

DEVELOPMENT OF SCADA SYSTEM BASED ON HIGH  
POWER WIRELESS SENSOR NETWORK (ZIGBEE)

SITI ROHAINIZA BINTI CHE MOOD

MEI 2009

DEVELOPMENT OF SCADA SYSTEM BASED ON WIRELESS SENSOR  
NETWORK (ZIGBEE)

SITI ROHAINIZA BINTI CHE MOOD

This Report Is Submitted In Partial Fulfillment Of Requirement For The Degree of  
Bachelor In Electrical Engineering (Mechatronic)

Faculty of Electrical Engineering

Universiti Teknikal Malaysia Melaka

MAY 2009

“I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Mechatronic)”

Signature : .....

Supervisor’s Name : EN. ZULHANI B. RASIN

Date : 11 MAY 2009

## **ACKNOWLEDGEMENT**

Bismillahirrahmanirrahim. In the name of Allah, who is the most Gracious and the most Merciful I would like to express my sincere gratitude and thank my supervisor, Mr. Zulhani Bin Rasin for his constant encouragement, support and his belief in me for successful completion of this thesis project. I would also Thankful to the panels in the Second Seminar for their advices and supports.

I would like to express my sincere appreciation and thanks my friends Hizzi Bt Hamzah, Siti Zulfa Bt Mohd Naw, Cheong Yew Wai, Nursabillilah Bt Mohd Naw and many others for their support throughout.

Thank You.

## **ABSTRAK**

Projek ini adalah mengenai sistem SCADA (Supervisory Control and Data Acquisition) berpandukan pada rangkaian pengesan tanpa wayar. Fokus utama projek adalah pada memerhati di peringkat seliaan. Sistem SCADA ini akan beroperasi menggunakan IEEE 802.15.4 iaitu standard untuk wireless baru, kos komunikasi tanpa wayar yang rendah dengan kadar data biasa. Sasarannya adalah untuk aplikasi automasi untuk rumah/pejabat, industri kawalan dan rangkaian pengesan. Kini, fokus bagi kawasan tanpa wayar adalah pada kelajuan yang tinggi dan aplikasi jarak jauh. Projek ini menggambarkan bagaimana Zigbee sesuai untuk rangkaian pengesan tanpa wayar dalam aplikasi telemetri logistik. Sistem ini akan menggunakan sistem pengesan tanpa wayar untuk menghantar dan menerima data dari tapak kerja. Sistem Zigbee ini hanya menggunakan bateri untuk berfungsi dan ianya amat menjimatkan. Didalam projek ini juga, perbezaan diantara Zigbee dan teknologi lain turut dikaji.

## **ABSTRACT**

This project is about SCADA (Supervisory Control and Data Acquisition) system based on wireless sensor network. This project focuses on monitoring at supervisory level. This SCADA system will operate using the IEEE 802.15.4 which is the new wireless standard, low cost wireless communication with moderate data rates. It is intended to be used in embedded applications for home/office automation, industrial control and sensor networks. Mostly these days the focus in the wireless area is on very high speed and long range applications. This project describes how Zigbee is suitable for wireless sensor networks in logistic telemetry applications. This system will be using the wireless sensors system to send and receive the data from work plant. The ZigBee system use a battery as its power supply and it saved our money. In this project, a comparison between ZigBee and other technologies will also be investigated.

## TABLE OF CONTENT

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRAK	v
	ABSTRACT	vi
	TABLE OF CONTENTS	vii
	LIST OF FIGURES	ix
	LIST OF TABLES	x
	LIST OF ABBREVIATION	xi
	LIST OF APPENDIX	xii
<b>1</b>	<b>INTRODUCTION/LITERATURE REVIEW</b>	
	1.1 Project Background	1
	1.2 Problem Statement	2
	1.3 Objective of Project	4
	1.4 Scope of Project	5
	1.5 Project Overview	5
<b>2</b>	<b>LITERATURE REVIEW</b>	
	2.1 Introduction	7
	2.1.1 SCADA System	7
	2.1.2 SCADA Concept	9
	2.2 Wireless Sensor Network (WSN)	9

2.2.1	WSN Conventional Method	10
2.2.2	Characteristic of WSN	10
2.2.3	Network Topologies in WSN	11
2.2.4	WSN Application	14
2.3	Zigbee 802.15.4 Standard	16
2.3.1	Comparison Zigbee and others wireless tehnology	18
2.3.2	IEEE 802.15.4	25
2.3.3	Zigbee Alliance	27
2.4	GUI (Ghrapical User Interface)	28
2.4.1	Visual Basic 6.0	28
2.4.2	Significant Language Features	29
<b>3</b>	<b>METHODOLOGY</b>	
3.1	Introduction	30
3.2	Project Flowchart	31
3.2.1	Literature Review	32
3.2.2	Software Development	32
3.2.3	Hardware Development	34
3.3	Integrating Software and Hardware	42
3.4	Performance Analysis	43
<b>4</b>	<b>RESULT AND DISCUSSION</b>	
4.1	Introduction	44
4.2	Water Level Sensor	44
4.3	ZMN2405/HP Coverage Performance	47
4.3.1	Background of analysis	48
4.3.2	Receiver Energy Detection (ED)	48



