DESIGNING AN EMBEDDED SYSTEM FOR THE PARAMETER MONITORING AND CONTROL INSIDE A GREENHOUSE

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Abstract

The paper proposes an embedded system to monitor and control the environmental parameters inside a greenhouse. The parameters include temperature, humidity, CO_2 concentration and light intensity. The control actions can be water spray, fog spray, LEDs etc. The sensor nodes form a Wireless Sensor Network. The primary node in the network will send the values to the user PC via GSM module. It accepts the command from PC and transfer in the network.

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1. INTRODUCTION

A general-purpose definition of embedded systems is that they are devices used to control, monitor or assist the operation of equipment, machinery or plant. "Embedded" reflects the fact that they are an integral part of the system. In many cases, their "embeddedness" may be such that their presence is far from obvious to the casual observer [1].

Greenhouses are frames of inflated structure covered with a transparent material in which crops are grown under controlled environment conditions. Greenhouse cultivation as well as other modes of controlled environment cultivation has been evolved to create favorable micro-climates, which favours the crop production could be possible all through the year or part of the year as required. Greenhouses and other technologies for controlled environment plant production are associated with the off-season production of ornamentals and foods of high value in cold climate areas where outdoor production is not possible [4].

The primary environmental parameters to be monitored in a greenhouse are temperature, relative humidity, and light intensity. The optimum range of these parameters varies from crop to crop. So, there is a need of keeping these parameters in a specific range that depends on the plant inside the greenhouse. With the help of a set of sensors and controlling devices, these parameters can get adjusted to the desired value.

Photosynthesis is the process of converting the water and Carbon dioxide into Carbohydrates in the presence of light.

6H2O+ 6CO2 + *light* $\longrightarrow$ C6H12O6 + 6O2 .....(1)

The equation (1) shows the basic equation of photosynthesis. From this, it is obvious that, the amount of Carbon dioxide present in the atmosphere also affects the growth of the plant. So, Carbon dioxide is also a parameter that should be measured and controlled.

In many larger greenhouses, additional supply of Carbon dioxide is provided. One of the things that should be taken care here is the leakage of Carbon dioxide from the greenhouses.

2. PROPOSED SYSTEM

There are a number of systems existing for the monitoring of environmental parameters inside the greenhouses. Some of them are not having the controlling action. Some other systems don't have the Carbon dioxide monitoring.

The proposed system is having a preset value range for all the parameters. These values are user defined based on the crop requirements. When the parameter value goes beyond this range, the controller will switch the control actions on. The control actions include water spray, fog spray, LEDs, shadow pads, natural ventilation etc.

The block diagram for the proposed system is as given in fig.1 The sensing unit contains five sensors. These sensors monitor the changes in the parameters such as temperature, humidity, light intensity, wavelength of the light, and Carbon dioxide concentration. The sensors send their data to the micro controller. The micro controller is connected to a PC via a GSM module. The PC is equipped with the support of LabVIEW. In the LabVIEW GUI, the user can adjust the minimum and the maximum range of each parameter.

The PC will compare the present value and the real time value. If the value is not in range, the PC will command the controller to adjust the change through proper action.

The wavelength sensor senses the wavelength of the light present in the greenhouse. The photosynthesis rate depends on the wavelength of the light. The photosynthesis rate is maximum in the wavelength range of 650-700nm. This wavelength is near the red light region [5]. With the wavelength value, the rate of photosynthesis can be determined. From this rate, we can get the consumption of Carbon dioxide at a time. By measuring the Carbon dioxide concentration, we can get the amount of additional Carbon dioxide to be supplied. The increase in the consumption rate also indicates a leakage.

