Available Online at www.ijcsmc.com

International Journal of Computer Science and Mobile Computing

A Monthly Journal of Computer Science and Information Technology

ISSN 2320–088X

IJCSMC, Vol. 2, Issue. 12, December 2013, pg.69 – 87

RESEARCH ARTICLE

Wireless Monitor and Control System for Greenhouse

Rana H. Hussain[1], Dr. Ali F. Marhoon[1], Dr. Mofeed T. Rashid[2]

[1] Computer Science Department, Collage of Science, University of Basrah, Basrah, Iraq

[2] Electrical Engineering Department, Engineering College, University of Basrah, Basrah, Iraq

rana_hameed2003@yahoo.com

ali_marhoon2003@yahoo.com

mofid76@yahoo.com

Abstract

Parameter monitoring and control of greenhouse environment play an important role in greenhouse production and management. This paper involve a design and implementation of an XBee based Wireless Sensor Network (WSN) that is used to monitor and control the essential greenhouse parameters, such as, temperature, humidity and light intensity. This implementation supports the farmers to increase the crop production. The standalone XBee module, i.e., without microcontroller, is integrated with specific small size sensors. All monitored parameters are transmitted through a wireless link to computer via coordinator to be analyzed, and then initiate suitable commands to the specific devices to overcome the drifts in an environmental parameters inside greenhouse.

Keywords – WSN; Greenhouse; XBee s2; ZigBee Technology; LM35; LDR

I. INTRODUCTION

As it is well known, greenhouse is a building where plants are grown. Greenhouses are often used for growing flowers, vegetables, fruits, and tobacco plant. Basic factors affecting plant growth are sunlight, water content in soil, temperature, CO_2 concentration etc. These physical factors are hard to control manually inside a greenhouse and there is a need for automated design arises. Greenhouses are very useful for following reason it they provide an optimal temperature around plants, protect them from weather extremes, extends the growing season, allowing you to sow plants earlier and harvest plants later and allows economic crops such as tomatoes, cucumbers, melons and aborigines to crop more successfully [1].

WSN have many important applications, Some of them are futuristic while a large number of them are practically useful like military application, home automation application, health application, commercial applications, environmental application which is basis relevant to our research [2].

WSN can form a useful part of the automation system architecture in modern greenhouses. Compared to the wired systems, the installation of WSN is fast, cheap and easy. Moreover, it is easy to relocate the measurement points when needed by just moving sensor nodes from one location to another within a communication range of the coordinator device. If the greenhouse's plant is high and dense, the small and light weight nodes can even be hanged up to the plants branches [2].

Many research and projects have been done in order to improve the conditions and cultivation of crops under greenhouse. Qian et al.[3] proposed wireless system solution for greenhouse monitoring and control. This system consist of wireless sensors, such as temperature sensor, humidity sensor, light sensor and so on (integrated with PIC 16F877 and ZigBee module). The data is stored and displayed on the LCD. After the data being dealt through control algorithm, which sends control commands to the actuators and PIC 16F877. All the wireless nodes are based on ZigBee module.

Ibrahim and Munaf [4] proposed system to control and monitoring the environment inside greenhouse. The system consists of a number of local stations and a central station. The local stations are used to measure the environmental parameters and to control the operation of controlled actuators to maintain climate parameters at predefined set points. For each local station a PIC Microcontroller is used to store the instant values of the environmental parameters, send them to the central station and receive the control signals that are required for the operation of the actuators. The communication between the local stations and the central station is achieved via ZigBee wireless modules.

Zhou Jianjun1 and .et al. [5] Presented system that consists of a data acquisition controller and greenhouse remote monitoring and control software. The system ,monitor temperature ,humidity, soil water content and concentration of carbon dioxide inside the greenhouse which then saved to a database. According to the current indoor temperature, the target temperature and the offset temperature, PID (Proportional Integral and Derivative) control method is used to control temperature control in greenhouse. The system is implemented using low power wireless components, and easy to be installed.

The objective of the present work is to design and implement wireless sensor network using ZigBee devices represented by XBee s2 kit for monitoring and control the environment parameters such as temperature, humidity and light intensity inside greenhouse.

The article is organized as follows; Section II show system architecture of the proposed system; Section III display system hardware description including brief overview of wireless standard, appropriate wireless technology, description to the hardware of sensor node and the types of sensor that used; Section IV explain the graphic user interface of the proposed system; Section V display the result of the experiment and a discussion fore these results; and conclusions.

II. SYSTEM ARCHITECTURE

The architecture of system is shown in Fig.1 which composed of two types of physical units: three remote sensor nodes, and a central control station. The remote sensor nodes are implemented with an XBee radio and analog sensors. These radios support ZigBee topologies which are configured to read analog signals directly from sensors to be transmitted with in a data packet. Each node is enabled to read temperature, humidity, and light levels. The measured data are sent periodically to the central computer. The central control unit consists of XBee radio kit which connected to personal computer through USB.

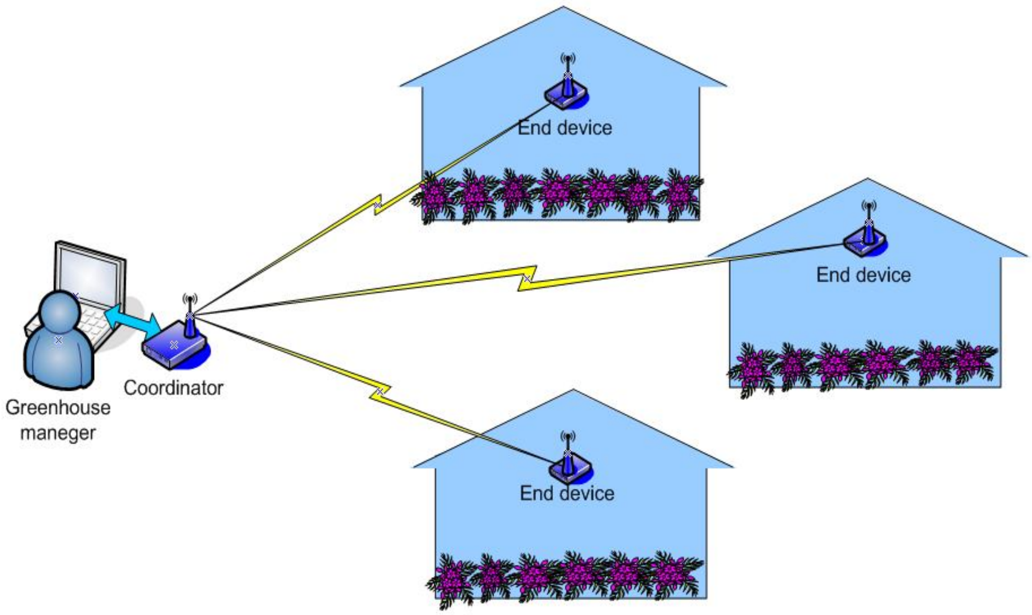

Fig.1 System Architecture

XBee is a device used to send and receive data wirelessly base on ZigBee/IEEE 802.15.4 network standard. XBee could be configuring to operate in different function including the Coordinator, Router and End Device. There are several types of XBee module, the very popular XBee is Series 1 (802.15.4), and series 2 that operate on ZigBee protocol. Each XBee radio has the capability to directly gather and transmit sensor data if it is configured as end device. In this work, XBee s2 is selected to be used as standalone device for gathering analog signals from three different sensors. In addition to the ability of this XBee s2 to initiate the control signals though it's digital output bits. Hence, there is no need to use any microcontroller to do (I/O) operation. Eliminating the external microcontroller means saving money for sensor networks with hundreds of nodes, also the power consumption and node size will be reduced[6][7].