4.3.3	Link Quality Indicator (LQI)	49
4.3.4	Procedure for Outdoor Environment	49
4.3.5	Procedure for Indoor Environment	55
4.4	GUI Result	59
4.4.1	GUI Commands	60
<b>5</b>	<b>CONCLUSION AND RECOMMENDATION</b>	
5.1	Introduction	65
5.2	Conclusion	65
5.3	Recommendation	66
	<b>REFERRENCES</b>	67
	<b>APPENDIX A</b>	68
	<b>APPENDIX B</b>	69
	<b>APPENDIX C</b>	70
	<b>APPENDIX D</b>	71

## LIST OF FIGURES

<b>NO</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	The revolution of SCADA	8
2.2	Star Topology	11
2.3	Mesh Topology	12
2.4	Hybrid Topology	13
2.5	The 802 Wireless Spaces	17
2.6	Typical Zigbee Device	21
2.7	Type of topologies in Zigbee	23
3.1	Main page of GUI	33
3.2	GUI for Facilities System Monitoring	33
3.3	Voltage Regulator 5 Volts circuit	34
3.4	Temperature Sensor Diagram	35
3.5	Temperature Sensor circuit	35
3.6	Water level circuit	36
3.7	Water level diagram	38
3.8	Zigbee Module	39
3.9	ZMN2405/HP Block Diagram	39
3.10	Setting the PC Communication Port	40
3.11	After the PC Communication Port Setup	41
3.12	The coordinator has detect the router	42
4.1	When the water is touched the high level	45
4.2	When the water in tank is touched the low level	46
4.3	Coordinator and End Device positioning	47
4.4	Graph of Link Quality Indicator	53

4.5	Graph of Link Quality Indicator for a distance at 0 degree direction	53
4.6	Coordinator and End Device positioning	56
4.7	Average value of LQI between Coordinator and End Device for different locations as shown in Figure 4.7	57
4.8	GUI when high water level	59
4.9	GUI when low water level	60

## LIST OF TABLES

<b>NO.</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	ZigBee Features	15
2.2	Bluetooth Features	16
2.3	Comparison ZigBee and others wireless technology	18
4.1	Average value of LQI between Coordinator and End Device for different distance and direction	52

## LIST OF APPENDIX

<b>NO.</b>	<b>TITLE</b>	<b>PAGE</b>
<b>A</b>	<b>SENSORS</b>	<b>68</b>
<b>B</b>	<b>WIRELESS SENSOR NETWORK</b>	<b>69</b>
<b>C</b>	<b>ZIGBEE</b>	<b>70</b>
<b>D</b>	<b>VISUAL BASIC 6.0</b>	<b>71</b>

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Project Background**

This chapter will state briefly all the problems statement, objectives, and the scope for this project. The explanations are about the literature review of SCADA (Supervisory Control and Data Acquisition), WSN (Wireless Sensor Network) and Zigbee 802.15.4 standard. This project is consisting of two parameters which are to measure water level and temperature.

For industrial markets, there are large numbers of applications that require wireless technologies that allow low data rates, less complexity and which provide batteries that stay alive for longer times. The industrial markets nowadays require wireless standards that are reliable, cheap and use low power. This wireless

technology based on the standard will address a lot of WSN (Wireless Sensor Networks) needs and low data rate wireless controls. For these kinds of needs to be fulfilled, IEEE has developed a standard called IEEE 802.15. This IEEE standard is used to describe or define the physical layer (PHY) and the media access controller (MAC) [1].

## **1.2 Problem Statement**

The earliest SCADA system is built in wired system and until now it widely used. Otherwise, this system has been updated to wireless system because of its advantages for human. There are lots of problems that inspired me the development of the wireless SCADA system. As the existed system using wired so that it contribute the problems of high cost in developing and fixing it.

Among others problems can be stated are as follows:

### **(a) Wired SCADA system is expensive**

The wired SCADA system is much expensive compared to the wireless system because the wired system has to use the cables in order to send and receive the signal. It takes a long distance because usually the SCADA used

for the distance about 1km to 1.5km. In addition every port must have at least two cables to receive and sent data.

