APPLICATION OF WIRELESS SENSOR NETWORKS FOR GREENHOUSE PARAMETER CONTROL IN PRECISION AGRICULTURE

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ABSTRACT

The technological development in Wireless Sensor Networks made it possible to use in monitoring and control of greenhouse parameter in precision agriculture. In last decades there have been tremendous advancements in technology for agriculture and growth of final yield. Due to uneven natural distribution of rain water it is very crucial for farmers to monitor and control the equal distribution of water to all crops in the whole farm or as per the requirement of the crop. There is no ideal irrigation method available which may be suitable for all weather conditions, soil structure and variety of crops cultures. Green house technology may be the best solution for this solution. All the parameters of greenhouse require a detailed analysis in order to choose the correct method. It is observed that farmers have to bear huge financial loss because of wrong prediction of weather and incorrect irrigation method to crops. In this contest with the evolution in wireless sensor technologies and miniaturized sensor devices, it is possible to uses them for automatic environment monitoring and controlling the parameters of greenhouse, for Precision Agriculture (PA) application. In this paper, we have proposed and analyse the use of Programmable System on Chip Technology (PSoC) as a part of Wireless Sensor Networks (WSN) to monitor and control various parameter of green house.

KEYWORDS

Greenhouse, Precision Agriculture, Programmable system on chip, Wireless sensor networks.

1. INTRODUCTION

In the Precision Agriculture (PA) various techniques are available to monitor and control the required environmental parameters for the particular crop. It is particularly crucial to analyse the methods which can effectively manage the proper environment. The use of wireless sensor network for the large area is now becoming popular in green house technology of precision agriculture. The parameters of green house to be control are increasing day by day so that it may cause the data traffic and congestion in the future. So that, the wireless sensors derived from PSoC technology with high-bandwidth spectrum or cognitive radio technology may be the proper solution for smooth data traffic and remote control of green house from long distance. With the use of green house concept, the farmer can produce different crops in different climates and various seasons. In proposed design of the green house, the farmer can easily keep the desired Crop's environment conditions.

To fulfil this requirement we need the environmental parameter sensors, such as Temperature sensor, humidity sensor, CO_2 sensor etc. All these sensors can be connected to server or sink node without wire. Such a network is called Wireless Sensor Network. This network can help to monitor and control all the environmental parameter of Precision Agriculture [1].

In a prototype green house (70m x 150m) design for a typical crop capsicum, will approximately require 40 to 50 wireless nodes (sensor and actuates). If we consider more preciseness in monitoring & control, the number of wireless nodes may be more than fifty. At a particular event, all the sensors may send information to the central node. The management server may face the problem of data congestion and intercommunication between nodes. Such challenges can be overcome by the application based WSN with a specific protocol and system on chip based hardware with programmable radio, which we would like to nominate for design of control for green house. A typical block diagram of wireless sensor node is as shown in figure 1.

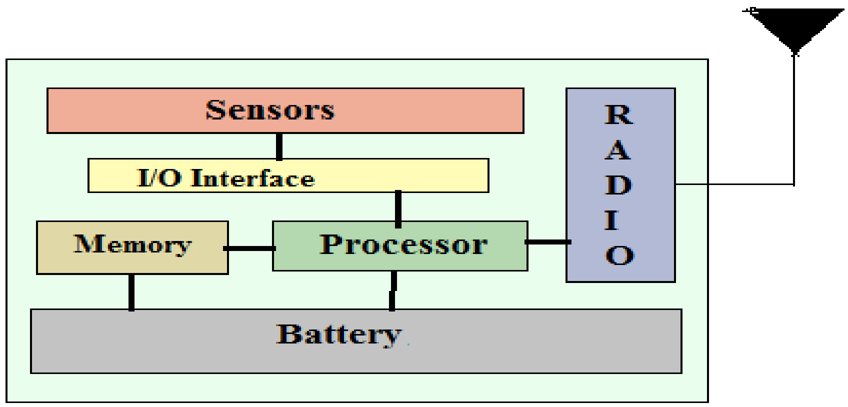

Figure 1, Typical Sensor node

Wireless sensor nodes are very small devices that with limited battery source. It's processing power and memory both are also limited. In automation and control applications, WSN are popular because they are scalable and easy to handle. Now-a-days there are a number of economical sensor nodes are available with a high-level technology. They are capable to collect the environmental data with precise sensors and are able to transmit it to control station with high efficiency.