III. SYSTEM HARDWARE DESCRIPTION

A. ZigBee standard

There are many types of wireless communication technologies such as ZigBee, Wi-Fi and Bluetooth. All these types are work at similar RF frequencies, and their application sometimes overlap for example can be used in greenhouse. In this project, ZigBee technology has been used because of the mainly advantages of this technology over the others technologies and most suitable to this application exactly following aspects of it: Reliable and self-configuration, Supports large number of nodes, easy to deploy, very long battery life, Secure and Low cost. Table 1 represents a comparison between these standards [8].

Table 1 Comparison between Wireless Technologies

parameters	ZigBee	Bluetooth	Wi-Fi
Standard	802.15.4	802.15.1	802.1.b
Memory requirement	4-32 KB	250 KB	1MB
Battery live	years	Days	Hours
Data rate	250 Kbps	1-3 Mbps	11Mbps
Range	300 m	10-100 m	100 m

B. XBee Modules

XBee is the brand name from Digi International for a family of form factor compatible radio modules. The first XBee radios were introduced under the MaxStream and were based on the 802.15.4 standard designed for point-to-point and point-to-multipoint communications at over-the-air baud rates of 250 Kbps. Two models were initially introduced a lower cost 1 mW XBee (S1 and S2) and the higher power 100 mW XBee-PRO.

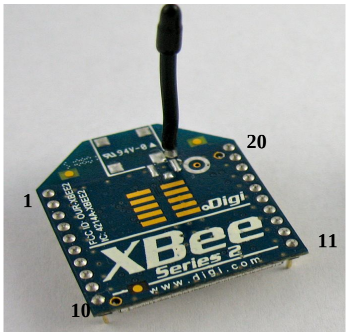

Fig.2 XBee Series 2 Radio

XBee (s1, s2 and pro) have 20 pin, as shown in Fig.2. Ten from XBee pins could be configured either as digital inputs for sensing switches and other things that operate like switches, or as digital outputs for controlling LEDs and small motors directly. Four pins could be configured as ADC input .The feature of ADC pins can read a range from 0 volts to 1.2 volts maximum. Voltage divider circuit has been used in order to limit the maximum voltage of sensors within the range of ADC[6]. The following equation is used to convert the A/D reading to mV [10]:

$$\mathbf{AD(mV) = (A/D\ reading * 1200mV) / 1024} \quad \mathbf{(1)}$$

Fig.3 show the relation between input voltage and decimal value of ADC of XBee.

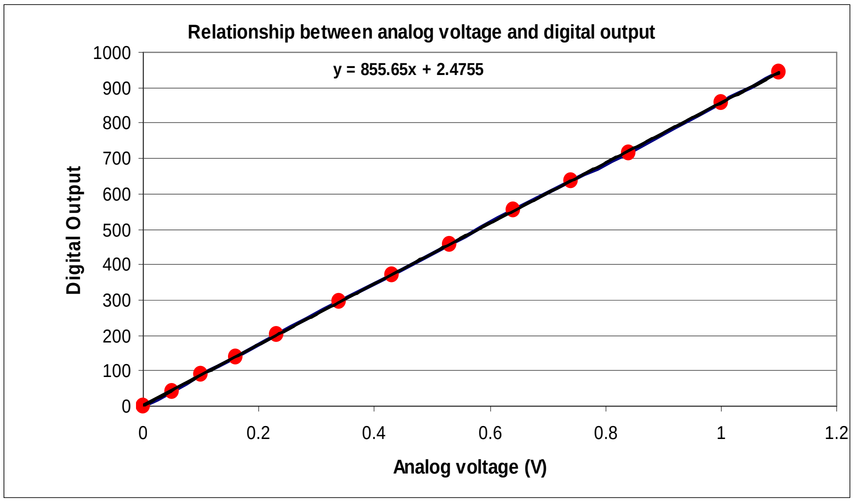

Fig.3 XBee Analog to Digital characteristic

The XBee works with two mode named; transparent AT mode and Application Programming Interface API mode. In this project, API mode has been used in which the data transmitted and received are contained in frames that define operations or events within the module. Through this mode of operation, it can send a particular module source address, destination address, name of a given node, RSSI signal, status, and more. A data could be transmitted to multiple destinations without entering Command Mode. Fig.4 shows the structure of frame in API mode.

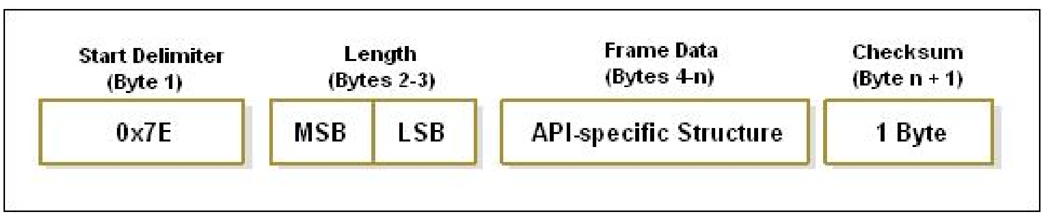

Fig.4 Structure of Frame Mode Data API [10]

Fig. 5 represents the overall design of sensor node. All end devices in this network are configured as follows:

1- Three of its I/O pins are configured to be used as Analog – To – Digital converter (ADC) to record the environmental parameters. These three pins are connected to the three sensors; temperature sensor (LM35), light sensor (LDR), and humidity sensor (AHT2M1).