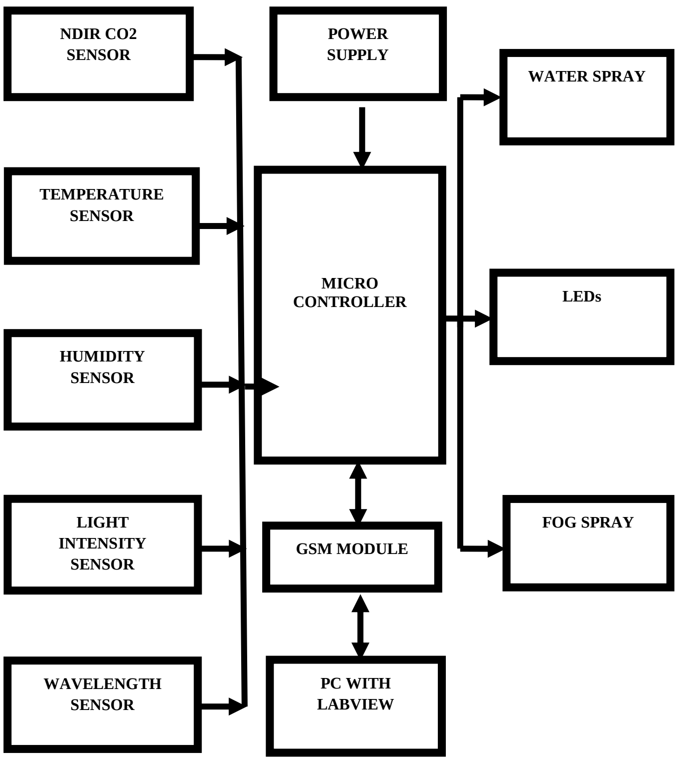

Fig.1 Block Diagram for the Greenhouse Monitoring System

3. HARDWARE DESCRIPTION

The temperature sensor used in the system is DS1820. DS1820 digital thermometer, which can convert the temperature to digital within 1second and provide 9-bit digital value of temperature readings, is chosen with the measurement range of −55° to +125° and value added volume of 0.5°. Single-mode 1-Wire bus is adopted by this thermometer to connect to the central processing unit and no external components or backup power supply is needed. Power for reading, writing, and performing temperature conversions can be derived from the data line itself with no need for an external power source [6].

SHT10 is Sensirion's family of surface mountable relative humidity sensor. The sensors integrate sensor elements plus signal processing on a tiny foot print and provide a fully calibrated digital output. A unique capacitive sensor element is used for measuring relative humidity while temperature is measured by a band-gap sensor. The applied CMOS technology guarantees excellent reliability and long term stability. The 2-wire serial interface and internal voltage regulation allows for easy and fast system integration [7].

The TSL2563 is a low-voltage, light-to-digital converter that transform light intensity to a digital signal output capable of direct I^2C or SMBus interface. Each device combines one broadband photodiode (visible plus infrared) and one infrared-responding photodiode on a single CMOS integrated circuit capable of providing a near-photopic response over an effective 20-bit dynamic range (16-bit resolution). Two integrating ADCs convert the photodiode currents to a digital output that represents the irradiance measured on each channel [8].

The WS-7.56 is a unique wavelength sensor based on silicon photodiode technology. This device is most useful for wavelength determination of monochromatic light sources. The voltage is proportional to wavelength in the range of 450nm to 900nm. The output is independent of intensity. The circuit provides switched gain controls to accommodate various output requirements. The actual output must be calibrated against know sources for accuracy. Resolution of 0.01nm is possible [9].

With broad measurement range, high sensitivity, fast response time, good selectivity and strong anti-interference ability, S-100 miniature CO2 sensor module is selected. This sensor adopts Non-dispersive infrared (NDIR) spectroscopic analysis technology, and is widely used in many fields such as air quality monitoring [10].

The LPC1768 is ARM Cortex-M3 based microcontroller for embedded applications featuring a high level of integration and low power consumption from NXP semiconductors. The ARM Cortex-M3 is a next generation core that offers system enhancements such as enhanced debug features and a higher level of support block integration [11].

SIM300 is a Tri-band GSM/GPRS engine that works on frequencies EGSM 900 MHz, DCS 1800 MHz and PCS1900 MHz. SIM300 provides GPRS multi-slot class 10 capability and support the GPRS coding schemes CS-1, CS-2, CS-3 and CS-4. With a tiny configuration of 40mm x 33mm x 2.85mm, SIM300 can fit almost all the space requirement in your application, such as Smart phone, PDA phone and other mobile device [12]. This is the GSM module used.

4. NEED FOR MULTIPLE NODES

A greenhouse may cover a very large area. For such an area, there will be a number of water sprays, LED units, fog sprays etc. The values of the parameters will not be the same at all the locations in a large greenhouse. So, sensing the parameters in a single location in the greenhouse will not give the data for the efficient parameter control. Therefore it is better to use a number of sensor nodes in a greenhouse.

This number depends on the size of the greenhouse. For example, in a greenhouse with a length of 45metre and a width of 15metre, two or three nodes are enough. Each monitors and controls the parameters in a specific area.

5. DESIGN OF WSN

A Wireless Sensor Network is having a number of sensor nodes. Each node is communicating with the other nodes. These nodes can make a cluster which is having a certain percentage of the total nodes. All of the nodes are having a certain protocol for the communication and the data collection. In the above example, we have considered a greenhouse of area 45 x 15 m^2. We need three sensor nodes for this greenhouse. The design of the WSN will be as shown in fig.2.