**(b) Distance for collecting data.**

As mentioned above, the distance for collecting data are high. This effect when collecting needed the real time data. The distance also affects the accuracy and efficiency of the system.

**(c) Time consuming to collect the data is high.**

As mention above, the distance of plant are take a long time to collect the data, so that with the SCADA system, user did not have to go to the plant to collect the data. With only simply stay and take the data which appear in the GUI, it saves lots of time used in collecting data.

**(d) The high number of quality complaint.**

With this system, the efficiency of one department or organization can be improved, so that, the number of complaint can be reduced. Certain problem can be solve earlier if using this system and did not need to wait until a small problem turn to big problem.



**(e) High number of man-hours required for troubleshooting or services.**

If there any change see at the GUI, the stand-by workers can check and fix the problem if need. With this system, the problem can be detected earlier and the troubleshooting only did follow to the schedule.

### **1.3 Objective of Project**

The main objective of this project is to build a simple wireless SCADA in order to solve the problem that has been faced. Besides, by implement such development process, it would create a user friend to the users. It is very easy to understand for the new user. Among others objectives can be stated as follow:

- (a) To apply the wireless sensor network in data monitoring and collecting
- (b) To develop Graphical User Interface (GUI) to display the data collected.
- (c) To control data from the control room using the GUI.
- (d) To reduce travel time to collect data.
- (e) To reduce the man-hours for troubleshooting or services.

## **1.4 Scope of project**

The scope for this project is build the simple SCADA system based on wireless sensor network. Among others scopes can be stated as follows:

- (i) Using Zigbee standard module to transmit and receive the signal.
- (ii) Build Graphical User Interface (GUI) using.
- (iii) This wireless SCADA designed to hospital building.
- (iv) Use of the sensors to monitor three parameters which are water level, temperature and ON/OFF a motor.

## **1.5 Project Overview**

This project thesis are divided into five chapter which are Chapter 1 for Introduction, Chapter 2 for Literature Review, Chapter 3 for Methodology, Chapter 4 for Result and Discussion and the last Chapter is Conclusion and Recommendation.

Chapter 1 will state and explain about background of SCADA and WSN systems, problem statement for the project, objectives for doing the project and the scopes set for this project thesis. Chapter 2 is about the Literature Review in SCADA system, WSN system and all the function and example case study in WSN, about the

Zigbee technology and the comparison with others wireless technology and lastly about the Visual Basic 6.0 for the GUI.

Then, the Chapter 3 is explaining about methodology used during this project thesis. The methodology explain from the first step until the last step which is from literature review, software development, hardware development, integration between software and hardware and lastly the analysis. The next chapter is Chapter 4 that focuses in explaining and discusses the result of the analysis. Chapter 5 as the last chapter is about the summary/conclusion for the project thesis that has been done during this period.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Introduction**

This chapter is focusing in explaining about all the research doing in related scope of this project thesis. Under this subtitle, the sources of literature review are from the article and pass thesis. The literature included in this section is about the SCADA system, WSN (Wireless A Sensor Network), Zigbee, and the Visual Basic 6.0 used for GUI.

##### **2.1.1 SCADA System**

SCADA stands for Supervisory Control and Data Acquisition. As the name indicates, it is not a full control system, but rather focuses on the supervisory level.

SCADA systems are typically used to perform data collection and control at the supervisory level. Some SCADA systems only monitor without doing control, these systems are still referred to as SCADA systems.

SCADA operates as a stand-alone, autonomous system, monitoring sensors, displaying data, outputting controls, activating alarms and logging information to facilitate and optimize the plant processes and on-going operations [2]. It is able to receiving and transmitting data, both in analog and digital. With SCADA system, it is not necessary for us to go to the plant site to collect the data (Figure 2.1).