1.1 Related Work

Many researchers observed that, the green house technology is well accepted in agriculture engineering. The integration of wireless sensor network in green house is the recent concept which leads to precision agriculture. Blackmore et al. in 1994 [2], explained that, the system can be designed to increase the quality agricultural yield by, properly monitoring soil and environment. They also observed that, in early stage of WSN, farmers were reluctant to deploy it, because of high cost. Technological development has reduced the cost.
In addition to MEMS technology for hardware, some other technologies like, satellite sensing, Remote Sensing, Global Positioning System and Geographical Information System are also contributing in overall progress [3]. Beckwith et al. had worked on WSN in large scale vineyard on very large scale design and deployment [4]. They work on 65 motes, which have only eight hops, to collect the data of pH values. Predesigned crop management in precision agriculture is studied in the Lofar Agro project, in Europe. In this project, Proper application of pesticides and fertiliser as per real time environmental changes is explored. For effective control of crop diseases like phytophthora, the information collected from a weather station and the wireless network is very much useful [5].

2. SELECTION OF TECHNOLOGY

For greenhouse control when a more number of sensors to identify the parameters are need to be networked wireless then various levels of networking may be required. A ZigBee sensor network can use to maintain network performance at a high level. A Remote Application Server (RAS) can also be employed in the area near to the localized sensor to gather localized data, to host and to manage the network.

Wireless sensors and smart transducers are equipped with some micro-controllers for providing processing and network management capability. Standard like IEEE 1451.5 is also suitable to integrate the wireless sensors with the special transducer to build intelligent wireless sensors with sensing, computing and communication capabilities. Intelligent sensors and actuators can be used to carry out various automatic functions. Wireless communication protocols, such as 802.11, 802.15.4 and 802.15.5 [6] can also combine. A requirement for design of wireless sensor communications, including issues related to wireless sensor model, user requirements, data integrity, security and bandwidth all are well defined in this Standards.

The Cypress inc., has developed CY3271 PSoC First Touch Starter Kit with Low-Power RF, which is a low-cost USB thumb drive kit including related IDE software for sense and control of the data collection. It consists of a PC dongle with RF and multifunction board with power amplifiers and two battery boards. It can be also used for touch-sensing, temperature-sensing, lighting-sensing and proximity sensing requirements of greenhouse.

3. PRECISION AGRICULTURE

Precision Agriculture model consist of, Wireless sensors to assist for spatial data collection, irrigation control model, Arrangement for supplying information to farmers, Variable-rate technology model and Green house parameter control system. In spatial data collection, a mobile field data acquisition system is available to collect useful data for crop management [7]. The system is consisted of, a data collection instrument, a manager vehicle, data collection and control systems on farm machines. This system can handle local field survey and collects data of soil water availability, biomass yield, soil compaction, soil fertility, leaf area index, leaf temperature, leaf chlorophyll content, local climate data, insect-disease-weed infestation, plant water status, and yield of grain etc.

The data from farm machines is retrieved by the data collection instrument through local network. Then it can be stored, analysed and transmitted to the manager vehicle via wireless radio. Based on this information the manager vehicle monitor and control the performances of the farm machines. The silage yield mapping system is consist of a moisture sensor, a GPS module, load cells and Bluetooth wireless communication module for yield mapping [8]. The system with infrared sensors, programmable logic controllers and low power radio transceivers is used to collect and transmit the data to a remote receiver placed at outside the farm. The precision irrigation control system is develop by using wireless sensors and can be scheduled to work on-site as per remotely sensed data for a particular application.