2- Another Four I/O pins are configured as digital output used to control the greenhouse parameters as following :

    1. Two pins to operate two fans in order to get four levels of air flow (OFF, Slow, Medium and Full).

    2. Two pins to simulate the operations of light and mist system.

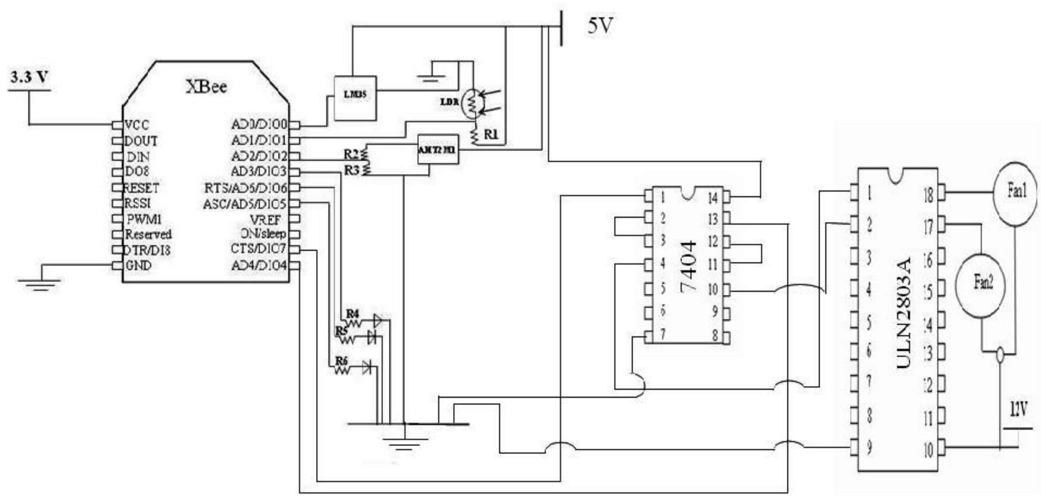

Figure5: Remote Node Circuit Diagram

C. XBee Configuration

X_CTU software utility is Graphical User Interface (GUI) application that provided by Digi corporation. This application is designed to interact with the firmware files found on Digi's RF products and to provide a simple-to-use graphical user interface to them. It has been used to configure XBee devices [11].

1- Programming the Coordinator (Talks to everyone in broadcast mode):

1.1- PAN ID: Make sure this value stays the same for all End Devices, and coordinator.

1.2- Set destination high address (DH) as 13A200

1.3- Select the destination low address (DL) as (FFFF) this number make the coordinator to send data in broadcast manner.

2- Programming the End Device (Talks only to Coordinator):

2.1- PAN ID: Make sure this value stays the same for all End Devices, and Coordinator.

2.2- DH: Set destination high address as (13A200)

2.3- DL: Set destination low to be the same DL to the coordinator this will ensure that the end device will talk only to the coordinator.

2.4 - set one or more of XBee pins to be ADC input.

2.5- set one or more of XBee pins to be digital output low.

D. Temperature Sensor

The LM35 series are precision integrated circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in º Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1⁄4°C at room temperature and ±3⁄4°C over a full -55 to +150°C temperature range. Low cost is assured by trimming and calibration at the water level. Fig.6 represented the range of temperature that can be reading by the ADC of XBee (0-102°C) [12].

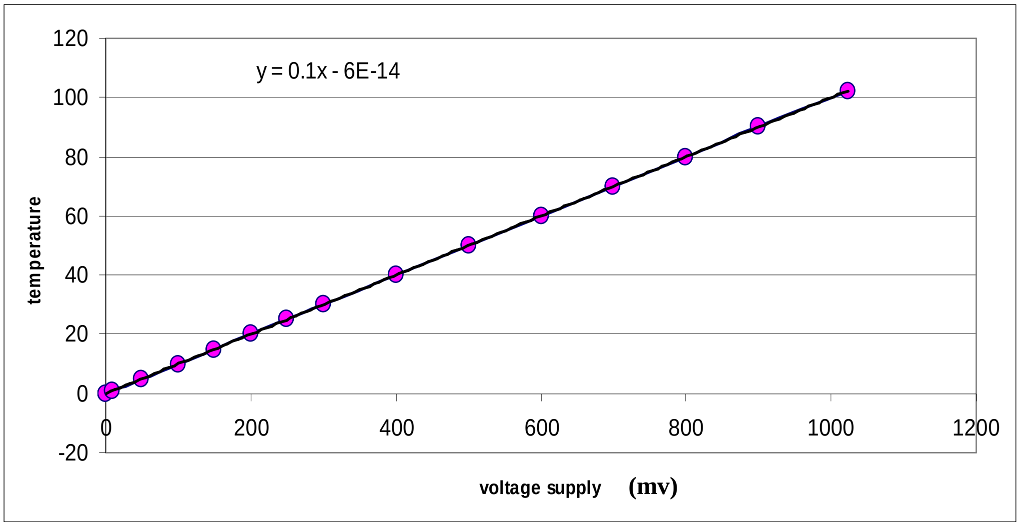

Fig.6 Relationship between Temperature & V_{out}

E. Light Sensor

LDR is variable resistor measure visible light as seen by the human eye. LDR is basically a resistor that has internal resistance increases or decreases dependent on the level of light intensity impinging on the surface of the sensor. The characteristic of this type of sensor: Fast response, Small in size [62]. The relationship between the change in sensor resistance (R_L) and light intensity (Lux) is shown in fig 7 and can also be expressed using the equation (4 and 5). Because LDR give variable resistor it must connected to voltage divider circuit as shown in fig.8.

The equation of Vout from the voltage divider is:

$$Vout = \frac{LDR \times Vin}{LDR + R1} \tag{2}$$

To obtain the value of LDR the equation will be:

$$LDR = \frac{Vout \times R1}{Vin - Vout} \tag{3}$$

To calculate the intensity of light uses this equation:

$$R_L = \frac{500}{Lux} \tag{4}$$

$$Lux = \frac{500}{R_L} \tag{5}$$

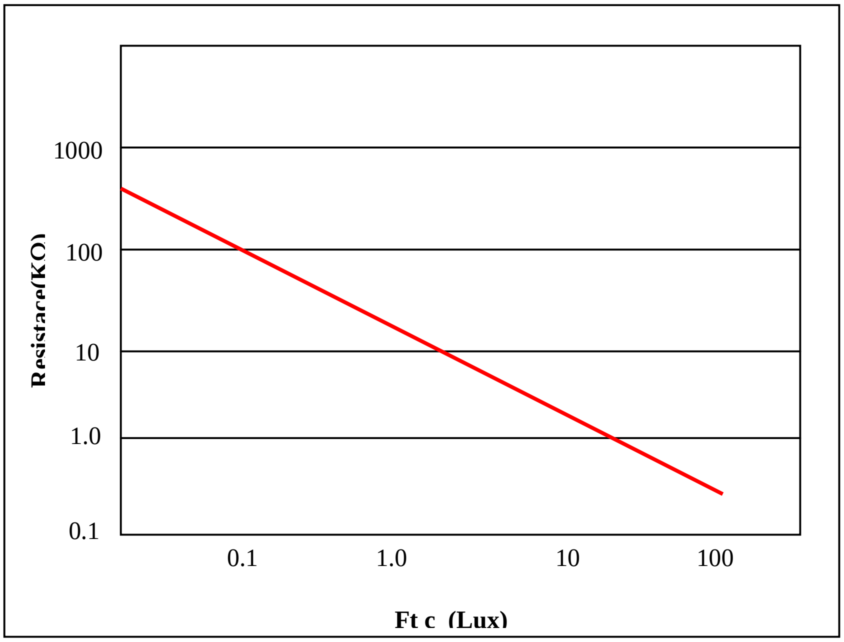

Fig.7 Resistance as Function of Illumination [13]