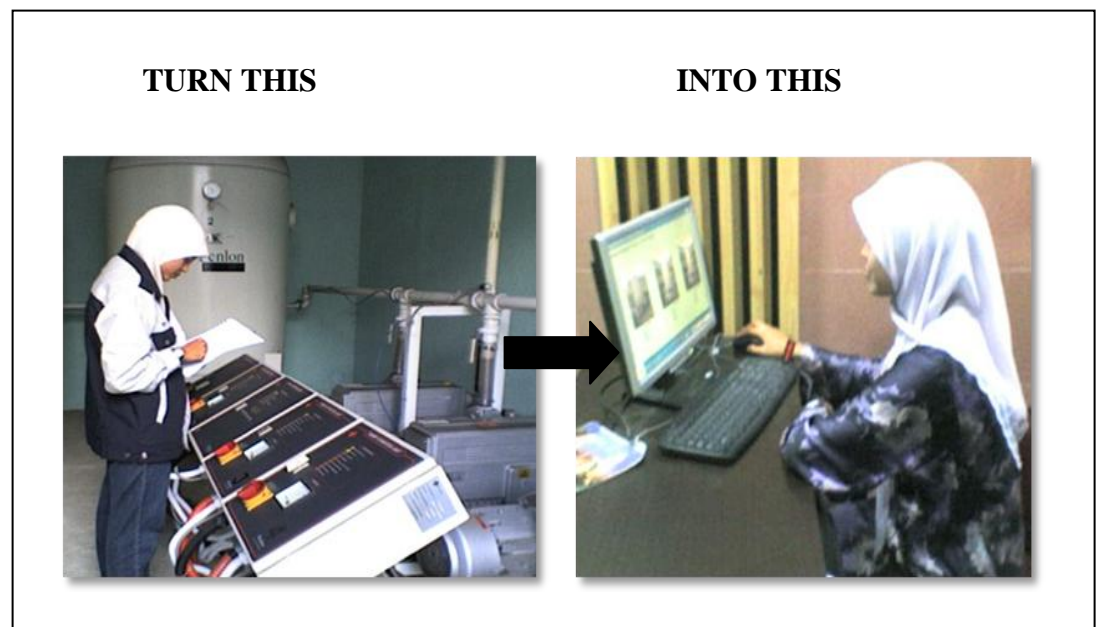


Figure 2.1: The revolution of SCADA

### **2.1.2 SCADA Concept**

The SCADA system includes input/output signal hardware, controllers, Graphical User Interface (GUI), networks, communication, database and software. As term SCADA refers to a central system that monitors and controls, a complete site or a system spread out over a long distance (kilometers/miles).

## **2.2 Wireless Sensor Network (WSN)**

This section presents the background material to this thesis. The ZigBee technology and logistic situations will be discussed thoroughly. The ZigBee is based on the IEEE 802.15.4 standard which gives the specifications of the Physical and MAC layers. Wireless sensor network (WSN) is a network sensor(s) embedded and forming a self-organized network. There wide usage of WSN, which are in military, health, home, environmental, traffic surveillance, and medical application[3]. The main characteristic of WSN is low energy use. This system can only used the battery  $\pm 9$ Volt as it power supply. Furthermore, this WSN is a dynamic and autonomous operation network.

### **2.2.1 WSN Conventional Method**

The conventional methods of WSN are divided into two which are:

- (i) The sensor nodes or end-device communicate with the base station or coordinator directly. The communication does not need other medium to transmit or receive the data except other wireless nodes.
  
- (ii) This system also used the multi-hop scheme, which means the data transmitted by the sensor nodes routes through some other intermediate nodes.

### **2.2.2 Characteristic of WSN**

First of all, a sensor network is a kind of network that is made up of a large number of sensor nodes. These nodes are spread to carry out different kinds of operations to find the values of different kinds of attributes like temperature, acceleration, humidity etc. in certain environments. So there is no need to have a big computer setup to evaluate all these things, instead cheap small sensor devices. One of the good uses of these wireless sensor networks is in the logistic telemetry applications in which one wants to know

the condition of goods during transfer and to know the condition of different attributes associated with the goods.

### 2.2.3 Network Topologies in WSN

WSN supports different kinds of topologies like star, mesh topologies, and hybrid topologies which add to the properties of the network and how the data will be transferred or how the communication is carried out.

#### (i) Star topologies

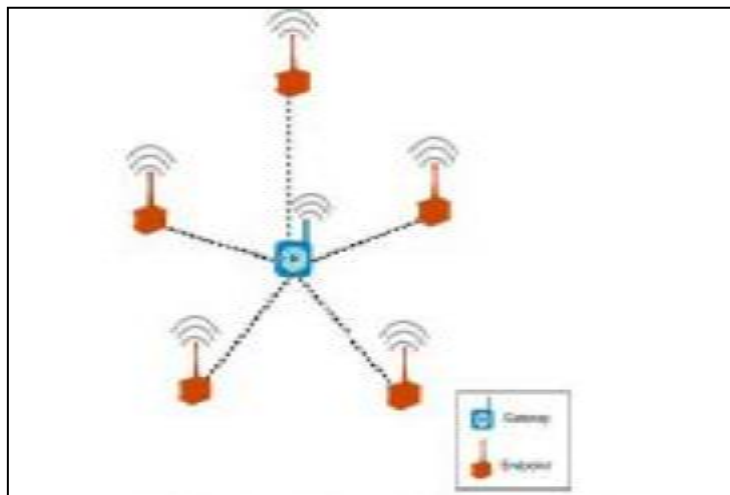


Figure 2.2: Star Topology

Figure 1.3 shows that the topology is in single hop to the Gateway. The Gateway (Coordinator) in the middle serves to communicate with all