Design and Implementation of a Web-based Greenhouse Remote Monitoring System with Zigbee Protocol and GSM Network

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Abstract: In modern and big greenhouses, it is necessary to measure several climate parameters to automate and control the greenhouse properly. Monitoring and transmitting by cable may lead to an expensive and stiff measurement system. Since, Wireless Sensor Network (WSN) is a distributed system that consists of small-size wireless sensor nodes equipped with radio and one or several sensors; it is a low cost option to build the required monitoring system. In this paper, we introduce and implement an intelligent monitoring system based on WSN by using Xbee modules. The Xbee Series 2 hardware uses a microchip from Ember Networks that enables several different flavors of standards-based ZigBee mesh networking. All gathered information by sensors, are sent to a remote center in form of GPRS packets through a GSM network and viewed by monitoring software. The proposed system has low power consumption, low cost and simple driver circuits. Furthermore, it can support various types of digital and analog sensors.

Index Terms: WSN, greenhouse, ZigBeevhi htjohv , greenhouse monitoring, temperature.

I. Introduction

Nowadays, agriculture is under the influence of quality and environmental impact regulations and the application of the ubiquitous and automatic control techniques have been increased considerably during the past few years in order to enhance the productivity by combining IT technology with agriculture [1], [2]. In order to make the crops grow in their best status, certain methods can be used to control the most important environmental factors such as temperature, humidity, light, concentration of CO2 according to the requirement for growth and the environmental impacts from the outside. This procedure can be defined as greenhouse monitoring [2], [3]. Continuous monitoring of these environmental variables provides information to better understand, how each factor affects growth and how to manage maximum productiveness and enables us to improve productivity and to achieve remarkable energy savings [3].

Wireless Sensor Networks (WSN) technology can form a useful part of such an automation system in modern greenhouses which allows a greater number of measurements in the greenhouse with low cost and ease of implementation. Furthermore, these wireless modules are equipped with microprocessors in order to develop different algorithms for data acquisition [2]-[4].

In this paper, we propose a greenhouse monitoring system based on WSN by Using Xbee modules, which use a microchip from Ember Networks that enables several different flavors of standards-based ZigBee mesh networking. By means of the proposed network, we are able to gather information about temperature, humidity, light intensity and monitor the greenhouse.

The organization of this paper is as follows: related works in greenhouse monitoring are represented in section II. In section III, the system architecture and application are shown and the deployment result and discussion for the result is investigated. It is followed by conclusion, in Section IV. Finally, in section V, we discuss about future works.

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II. Related Works

In [3], a wireless sensor node is developed for greenhouse monitoring by integrating a sensor platform provided by Sensinode Ltd. which is feasible and reliable, in order to measure four climate variables. It is shown that the network can detect the local differences in the greenhouse climate caused by various disturbances, such as direct sunshine near the greenhouse walls.

A remote intelligent monitoring system (RIMS) based on ZigBee WSN is presented in [4]. In the RIMS data is transmitted to the controlling center through ZigBee mesh network and the remote control will be available. Moreover, redundancy router nodes are designed to improve the transmitting reliability.

In [5], the results of real deployment of A^2S which consists of WSN to monitor and control the environments and a management sub-system to manage the WSN and provide various and convenient services to consumers with hand-held devices such as a PDA living a farming village. It has been used to monitor the growing process and control the environment of the greenhouses. Valuable experiences and ideas from this real deployment and operation of A^2S are acquired.

In [2], an event-based WSN system has been investigated. In such a system, WSN distributed modules allow to perform an event-based algorithm before transmitting the data to define when it is necessary to transmit the acquired data, so transmissions could be minimized. Thus, modules energy consumption can be reduced, extending the battery life.

In some papers, new automated control methods such as fuzzy neural network [6] have been studied. In [7], two fuzzy logic controllers are developed, embodying the expert knowledge of agriculturists for monitoring the greenhouse’s indoor luminance, temperature, relative humidity, CO2 concentration and the outside temperature. These controllers consist of fuzzy P (Proportional) and PD (Proportional-Derivative) control using desired indoor climatic set-points.