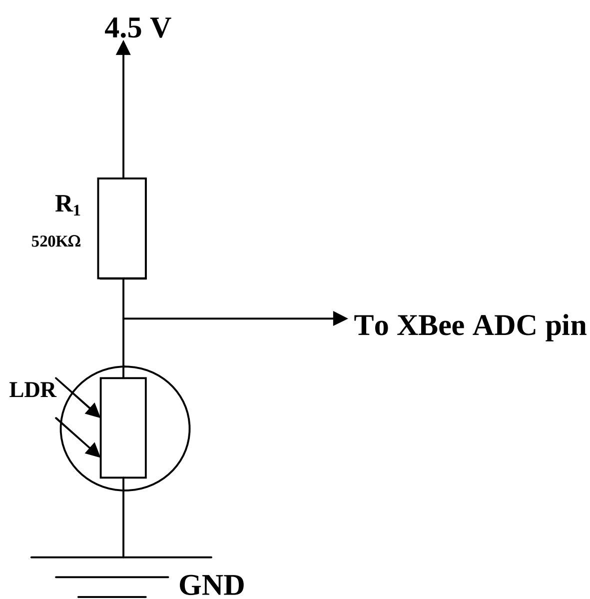

Fig.8 Voltage Divider Circuit of LDR Sensor

F. Humidity Sensor

The sensor that used in the project is Capacitive-type humidity sensor (CHS)called AHT2M1. This type is widely used in industrial, commercial, and weather telemetry applications. The changes in the dielectric constant of a CHS are nearly directly proportional to the relative humidity of the surrounding environment [14]. Technical Specification of this model was:

Power supply: 4.5-6V DC, Detecting range: humidity 0-100% RH, Storage humidity below 95% RH.

The humidity sensor is connected to the ADC via potential divider to match the XBee maximum allowable analog voltage (1.2 V) as shown in Fig .9, this sensor is calibrated using standard humidity meter Fig . 10 the calibration.

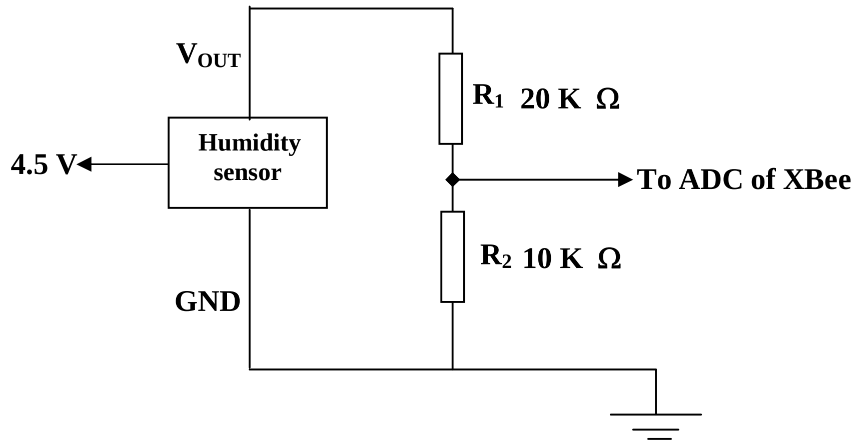

Fig. 9 Humidity Circuit

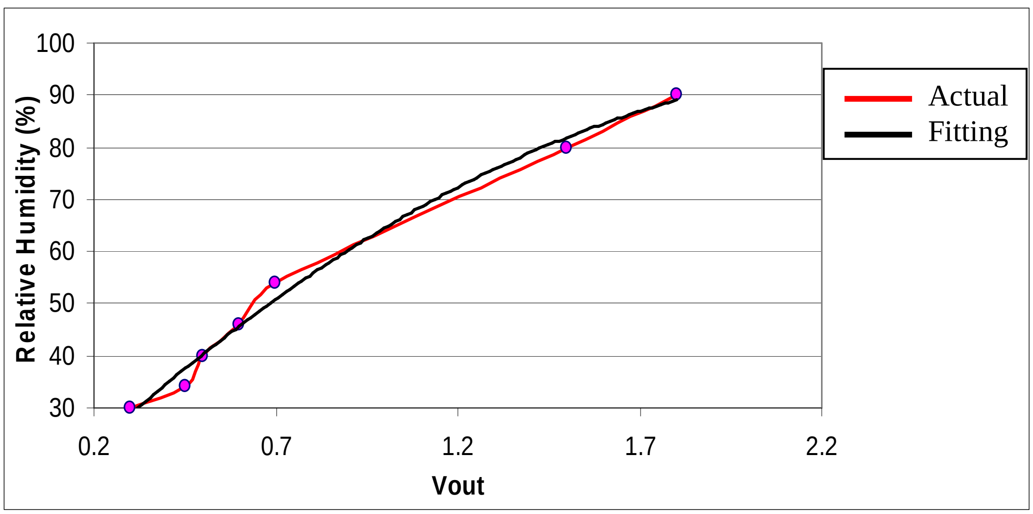

Fig.10 Relationship Between Humidity and Vout

IV. SYSTEM DRIVING SOFTWARE

Visual Studio.net has been selected to design the system driving software of this project which is used to control and display the information that received from serial port from sensor. The software consists of two forms the first one is used to select the type of plant and the set point to each parameters of greenhouse as shown in Fig.11 while the second form is to monitor and control the environment parameters which are stored in the local database as shown in Fig.12.