The Variable-rate technology is available to determine the quantity of fertilizer to be used for tree crops. In this system, real-time sensor data acquisition console and GPS with input model are the integral part. This collected data can supply to farmers by using web server. This contains information on pesticide, disease infestation and climate forecasts which can download directly via Internet. Finally, the Greenhouse control can be achieved through WSN via Ethernet connected to the central PC of a remote network. A Bluetooth technology can be different for some fields to collect environment data from a sensor network and transmit to a central control system. This type of remote control technology significantly improves productivity and reduces the labour cost.

4. GREEN HOUSE

It is an upcoming technology in the precision agriculture which helps farmers to grow a high-quality crop. This paper is an attempt to design WSN application for the control and monitor the parameters of greenhouse in Precision Agriculture scenario. A sensor network is composed of a large number of tiny autonomous devices, called sensor nodes. Main objective is to monitor and control the environments as per the crop requirements. All sensors are reconfigurable as per the stages of crop growth, dynamic changes in the targeted area, nature of soil, climate, season and type of crop are taken into consideration. A typical green house can be as shown in figure 2.

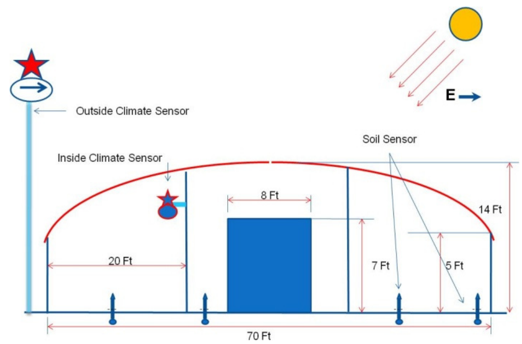

Fig.2, Sensors and structure of green house.

In a green house, there may be a different structure of the crop in different stages of its growth. As per the actual conditions of the green house and the requirements of the crop at a different location in Green House, the application is expected to control acuter like pump, valve, carton slider and fans etc.

4.1 Numbers of Sensor Nodes and Input parameters

The total number of sensor nodes and actuators are depends on the size of greenhouse. About 200 nodes are sufficient if the size of green house is 35m x 200 m. This is the physical size of the targeted area. It is under the range of sensing capacity of the hardware. The sensor nodes can be classified as 'A', 'B' and 'C'. Where type 'A' is climate sensor for outside, and type 'B' is climate sensor for the inside of the greenhouse. Maximum two nodes are more than enough for outside. Type 'B' sensors can be placed at a distance of 10 to 15 meters of diameter, to capture precise environmental condition. The type 'C' sensors are soil sensors, which are recommended to use, as per the layout plan of the crop plantation. They can also control water flow of irrigation system used in Greenhouse. They are typically used after every two meters. The different controlling parameter ranges in various modes for some typical crop is as shown in Table 1. This information collected from the data sheet about the crop [10].

Crop	Temp ºC	CO_2 PPM	Light K Lux	Moisture		pH Value
				Air	Soil	
Carnation	16-22	1000	45-50	65	16	5.5-7.0
Gerberas	27-30	1000	35-40	65	17	5.5-6.5
Anthurium	24-26	1000	18-35	75	20	5.5-6.5
Tomato	16-35	1500	45-50	65	16	5.5-7.0
Roses	15-30	1000	30-40	70	17	4.0-5.5

Table 1, Input parameter for the system

4.2 Sensor Parameters and its use in System

The main objective of WSN system for PA is to control the climatic condition as per the crop data sheet. The outside sensor is designed for collecting information about the outside climate of the green house like Temp, Pressure, Light, Humidity, CO_2,Wind speed and wind direction. All these parameters gives the outside world information about the climate. With the help of this, system will decide the action about the controls like, in out air flow control, screen control (protect the direct sunlight and sun heat) and sprinkler (to maintain the humidity and temp). A typical greenhouse with sensor nodes is as shown in figure 3.