A robust control design is proposed in [8]. Simulation results show promising performances despite the high interaction between the process internal variables and the high impact on these variables of the external meteorological conditions.

Neural networks are also tools of interest which have been studied in some papers. In [9], radial basis function neural networks have been used for greenhouse air temperature prediction and different neural network models have been compared with conventional models. In [10], neural network greenhouse models were trained using data collected over two summer months in a small greenhouse. The models were reduced to minimum size, by predicting separately the temperature and CO2 concentration, and by eliminating any unessential input. The resulting models produce reasonable optimization results. An Elman neural network has been used to emulate the direct dynamics of the greenhouse in [11]. Based on this model, a multilayer feedforward neural network has been trained to learn the inverse dynamics of the process to be controlled. The inverse neural network has been placed in cascade with the neural model in order to drive the system outputs to desired values. Simulation results will be given to prove the performance of neural networks in control of the greenhouse. It can be concluded that finding the balance between the numbers of neurons in the hidden layer of the system based on neural network and the number of iterations for model training play an important role in obtaining a good performance [12]. Furthermore, in [13] the use of neural networks for air temperature prediction inside buildings has been studied. It is shown that by using multi-objective genetic algorithms for the off-line design of radial basis function neural networks, the neural models can achieve better results than state-of-the-art physical models.

The 2.5G GSM network is a proper and cost-effective communication platform for transmitting a WSN data via SMS or GPRS packets [14]. In [15], a real-time, reliable and expansible monitoring system for a greenhouse is proposed by using GPRS service and a WSN. The design and implementation of electronic system based on GSM for controlling the climate parameters by SMS for remote control of the climatic parameters is discussed in [16].

Our proposed system presents a simple and applicable method which can be easily used in practical environments. By using the data collected from greenhouse in this system, we are able to study other control methods for greenhouse control and other important issues such as optimization of the greenhouse structure based on geographical data.

III. Greenhouse Monitoring System

A. System Architecture

In this project, a greenhouse is studied in Jahrom. Since monitoring of major factors in a greenhouse is important, several sensors have been implemented in the greenhouse for gathering data about temperature, humidity and light intensity. A WSN is applied for communication between sensors. Fig. (1) shows the proposed structure based on WSN and GSM Link. Each sensor node, receives the signals of sensor as the environmental status in certain time intervals. All gathered information by sensors, are sent to a sink node which plays the role of a gateway. The received data in the gateway are sent to a remote server in form of GPRS packets through a GSM network and in certain time intervals. In the remote server, the data are delivered to a computer equipped with monitoring software by means of IP packets. This software provides different graphs versus time based on the data of each sensor. Thus several users can access to these information. In general, the system is composed of three parts as follows: 1- wireless sensor network, 2- GSM link, and 3- web based monitoring software.

B. Implementation

In order to implement a WSN, selecting and designing of sensors and nodes in the network are major factors. The nodes in the network should support Zigbee/IEEE 802.15.4 protocol and have the ability to connect to different sensors. Furthermore, sensors should have good precision and proper physical structure for utilizing in greenhouse and agricultural applications. The proposed sensors and network nodes will be presented in the following.

B.1 Sensors

In general, sensors are divided to two digital and analog categories. Analog sensors convert the environmental status to an analog signal. The output of these sensors is electric voltage which increases or decreases according to variation in environmental status. When these sensors are used in digital systems, sampling of analog signal is necessary and the precision depends on the sampling rate. By developing of the micro-electronic technology in recent years, digital sensors are manufactured with high precision and flexibility. The output of these sensors is a digital signal. These sensors are more precise than analog sensors and can be used in digital systems such as microcontrollers simply.

In the proposed system, we have used a digital sensor called “SHT 75” for gathering temperature and humidity information. This sensor is shown in Fig. (2). Furthermore, this sensor samples from temperature and humidity of the environment with high precision (14 bits) simultaneously and provides the output data in serial protocol. Other features of this sensor are small size, not requiring complex driver circuits, low power consumption and low cost.