Fig. 11 Main Window

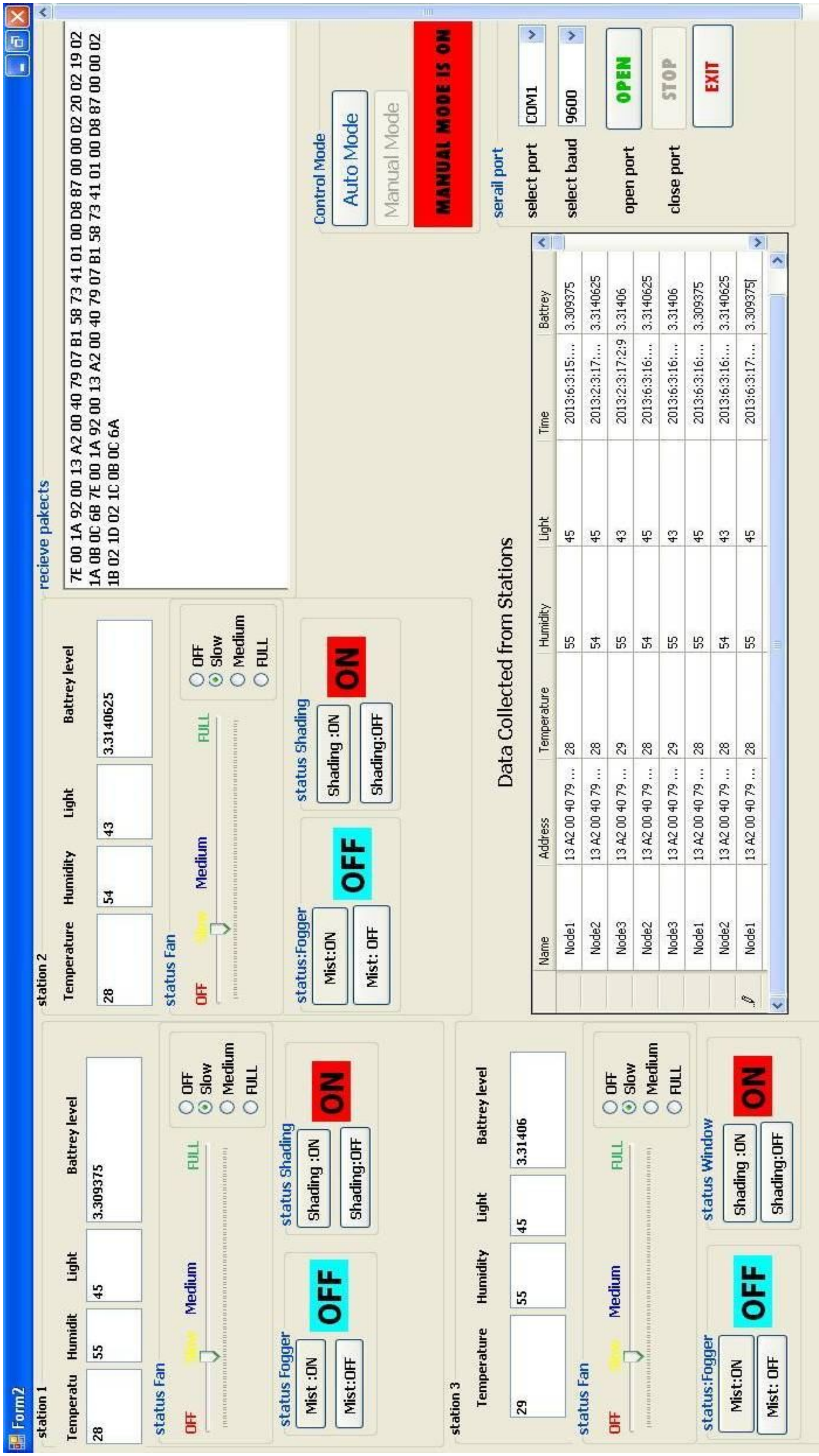

Fig. 12 Monitoring and Control Window

Fuzzy logic used to determine the error between the data that received with set value. Fig.13, Fig.14, and Fig. 15 respectively show membership function of error of temperature, humidity error and light intensity values. By using the rules base in tables 2 and 3 these tables are built in this form because the parameters of greenhouse interconnected with each other. Is high, the humidity will drop down and vice versa. The absence of light makes temperature reduce. So the system will take the decision to turn on or off the devices that represent the heating, cooling or lighting systems. The Fig16 show how system driving software process the data that received from greenhouse station.