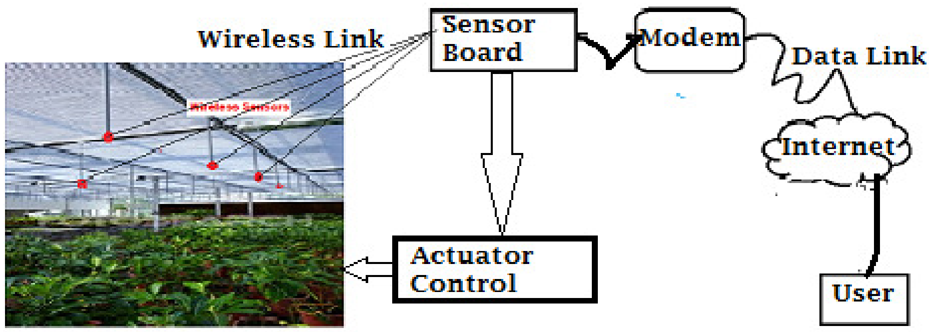

Figure 3, Typical Greenhouse and remote control

In typical green house control, it is necessary to monitor outside wind direction and wind flow. These two parameter helps the system to decide the control of fans which are place at different places to throw the inside air to outside or vice-versa, such that it will synchronize with outside-wind flow.

Soil sensors are placed in heavy density as compare to others. Sensors based on time-domain reflecto-meter (TDR) principal will be used to measure the soil parameter. It is expected to get the soil moisture, soil temp, soil pH value, and soil electric conductivity. In a real-time environment, we require only two of them, soil temp and soil moisture. This will help to decide either sprinkler or drift irrigation is to be control. Other parameters will help to improve the soil condition through fertilizer or other treatment of the soil. Some of this process is worked in the background of the system. It may just display the parameters and log it for further process or application to decide the soil treatment.

4.3 Greenhouse Climatic Control Problem

Crop growth is mainly influenced by the surrounding environmental climatic variables, the amount of water and the fertilizers supplied by irrigation. Greenhouse is ideal for cultivation of proper crop, in which climatic and fertilization variables can be controlled to allow an optimal growth and development of the crop.

As the climate and fertilization are independent issues, they have different control problems. The exact need of nutrients and amount water for different crop species can be very well controlled, by automated machine which works on collected data. The amount of water and fertilizers require to the plant is a function of climate environmental conditions on which growth of the crop is depended. So that greenhouse crop production is a complex issue [11].

The Climatic Control Variables are the dynamic behaviour of the greenhouse. Microclimate is a combination of physical processes involving energy transfer (which includes radiation and heat) and mass balance (which includes water vapour fluxes and CO_2 concentration). This system depends on the outlet environmental conditions, architecture of the greenhouse, performance of the control actuators and variety of crop. Proper ventilation and heating are the main way of controlling green house climate. For controlling inside temperature, humidity and shading the artificial light is used. CO_2 injection is a control to influence photosynthesis and fogging [12].

In this paper, the approach is to introduce the method for the climatic conditions of seasons for greenhouse, where the production in greenhouses is made without CO_2 enrichment and the demand of quality products is increasing every day. Considering the greenhouse structures, the commonest actuators, the crop types, and the commercial conditions of this geographical area, the main climate variables to control are the temperature and humidity. The Photo-synthetically Active Radiation which is the spectral range from 400 to 700 W/m^2. They are used by the plants as an energy source in the photosynthesis process. The PAR is controlled with shade screens but, its use is not much extended. This paper is focused on the temperature and humidity control problems.

5. TYPES OF SENSORS AND CONTROLLING PARAMETERS IN GREEN HOUSE

In this case study and analysis, we have considered three types of sensors. Sensor Node 'A' which is, outside climate sensor will help to get time to time information about wind flow, wind direction, ambient light, temperature, ambient pressure, humidity and percentage of CO_2. Sensor node 'B' is inside climate sensor and will monitor ambient light, temperature, ambient pressure, and humidity and CO2 percentage from the inside of the green house. Soil sensor node type 'C' would be specially design for to monitor the soil conditions like humidity of soil, temperature, pH value, and electric conductivity of a soil. As shown in fig.4.