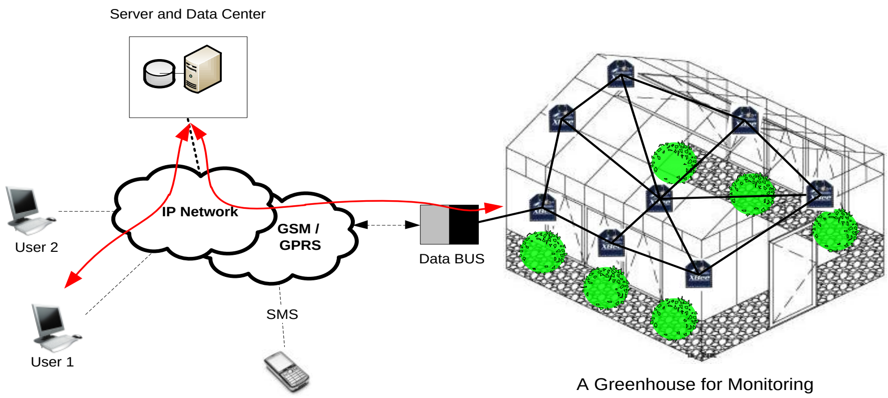

Fig. (1): The proposed structure based on WSN and GSM Link

Fig. (2): SHT75 sensor for temperature and humidity

For gathering data about light intensity in the greenhouse, we have used a digital sensor called "TSL2550" which is shown in Fig. (3). High precision, driving simply and low power consumption are some features of this sensor. TSL2550 sensor computes the light intensity in terms of W/m^2 with format of serial 12 bits data. This sensor have been used in other applications such as controlling light of monitors in laptops and PDAs and computing light intensity of environment in digital cameras.

B.2 Network Nodes

Different network nodes based on Zigbee/ IEEE802.15.4 have been offered until now. According to the application, Xbee module has been chosen which is shown in Fig. (4). This module supports the Zigbee/IEEE802.15.4 protocol and has some particular features for utilizing in the network. Some significant features of the module are low power consumption, low cost and simple driver circuits. Furthermore, this module can support various types of digital and analog sensors. On the other hand, easy configuration, support of AT commands and the ability to program it online and with wireless links are other advantages of this module. Radio coverage of the module is more than 100 m for indoor and more than 300 m for outdoor which is reasonable for applying in a greenhouse.

Here, we have used the series 2 which uses a microchip from Ember Networks that enables several different flavors of standards-based ZigBee mesh networking. Mesh networking is the heart of creating robust sensor networks, the systems that can generate immensely rich data sets or support intricate human-scale interactions [17].

Accordingly, the IEEE 802.15.4 standard defines two classes of physical devices: a full-function device (FFD) and a reduced-function device (RFD). Xbee module can be configured as a coordinator, FFD node or RFD node in implementation of the network. Network coordinator is an FFD device which is responsible for network establishment and control. The coordinator is responsible for choosing key parameters of the network configuration and for starting the network [18]. Xbee module can also support various network topologies such as star, Peer to Peer (or Mesh) and cluster tree. Fig. (6) shows these various network topologies.