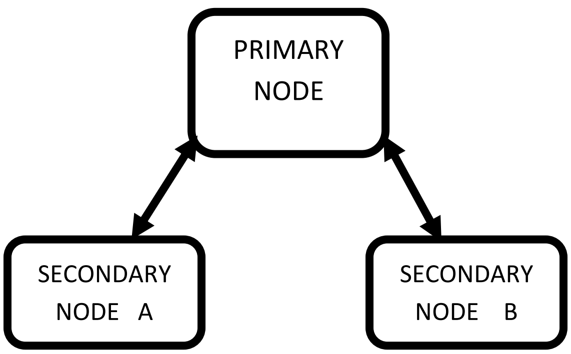

Fig.2 The design of WSN

One of the nodes is considered as the primary node. Only the primary node is having the GSM module. Thus, the PC is having the communication with this primary node only. The other two nodes are sending their data to the PC via the primary node. The communication between the primary and the secondary nodes is by means of the transceivers.

The data collected by the secondary sensor nodes will be sent to the primary node. The primary node sends this data to the PC along with the data gathered by it. The commands from the PC are given back to the nodes via the GSM module and the primary node. Each transceiver is having a unique id. The data transfer is done with the help of this id.

6. EXTENSION TO THE WSN

The model of the WSN shown in fig.3 is relevant to the greenhouses that are similar in size to the example greenhouse shown in fig.2. As the size of the greenhouse increases, the number of nodes needed also increases. The extension in the greenhouse area or the size of the WSN must not affect the other nodes.

The transceiver in each node is having a unique id. The nodes in the WSN can be categorized as primary, secondary, tertiary etc. Each node is having a path to communicate to the PC. The extension of the WSN up to the tertiary level is as shown in fig.3. The tertiary node sends the data to the secondary nodes. Then the data is transferred to the primary node and finally, the primary node sends it to the PC.

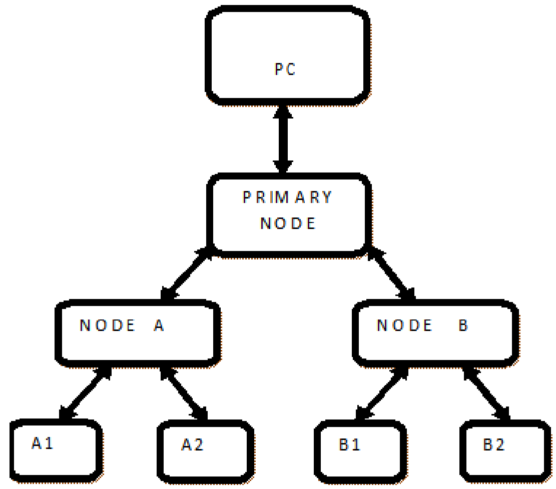

Fig. 3 Extended WSN

7. USER INTERFACE

The user interface can be done by one of the most powerful method called LabVIEW. LabVIEW has the capability to connect and interact with a large number of hardware devices. NI-DAQmx is a programming interface that is used to communicate with data acquisition devices [13]. LabVIEW supports the interface of a GSM module. Thus the data will be stored and displayed in the PC. The Graphical User Interface is as shown in fig.4

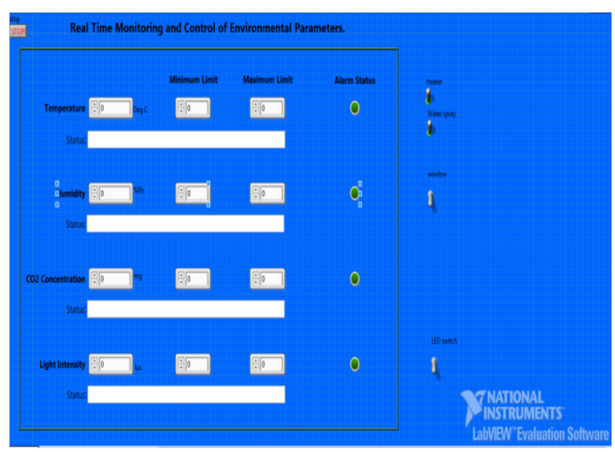

Fig. 4 LabVIEW GUI

Here we have to set the desired range of the parameters by setting the minimum and the maximum values in the GUI panel. These ranges are based on the crop inside the greenhouse. When the crop is changed, the range also gets changed.

8. CONCLUSIONS

Based on the CO_2, temperature, light intensity and humidity sensor values, the control room PC acquires the real time environmental condition inside a greenhouse. The sensors are positioned in such a way that each can get the corresponding values in a specific area of the greenhouse. The sensor nodes form a Wireless Sensor Network. The user interface is a PC with the support of LabVIEW. In this panel, we set the minimum and maximum values of a parameter can be varied. This gives the range of the parameters required.

Then based on the PC command, the controllers will make the appropriate actions to keep the parameters in range.

The protocol used for the communication between the nodes in the WSN is effective only up to tertiary level. For more number of nodes, a better protocol must be used.

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