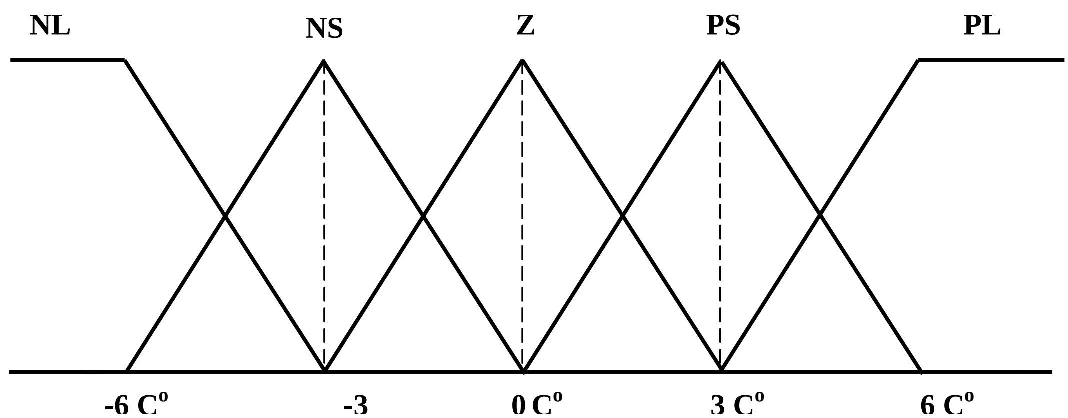

Fig.13 Membership Function to the Temperature Error

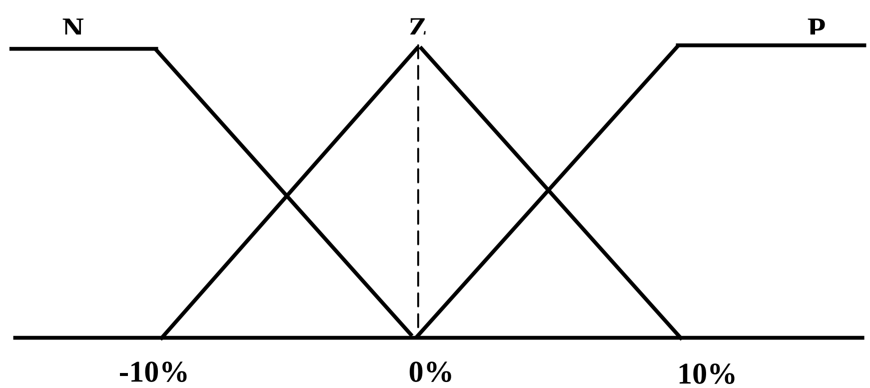

Fig.14 Membership function to the Humidity Error

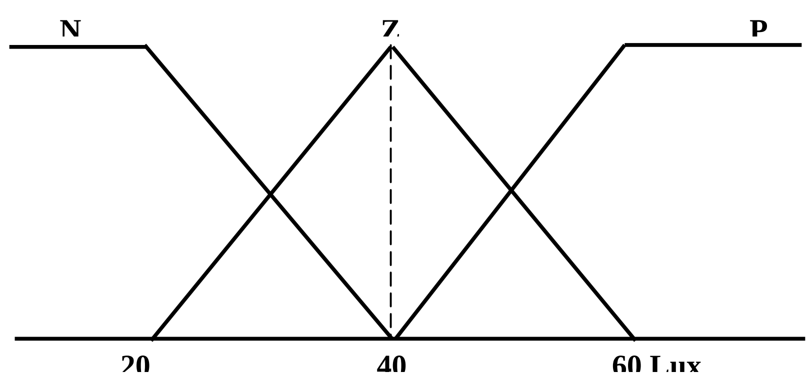

Fig.15 Membership Function to the Light Intensity Error

Table 2: Control rules of Temperature and Humidity

Light	Temperature					
		NL	**NS**	**Z**	**PS**	**PL**
	N	**Shading off**	**Shading off**	**Shading off**	**Shading on**	**Shading on**
	Z	**Shading off**	**Shading off**	**Shading on**	**Shading on**	**Shading on**
	P	**Shading off**	**Shading on**	**Shading on**	**Shading on**	**Shading on**

Humidity error	Temperature error					
		NL	NS	Z	PS	PL
	N	**Fan off Mist on**	**Fan off Mist on**	**Fan off Mist on**	**Fan medium Mist on**	**Fan full Mist on**
	Z	**Fan off Mist off**	**Fan off Mist off**	**Fan slow Mist off**	**Fan medium Mist off**	**Fan full Mist off**
	P	**Fan off Mist off**	**Fan slow Mist off**	**Fan medium Mist off**	**Fan full Mist off**	**Fan full Mist off**

Table 3: Control Rules of Temperature and Light

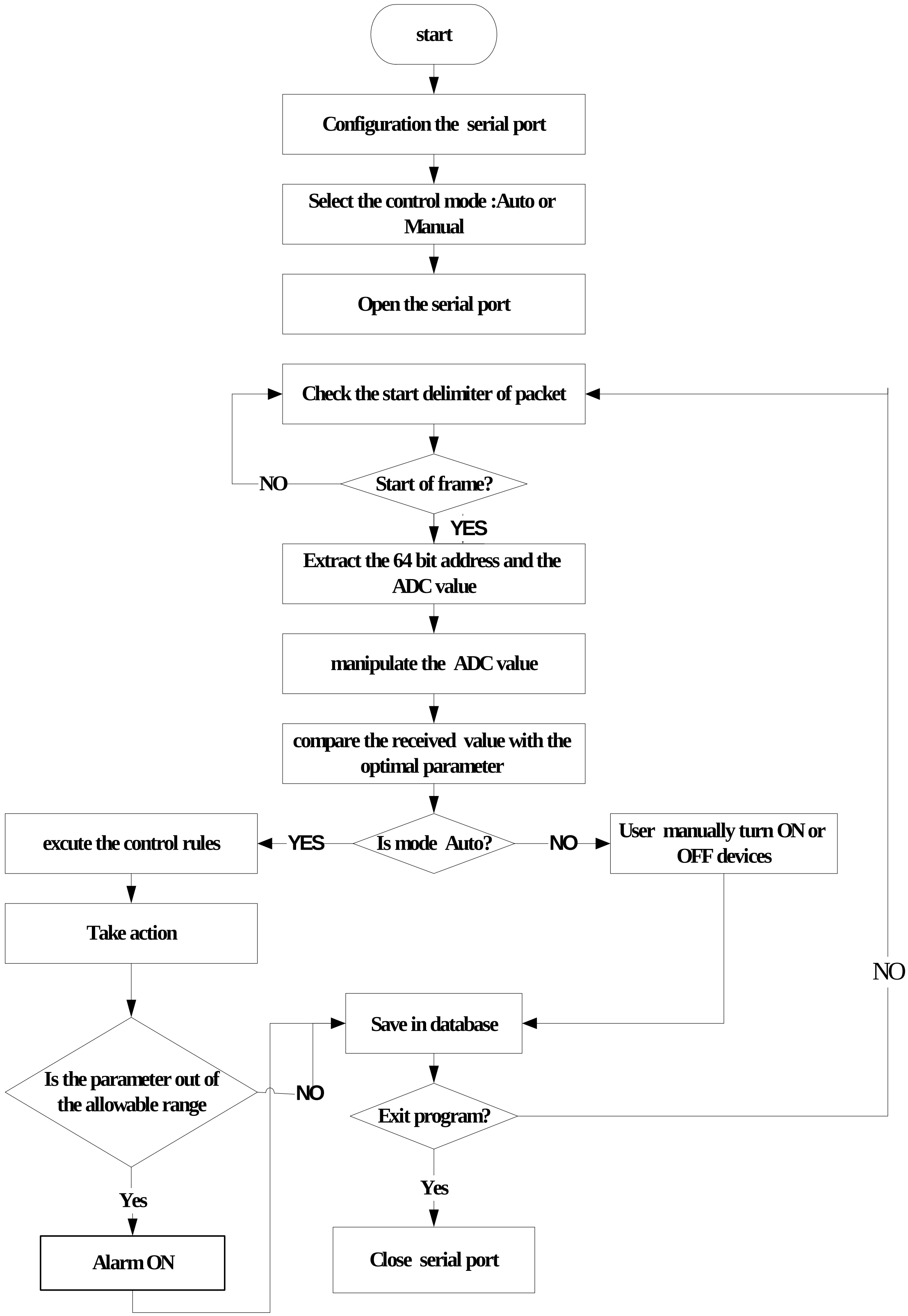

Fig.16 Flowchart of Processing Data

V. EXPERIMENTS and RESULTS

More than one experiments were carried out to test the reliability and feasibility of the system design. An experiments were carried out at the garden of my house. The greenhouse that used in these experiments has the following dimensions:

length = 50 cm

width = 30 cm

height = 60 cm

As shown in Fig.17,there are two small fan in addition to air filter to simulate the cooling system (fan and pad system. The prototype structure built from aluminum and class.

Fig.17 Experimental Setup

The experiments consist of two test, the first test was get the data from prototype for a period of sixteen hours from (4 AM to 7 PM) by using the control procedure, and show how the system attempt to keep the parameters inside the prototype smaller than the outside. The second test was get data from prototype in the same period without using control procedure so the system will operate as monitoring system to show the affect of the proposed controller.

Many tests are done to ensure the ability of the system work without any problems and the result show how the system work with simple possibility to achieve proposed goals. The following graphs show the greenhouse parameters (temperature, humidity, and light) collected from the greenhouse with and without control.