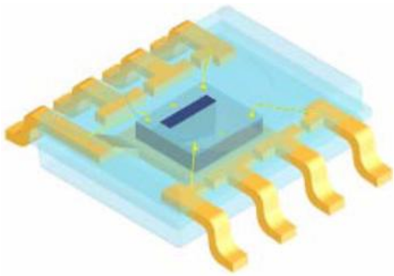

Fig. (3): TSL2550 digital sensor for light intensity

Fig. (5): Xbee module

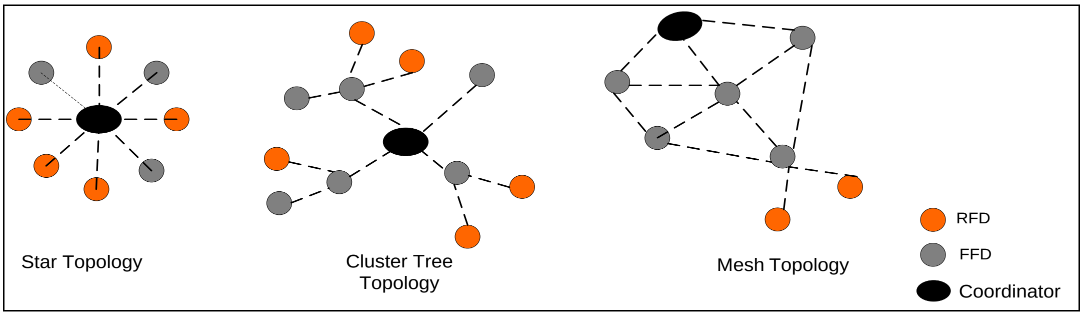

Fig. (6): Various network topologies

C. GSM Communication Link

In order to achieve remote connection between the sensor network in the greenhouse and monitoring computer, one GSM modem has been used in the greenhouse side in order to send collected data to a remote web based server via GPRS packets. The GSM modem selected for our system is “WISMO Quik Q2403” model manufactured by WAVECOM company. Fig. (7) shows the WISMO Quik Q2403 GSM modem. It has some good features such as support of SMS/GPRS systems, noise cancellation system, support of AT commands and low power consumption.

Fig. (7): WISMO Quik Q2403 GSM modem

For driving the GSM modem, a microcontroller is used for creating a connection and sending various commands to the modem, in addition to interfaces. In our design, AVR microcontrollers are used, since they have good performance and can support many interfaces.

In the greenhouse side, the AVR microcontroller is programed in such a way to receive the collected data by WSN and also to send it to the GSM modem after converting to a proper format. This process is illustrated in Fig. (8).

Acquired data from the greenhouse are gathered in a remote server. These data are displayed as graphs in the monitoring devices which are received via IP packets and can be viewed by an explorer. This structure is depicted in Fig. (9).

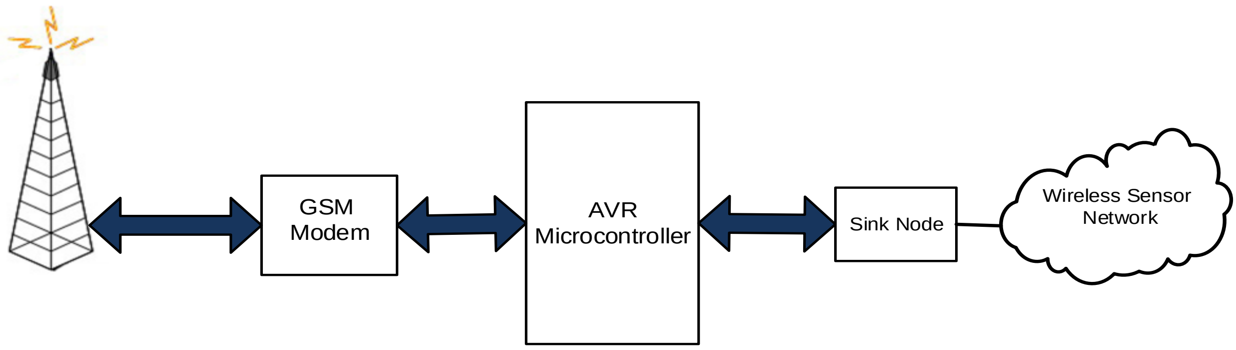

Fig. (8): Hardware in the greenhouse side

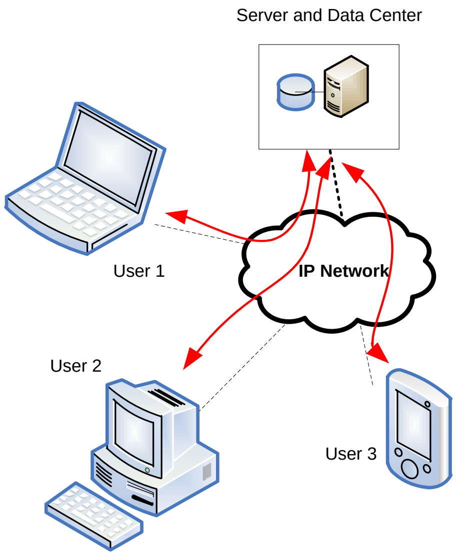

Fig. (9): Hardware in the monitoring computer side

D. Monitoring Software

Monitoring software should be able to receive data from the board serially and plot the temperature, light intensity and humidity curves versus time. Furthermore, it provides a proper environment for data processing in order to perform control operations in the greenhouse, which is left for future works.

