksanaan Rangkaian Sensor Tanpa Wayar (WSN) di Persekitaran Pertanian di Utara Malaysia

ABSTRAK

Kemunculan rangkaian sensor tanpa wayar (WSN) telah sebahagian besarnya didorong oleh kemajuan pengecilan peranti elektronik dan peningkatan dalam pembuatan berkapasiti tinggi telah menjadi faktor utama untuk menyokong dari sudut ekonomi. Krisis makanan baru-baru ini berlaku di beberapa tempat di dunia yang mencetuskan kesedaran tentang keselamatan makanan dan kapasiti pengeluaran makanan. Untuk pengeluaran makanan secara moden berjaya, pemahaman yang mendalam dan pengetahuan perubahan temporal dan spatial tanaman adalah sangat kritikal. Oleh itu, penggunaan sensor dan rangkaian tanpa wayar dalam perancangan dan pelaksanaan yang betul untuk menyokong pertanian adalah kunci untuk mewujudkan liputan tanpa wayar yang optimum di ladang. Tesis ini telah ditulis berdasarkan objektif-objektif berikut; menilai penggunaan tenaga dalam nod WSN sebagai fungsi jarak penghantaran data dan penghantaran tetapan paras kuasa; mengkonfigurasi sistem untuk jarak pendek hingga pertengahan julat bagi pengukuran pautan untuk kajian dalam persekitaran pertanian. Tesis juga menilai path loss model yang sedia ada, mengenal pasti dan membangunkan model baharu untuk sistem WSN dalam persekitaran pertanian. Di samping itu, tesis juga mereka bentuk dan model bagi liputan kawasan penempatan WSN dalam persekitaran pertanian. Bagi memenuhi objektif, kajian dalam pelbagai jenis persekitaran pertanian yang meliputi penilaian di ladang campuran tanaman, kolam akuakultur, rumah hijau dan perladangan tanaman tunggal dijalankan. Path loss model telah dinilai dan hasilnya digunakan dalam simulasi WSN. Pada masa yang sama, penilaian tenaga WSN nod telah dijalankan dan hasilnya digunakan dalam simulasi WSN. Hasil pengukuran yang diperoleh daripada kajian menunjukkan bahawa model Log distance adalah yang terbaik dan model patut untuk ukuran, dalam lading tanaman campuran, manakala model 2-ray adalah mencukupi untuk menggambarkan persekitaran akuakultur. Perubahan isyarat dalam akuakultur dipengaruhi oleh perubahan suhu, kelembapan dan indeks biasan. Kajian di rumah hijau Mangga menunjukkan bahawa turun naik isyarat yang berbeza dengan kepadatan tumbuh-tumbuhan dan Non Zero Gradient model boleh menggambarkan penyebaran isyarat global manakala Modified Exponential Decay adalah lebih sesuai untuk antenna tahap rendah. Model Non Zero Gradient parameter tertentu boleh digunakan untuk menggambarkan jenis anggur rumah hijau. Bagi lading satu tanaman, model Non Zero Gradient sesuai untuk menggambarkan isyarat bagi ISM (Industri, Saintifik and Medical) jalur frekuensi manakala Modified Exponential Decay lebih sesuai untuk julat frekuensi di antara 800 MHz dan 4.2 GHz dalam perladangan getah. Model Modified Exponential Decay adalah lebih baik untuk menggambarkan perambatan di peringkat cabang manakala Non Zero Gradient diperingkat kanopi. Bagi ladang kelapa sawit, Modified Exponential Decay adalah yang lebih baik menggambarkan perambatan isyarat di kawasan batang, manakala Maximum Attenuation di peringkat cabang. Satu simulasi model penempatan yang telah dilakukan pada akhir tesis menggambarkan liputan berpotensi berdasarkan penggunaan kuasa dalam pelbagai tingkah laku isyarat dalam perladangan tanaman campuran.

Deployment of Wireless Sensor Network (WSN) in Agricultural Environment in Northern Malaysia