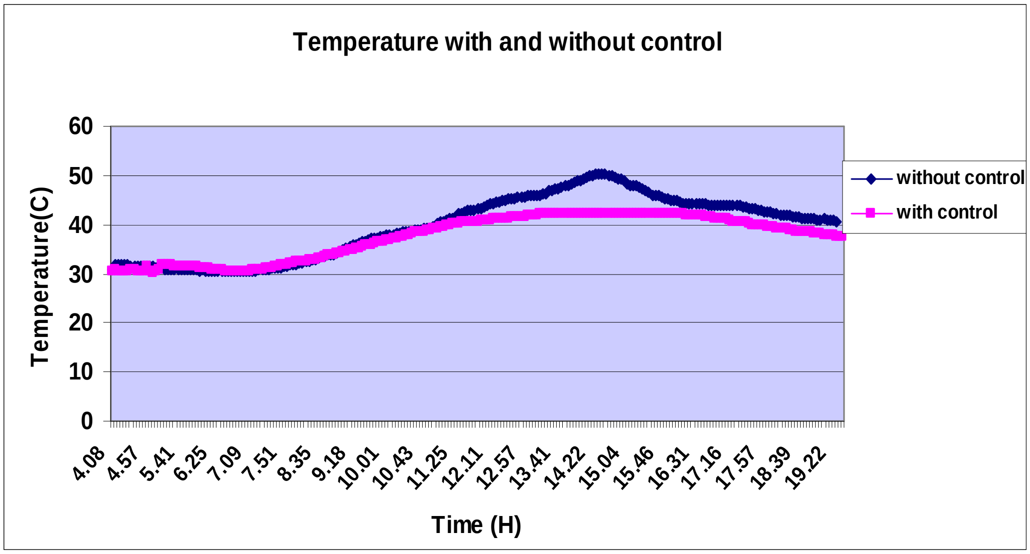

Fig.18 Temperature Collected from Greenhouse with and without Control

Refer to Fig.18 which show the temperature with and without control, the first line represented the temperature change without using control. It is clear that the temperature increase proportional to the light of sun, and reach to 50 ^{o}C or above during this period. The high temperature inside the greenhouse affect on development and growth but can also stop process essential for life such as the structure and functioning of enzymes. Temperature can cause changes indicative of possible changes occurring with in other environmental factors such as relative humidity and soil moisture. The second line represented the temperature change when applying control inside greenhouse. The affect of control is clear which is reduced by (9-10)^{o}C using the small fans. This reduction may increase when using suitable size of fans for cooling.

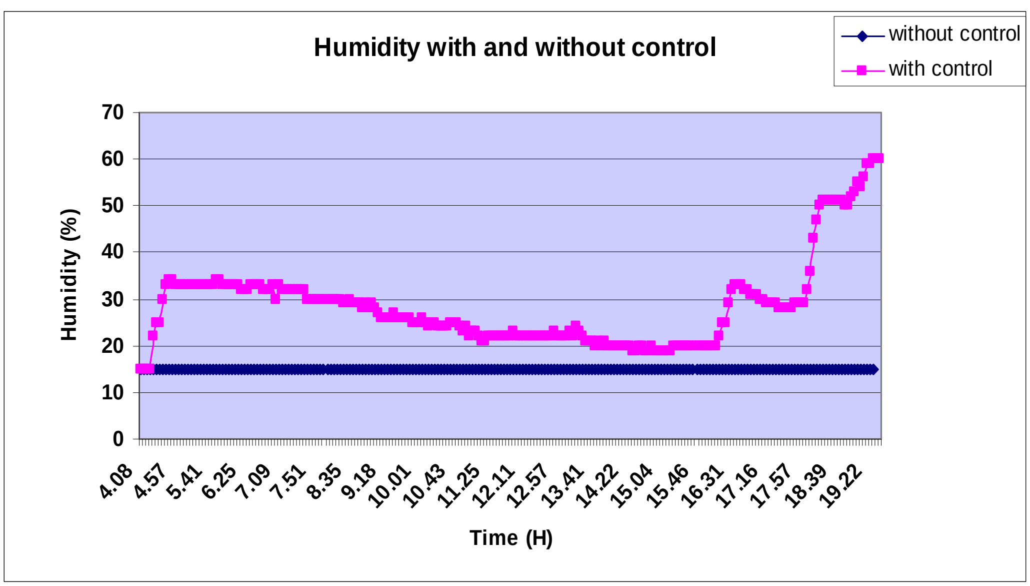

Fig.19 Humidity Collected from Greenhouse with and without Control

Fig.19 represented humidity reading beginning with line that represented the reading without control it is clear that humidity was very low and constant this because there is no air flow or any thing cause humidity. If plants growing in a dry environment can lose humidity overtime, plants lose water constantly through their leaf pores in transpiration process. Similarly if humidity was above 80 percent this will extend the risk of spread the disease. In such cases the agricultural product can be affected significantly particularly the flowering and fruit development, therefore control the humidity consider important issue. The second line represented the reading of humidity with control and how reading of humidity was double of the reading without control this was because used fan and pad system which provide suitable level of humidity from the water that pass through the filter. Also using LED as indication to operate the mist system this will provide high level of humidity and also the mist system provide simple method to irrigation.