C# is a high-level approach which is usually fast to develop in. It comes with a large framework of predeveloped components, which makes it particularly useful for server-side programming. It is full of features that make development fast and easy, usually at the cost of flexibility and/or runtime performance.

The Model-View-Controller (MVC) is a well-proven design pattern to solve the problem of separating data (model) and user interface (view) concerns, so that changes to the user interface do not affect the data handling, and that the data can be changed without impacting/changing the UI. The MVC solves this problem by decoupling data access and business logic layer from UI and user interaction, by introducing an intermediate component: the controller. This MVC architecture enables the creation of reusable components within a flexible program design. Thus the MVC as the name applies considers three components: 1- Model which is responsible for the data of the application domain, 2- View that presents the display of the model in the user interface, and 3- Controller that really the heart of the MVC, the intermediary that ties the model and the view together, i.e. it takes user input, manipulates the model & causes the view to update. Fig. (10) illustrates a typical relationship between the MVC components.

So, in order to achieve a monitoring system, a webpage for greenhouse monitoring system is realized as seen in Fig. (11).

E. Result

As a result of applying the system to a greenhouse, information of environment in greenhouses is collected through sensors and the greenhouse can monitor by means of a user friendly GUI. Fig. (12) is the window for the temperature graphs that are collected from the greenhouse.