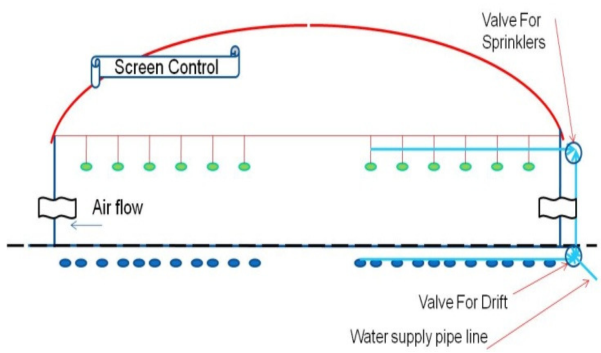

Fig. 4.Controls in green house

The minimum size of the each parameter value shall be one byte, hence the size of data for each type will be required as: 07 byte for 'A', 05 byte for 'B', 4 byte for 'C' will be sufficient.

5.1 Air Temperature Control

Growth of Plants depends on the photosynthesis process which is a measure of photo-synthetically active radiation. It is observed that proper temperature level influences the speed of sugar production by photosynthesis radiation. Temperature has to be control properly since higher radiation level may give a higher temperature. Hence, in the diurnal state, it is necessary to adjust the temperature at an optimal level for the photosynthesis process. In nocturnal conditions, plants are not active therefore; it is not necessary to maintain such a high temperature. For this reason, two temperature set-points are usually considered are diurnal and nocturnal [13].

In favourable weather conditions of temperature during the daytime the energy required to reach the optimal temperature is provided by the sun. In fact, the usual diurnal temperature control problem is the refrigeration of the greenhouse using natural ventilation to achieve the optimal diurnal temperature. On the other hand, heating of the greenhouse up to required temperature is the case of nocturnal temperature control. Some cases forced-air heaters are commonly used as heating systems.

5.2 Humidity Control

Water vapour inside the greenhouse is one of the most significant variables affecting the crop growth. High humidity may increase the probability of diseases and decrease transpiration. Low humidity may cause hydria stress, closing the stomata and thus it may lower down the process of photosynthesis which depends on the CO_2 assimilation. The humidity control is complex because if temperature changes then relative humidity changes inversely. Temperature and humidity are controlled by the same actuators. The main priority is for temperature control because it is the primary factor in the crop growth. Based on the inside relative humidity value the temperature set-point can be adjusted to control the humidity within a determined range. Hence to control the required humidity is very complex task. For proper control of humidity internal air can be exchange with outside air by properly controlling ventilations of the green house [14].

5.3 Soil Condition Control

Soil water also affects the crop growth. Therefore, the monitor & control of soil condition has a specific interest, because good condition of a soil may produce the proper yield. The proper irrigations and fertilizations of the crops are varies as per the type, age, phase and climate. The pH value, moisture contains, electric conductivity and the temp of a soil are some key parameters. The pH valves and other parameters will help to monitor the soil condition. The temperature and the moisture can be controlled by the irrigation techniques like drift and sprinkles system in a greenhouse. The temperature of the soil and the inside temperature of the green house are interrelated parameters, which can be, control by proper setting of ventilation. Since the temperature control is depends on direct sun radiation and the screen material used, the proper set point can adjust to control soil temperature. The temperature set-point value depends on actual temperature of the inside and outside of the greenhouse [15].

6. WSN AND EVENT-BASED SYSTEM FOR GREENHOUSE CONTROL

The greenhouse climate control is an event-based control system with level crossing sampling technique. In this system, controls are executed in an asynchronous way. The sampling period is governed by system events. This method of sampling consists of transmitting information only when a significant change in the signal occurs which can justify the acquisition of a new sample. This method also known as adaptive sampling or send-on-delta method. The block diagram of WSN green house control system is as shown in Fig.5.

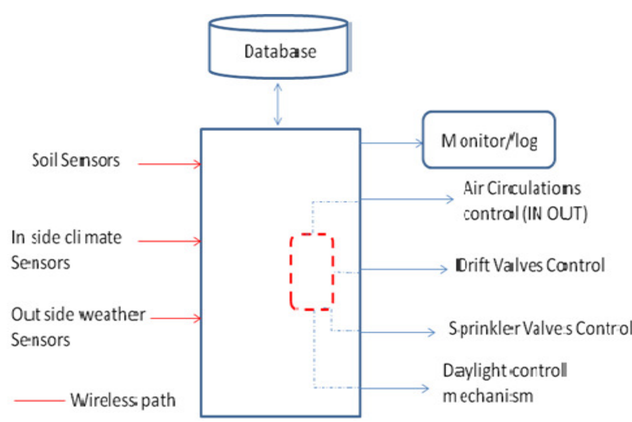

Figure 5, WSN Control blocks Diagram for Green House.