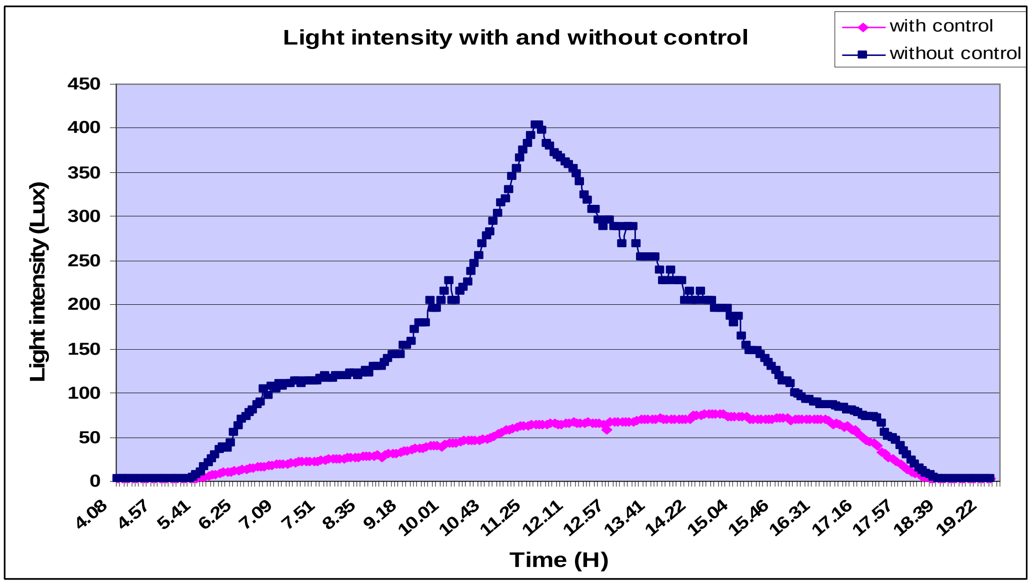

Fig.20 Light intensity Collected from Greenhouse with and without Control

Finally the Fig 20 which represent the value of light sensor. First line show the light intensity without control which increase when the reading reach to the highest range in 12 PM and after this periods it will be drop to reach to the lowest value at sunset. Light has an effect on growth processes of plants in agricultural environments, as strong sunlight causes greater transpiration while the plants that grown in darkness are seen as weak plants lacking chlorophyll. Therefore monitoring light plays an important issue to control greenhouse. The second line represented the light intensity with control which was smallest comparing to first line without using control. The white shading are used to decrease the light intensity because the white color considered less absorption of sunlight than the other shading colors.

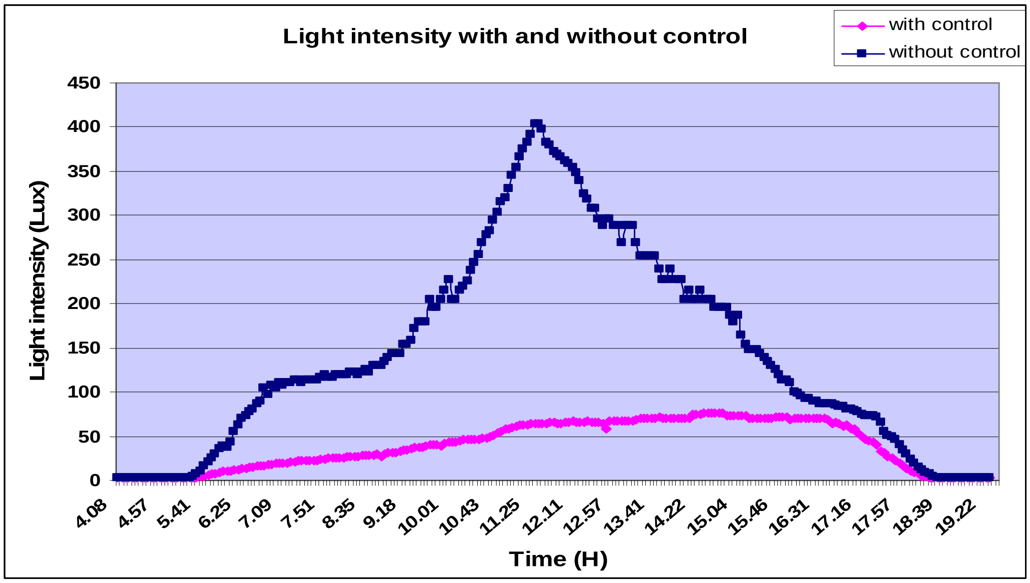

Figure (20): Light intensity collected from greenhouse with and without control

VI. CONCLUSION

In this work, a design and implementation of greenhouse parameter monitoring and control system has been proposed. This system is able to collect the information about the main environmental parameters such as; Temperature, Humidity and Light inside the greenhouse. And have the ability to keep these parameters smaller than the outside environment by using two simple fans. The analog signals of different sensors are converted into digital values utilizing the capability of XBee via its analog to digital converters of the end devices.

These information are transmitted through wireless manner to central computer to be processed and making a decision based on simple fuzzy controller to initiate suitable digital command signals via digital outputs of XBee to regulated the greenhouse parameters for specific crop. Because the overall design of the wireless sensor network has been designed by using XBee only without microcontroller, the cost and required power of system has been reduced, also the system more simple and easy to install. The collected data and the generated control signals are stored on database to be analyzed for enhancement of the crop growing purposes.

References

[1] D.D.Chaudhary1, S.P.Nayse2, L.M. Waghmare, "Application Of Wireless Sensor Networks For Greenhouse Parameter Control In Precision Agriculture", International Journal of Wireless & Mobile Networks (IJWMN) , February 2011,Vol. 3, No.1, pages 1-3.

[2] Andrzej Pawlowski, Jose Luis Guzman ,Francisco Rodríguez, Manuel Berenguel,José Sánchez and Sebastián Dormido, "Simulation of Greenhouse Climate Monitoring and Control with Wireless Sensor Network and Event-Based Control",' sensor Journal', 2009, Vol 9, Page 2.

[3] ZHANG Qian, YANG Xiang-long, ZHOU Yi-ming, WANG Li-ren and GUO Xi-shan, “A wireless solution for greenhouse monitoring and control system based on ZigBee technology" ,Journal of Zhejiang University SCIENCE 2007 8(10): page 1-2.

[4] Ibrahim Al-Adwan and Munaf S. N. Al-D " The Use of ZigBee Wireless Network for Monitoring and Controlling Greenhouse Climate"International Journal of Engineering and Advanced Technology (IJEAT) ',2012 , Volume-2, page 1-5.

[5] Zhou Jianjun, Wang Xiaofang, Wang Xiu1, Zou Wei1 and Cai Jichen "Greenhouse Monitoring and Control System Based on Zigbee" , Proceedings of the 2nd International Conference on Computer Science and Electronics Engineering (ICCSEE 2013) ,page 1-5.

[6] Robert Faludi, “Building Wireless sensor networks ", United States of America ,O’Reilly, First Edition, December 2010.

[7] Ning Wang , Naiqian Zhang and , Maohua Wang , “Wireless sensors in agriculture and food industry—Recent development and future perspective",' Elsevier Journal of Computers and Electronics in Agriculture,2006,Vol 50 ,Page 1-14 .

[8] Jin-Shyan Lee, Yu-Wei Su, and Chung-Chou Shen, “A Comparative Study of Wireless Protocols: Bluetooth, UWB, ZigBee, and Wi-Fi ",' Proceedings of The 33rd Annual Conference of the IEEE Industrial Electronics Society (IECON),2007, Taipei, Taiwan, page 1-5

[9] Yu Chengbo Cui Yanzhe Zhang Lian Yang Shuqiang," ZigBee Wireless Sensor Network in Environmental Monitoring Applications ".IEEE,October ,2009,page 1-5

[10] DIGI. XBee ® / XBee – PRO ® ZB OEM RF MODULES. 2008 http://www.digi.com.

[11] Digi. X-CTU Configuration & Test Utility Software. [cited 2008 20-8]

[12] LM35 Precision Centigrade Temperature Sensors datasheet , November 2000.

[13]. Light dependent resistors datasheet, March 1997232-3816.