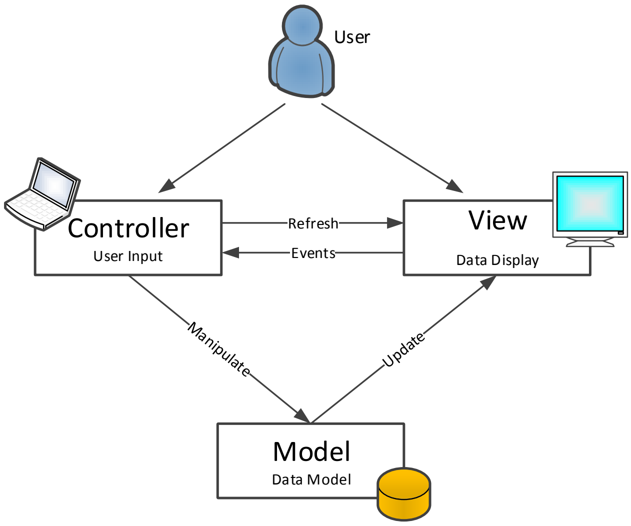

Fig. (10): A typical relationship between the MVC components

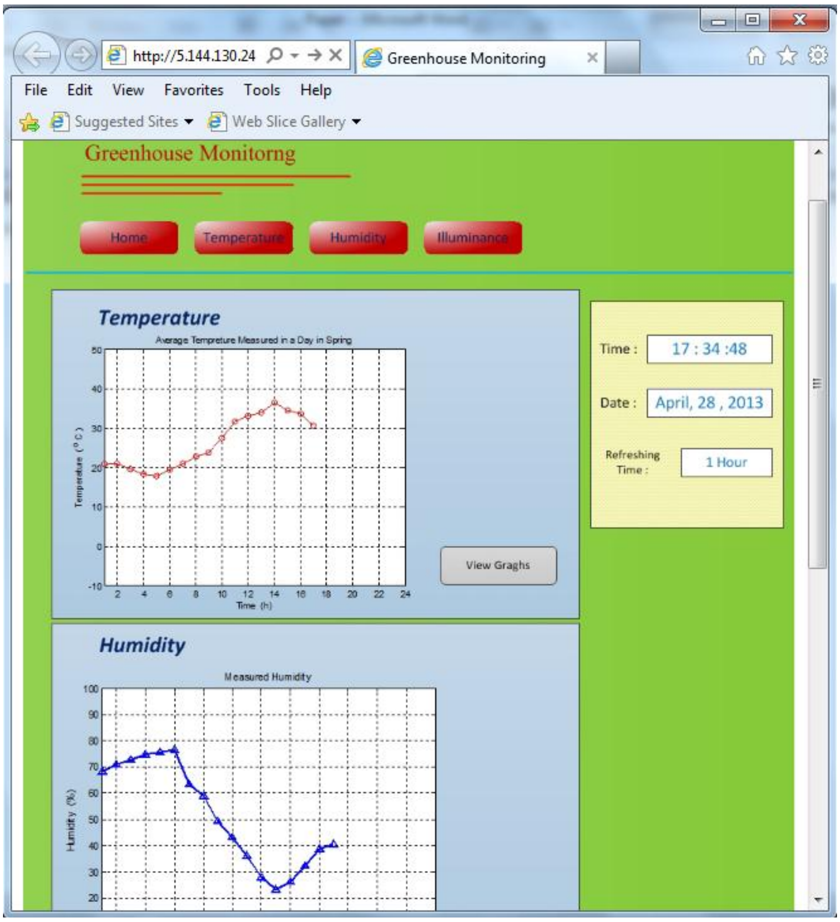

Fig. (11): Website for the monitoring system

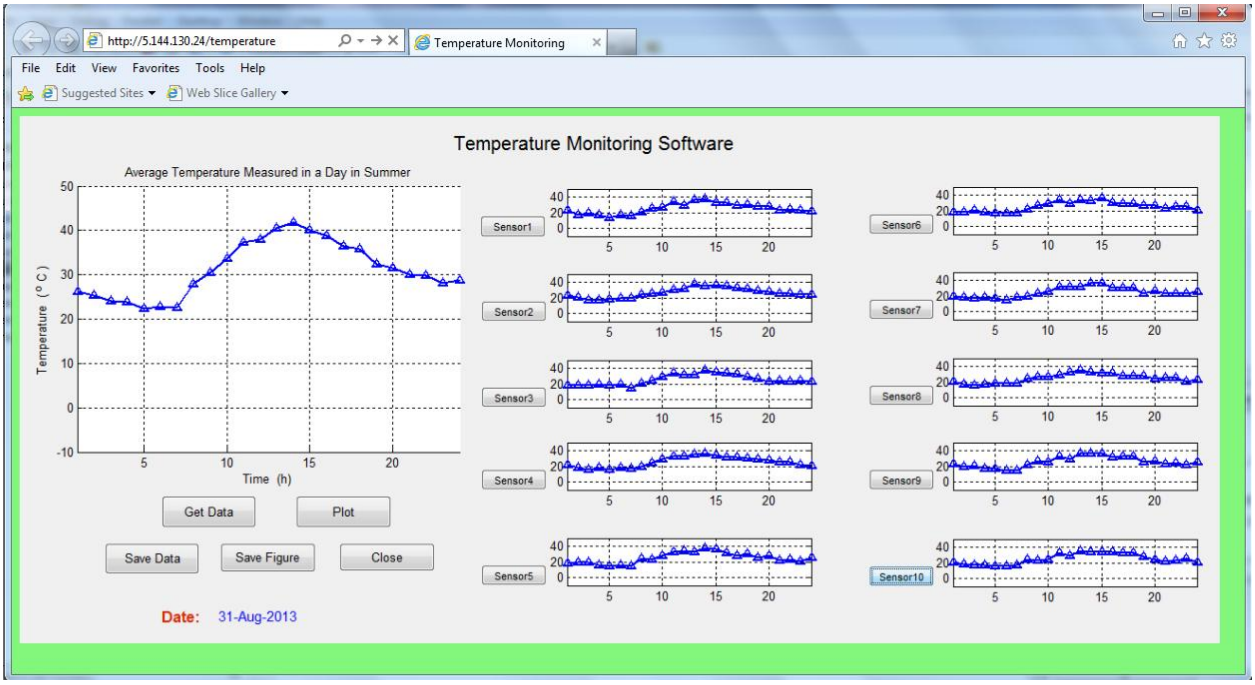

Fig. (12): Webpage for temperature monitoring system and its graphs

The user can view the curve of temperature every hour by pressing Plot button. Furthermore, it is possible to view the data of each sensor separately. Note that we have used 10 sensors in our implementation. This Webpage also provides the ability to save the curve and data collected by sensors.