ABSTRACT

The advent of Wireless Sensor Networks (WSN) has been fuelled mainly by the advancement in miniaturization of electronic devices and the rise of high volume manufacturing that has been the key supporting factor for the advancement economically. Recent food crises happening over various parts of the world triggered the consciousness over food security and food production capability. For the modern food production to be successful, a thorough understanding and awareness of temporal and spatial crops behaviour is super critical. Thus the use of sensor and wireless sensor networks and proper deployment planning to support modern precision farming is the key to optimum coverage establishment in the farmland. This thesis was written based on the following objectives; assessment energy consumption in WSN nodes as a function of data transmission interval and transmission power level setting; configure a system for short to mid-range link measurement for the study in agricultural environment. The thesis also evaluates existing signal path loss models, identifies or develops new path loss models for WSN system in agricultural environment. Additionally, the thesis also design and model a wide area WSN in agricultural environment. To meet the objectives, propagation path loss measurements were conducted in multiple types of agricultural environments which cover assessment in mixed crop plantation, aquaculture ponds, green houses and mono crop plantations. Path loss models were evaluated and or developed and results were used in WSN simulation. Concurrently, WSN nodes energy consumption assessment was carried out and results used in the WSN simulation. Output from these study and measurements are energy consumption assessment in WSN nodes, path loss models and results from WSN simulation in agricultural environment. Measurement results acquired from the studies show that Log-distance model is the best fit model for measurement in mixed crop plantation while 2-ray model is sufficient to describe the propagation in aquaculture environment. Signal variation in aquaculture is influenced by changes in temperature, humidity and thus refractive index of the medium. Studies in mango greenhouse shows that signal fluctuation varies with vegetation density and Non Zero Gradient model can describe the overall signal propagation while Modified Exponential Decay is more appropriate for lower antenna height. Non Zero Gradient model with specific parameters can be used to describe overhead trellis type grape in greenhouse. For mono-crop plantation, Non Zero Gradient is suitable to describe ISM (Industrial, Scientific and Medical) band frequencies while Modified Exponential Decay is more suitable for frequency 800 MHz to 4.2 GHz in rubber plantation. Modified Exponential Decay is best describe the propagation at branch level while Non Zero Gradient at canopy level. For palm plantation, Modified Exponential Decay best describe signal propagation at trunk while Maximum Attenuation is at canopy level. A deployment model simulation was done at the end of the thesis illustrating the potential coverage based on power consumption in various signal behavior in mixed crop plantation.

CHAPTER 1

BACKGROUND AND INTRODUCTION

This chapter provides a background of the issues in the planning of wireless sensor network (WSN) coverage in agricultural environment.

1.1 Introduction

In most agricultural societies, agricultural practices is mainly subsistence farming. The increase in many countries has resulted in a steep decline in the number of people in agriculture. Thus there is extensive reliance on commercial farming activities. This means that food production is now done on industrial scale by fewer people and food is exported to many markets. This also means that a poor yield in one country will certainly have impact on distant cultures. As in recent example, the increase in food price in 2008 was due to a low food production in Russia which led to export ban of grain by Russian government (Cha & Zacharia, 2010). This affected a number of countries relying on Russian wheat. Apart from this, climate change is resulting in an increase in unpredictable weather which will have an impact on food production.

It is now widely believed that the application of technology is the only way to mitigate the impact of climate change and also to increase efficiency in food production. One of such technologies is the application of sensors which can be used not only to monitor crop growing condition but also to reduce the cost of food production by efficiently managing the input, e.g. fertilizer and water.

1.2 Problem Statement

The application of technology in agriculture is widely referred to as precision agriculture which is a general term that is used to describe any farming technology that is tailored to reduce cost and optimize yield. In some areas, precision agriculture is undertaken through the application of manual techniques, e.g. manual soil sampling and application of input such as fertilizer and water. This practice however, is labour intensive and prone to human error. Because of the diversity and the harshness of agriculture environments, any deployment of technology has to be carefully planned. An obvious solution is to deploy systems that do not communicate via wired connections hence this makes wireless systems prime candidate for application in agriculture. However, the diversity of the type of crops that grow in agricultural environments poses a challenge to the planning and deployment of wireless system; hence detail knowledge of agricultural environment is necessary for the planning and deployment of any wireless system.

One of the important problems normally found in deployment planning is node battery energy consumption behaviour to support variety of applications. Furthermore, the propagation characteristics of wireless signal in agricultural environment are of critical factor to consider as well. Another problem associated with deployment planning is network creation and maintenance to meet connectivity and quality of service.

1.3 Research Objectives

The main objective of this research is to conduct wireless signal propagation study in selected agricultural environments and utilizes the analysis to propose WSN

deployment plan with optimum coverage to support agricultural activities. The details are as follows:

I. To assess energy consumption in a wireless sensor network (WSN) as a function of data transmission interval and transmission power level setting.

II. To configure a system for short to mid-range link measurements study in agricultural environment.

III. To evaluate existing signal path loss models, identify and develop a new model for WSN system in agricultural environment.

IV. To design and model a wide area WSN in agricultural environment.

In order to meet the set objectives, studies needed to be conducted in;

I. Open field;

II. Mixed crop plantation;

III. Mono crop environment;

IV. Aquaculture environment; and

V. Greenhouses;

The variety of crops also needs to cover a broad range to ensure the wide application of this study. This ranges from short crops e.g. herb, rice to large forest-type plantation e.g. rubber and palm oil. As the main focus is for managed environment, the studies focused on planted crops growing environments with identifiable planting patterns.