As shown in figure 5, an event-based controller consists of two parts, an event detector and a controller. The event detector deals with indicating to the controller when a new control signal must be calculated due to the occurrence of a new event. In this paper, it is proposed to design WSN to analyse the diurnal and nocturnal parameter control with natural ventilation, heating systems, screen control and sprinkler control as a primary control objective. Humidity, Soil temperature, Daylight and CO_2 control can think of as a secondary control. When it is diurnal conditions then the controlled variable is the inside temperature and the control signal is used to control the vent opening. This natural ventilation produces promotes an exchange between the inside and outside air, which helps to decrease in the inside temperature of the greenhouse.

The controller must calculate necessary vent opening to reach the desired set-point. Inside temperature can be control by forced-air heaters. An on-off control with dead-zone is used for selection of heating controller.

For some parameters of greenhouse, economical wireless sensor nodes can be developing by using the Programmable System-on-Chip (CY3271). This is Low-Power RF kit designed by Cypress Inc, to evaluate mixed-signal capabilities with the flexibility and integration. It can be used in wireless applications of common sensors (thermistor) and actuators (LEDs). These kits works on RF 2.4 GHz with high reliability, easy to use and power efficient wireless connectivity for embedded designs.

It consists of PC Bridge (FTPC), which is used to program all PSoC devices in the CY3271 kit. It works as a Hub point in CyFi wireless networks. It has Multi Function Expansion Card (FTMF) which consist of 7-element Cap-Sense slider, Proximity sensor, Ambient light level sensor, Thermistor, Red, Green or Blue triple LED cluster and Speaker. It has RF Expansion Card (FTRF) which is a, transceiver (with RF output power up to +20 dBm) which works as a main node in CyFi wireless system with an on board thermistor for temperature measurements. It enables to transmit the values of the sensors to the PC. [16].

With respect to event-control System in this paper, it is assumed that the greenhouse is provided with a WSN, where each sensor will transmit data, if the final value of the difference between the current value and the previous value is greater than a particular limit. Therefore to calculate suitable limits for each green house parameter variable is the first step. This limit has a direct influence on the event generation and on the amount of transmitted data. Typical values of some variable are shown in Table 2.

Table 2. Limits for greenhouse variables.

Variable	Limit δ =3%	Limit δ =5%
Soil Temp	0.48	0.57
Wind flow	10.70	17.84
Soil Moisture	3.0	5.0
Solar Radiation	28.58	34.3
Humidity	1.2	2.0
Inside Temp	0.36	0.66
Outside Temp	0.36	0.61

As per table No.2, it is considered that the individual limits for the commonest variables used for control purposes. These limits of δ=3% and δ=5%, were calculated based the data available. The calculation of δ limit for each individual variable is performed after studying its minimum and maximum values. This value is determined by assuming 3% and 5% of the difference between the maximum and minimum values. The two different limits are considered to analyse their effects. The WSN may control the events which may be detected by the event generator according to the limits shown in Table 2. Control action can be taken accordingly with the help of simulation results [17].

7. CONCLUSIONS

In green house technology, more number of the parameters is to be control because, the varieties of the crop are large. They are increasing day by day because of the development in agriculture technology. In this situation, the wireless sensor network with additional hardware and software is an efficient solution for green house control.

Experimentally it is proved that the hardware develop by Cypress Inc. is the best solution which works on low power with less complexity and high reliability for greenhouse control. In the future, if parameter still increase, then for WSN technology with currently available bandwidth, may not be sufficient. Then WSN with cognitive radio technology may be the solution.

This advancement in precision agriculture through Wireless Sensor Network in green house control is extremely useful. This has scope in developing countries in globe, where agriculture is the main business.

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