First by pressing Get Data button, the data that are collected by sensors enter the monitoring computer from the server by means of IP packets. Finally, the curve is plotted by pressing Plot button.

The Webpage for humidity monitoring and its resultant curves are shown in Fig. (13). This Webpage is similar to Webpage for monitoring temperature curves.

Fig. (13): Webpage for humidity monitoring system and its graphs

The GUI for light intensity monitoring and its resultant curves are shown in Fig. (14). This GUI is similar to GUI for monitoring humidity curves.

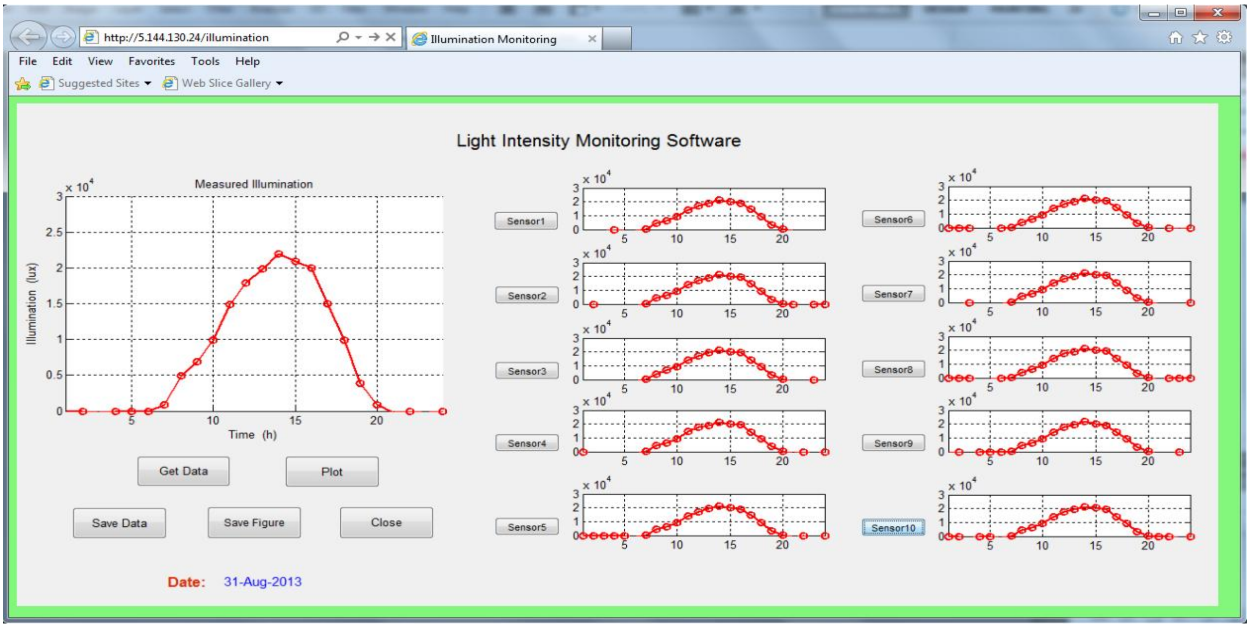

Fig. (14): Webpage for light intensity monitoring system and its graphs

IV. Conclusion

In this paper, we proposed a greenhouse monitoring system based on wireless sensor network and GSM network as the systems to monitor the greenhouse. We used the Xbee Series 2 hardware for implementation of WSN which has several flavors of standards-based ZigBee mesh networking. This system implemented in a greenhouse for collecting data about temperature, humidity and light intensity. The data can be sent via SMS or GPRS packets through a GSM network. This ability is very useful in remote control of the greenhouse. As a result of the implementation and monitoring of the greenhouse several GUIs were designed to show the curves of environmental factors. Furthermore, the proposed system is cost effective, easy to implement, has a user friendly GUI, low power consumption. Furthermore, it can support various types of digital and analog sensors. By using the data collected from greenhouse in this system, we are able to study important issues such as optimization of the greenhouse structure based on geographical data.

V. Future Works

Gathering other environmental data such as concentration of CO2, soil fertilizer, etc. and also applying new control methods such as fuzzy controller, artificial neural networks and neuro-fuzzy controllers are fields of study which will be followed in future works.

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