Design of Energy Efficient Smart Wireless Embedded System for Study of Greenhouse Related Parameters using Multi-nodal Sensing Approach

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ABSTRACT:
This paper discuss proposed model for an energy efficient smart wireless multi-nodal sensor network. It is used for the collection of greenhouse related parameters at different locations inside and outside the greenhouse. The sensing nodes are the independent embedded system units which calculate sensing parameters under observation and measures them at different locations inside and outside greenhouse using close loop control.

To achieve this it is decided use of MSPez430RF2500T target board embedded system for each sensor node, which contains 16 bit microcontroller with eight analog channel, 10 bit SAR ADC and RF trans-receiver for wireless communication. At receiving end the same trans-receiver will be employed along with the host computer (base station). A special communication protocol called SensitiviTI ™ which is designed by Texas Instruments Inc. establishes RF communication between a node and base station. Furthermore this data will be processed in tabular and graphical format by the host computer. This information is use to control the motion of cooling fans and foggers On and Off remotely or manually. The same information can also be communicated via internet.

General Terms
Wireless Sensor Network, Embedded system

Keywords
Greenhouse, MSPez430RF2500T, Communication protocol, SensitiviTI ™

INTRODUCTION
Technological advancement in every aspect of life has dramatically changed everything around us including an agricultural field. The use of science and technology provides best tools for achieving new standards in crop science so that different crops at different places and in different seasons with different soil structures can be grown throughout the year at one place under controlled environmental conditions [1]. In plants transpiration rate, stomata conductance, water precipitation, leaf temperature, water vapor pressure difference and CO_2 assimilation rate etc. These parameters decide the growth rate of plants. It is strongly dependent on external environmental conditions around the plants [2].

The use of highly sophisticated technologies for environmentally controlled greenhouse using electronics and instrumentation in various agricultural fields such as Agro-industries, Biotechnology laboratories, Greenhouses etc. is the revolutionary and interdisciplinary approach [3]. Now a days the microcontroller and computer based instrumentation systems play vital role in the measurement and controlling of various chemical and physical parameters under investigation. Similar to the industrial fields, the measurement and control of various parameters in agriculture field is also equally important. Particularly, in case of greenhouse, wherein the crops are cultivated in controlled environmental conditions, like temperature and humidity of environment, CO_2 concentration, solar radiations etc. are controlled, which can result into good yield [4]. To achieve protection from solar radiations a film, which absorbs long wave infrared radiations, is employed. However, to control temperature and relative humidity, CO_2 concentration, air circulation, ventilation etc. a sophisticated electronic system is essential [5]. A microcontroller, being flexible and reliable device, can be employed to develop an electronic instrumentation to measure above parameters [6].

RELATED RESEARCH WORK
M. Nesa Sudha, et. al. [7] explained TDMA based MAC protocol used to collect environmental parametric information of a wireless irrigation system using RF link, in which TDMA scheduler assigns time slots for each node information transfer and ON/OFF times. Data collection was done using two methods named as direct communication and data fusion (aggregation) techniques. Simulation result confirmed that the aggregation method was providing 10 % increase in the residual energy and 13 % increase in the throughput. K.P. Sampoornam, et. al. [8] have emphasized on Wireless Sensor Network (WSN) where sensor nodes can be situated in random fashion .It is highly important to design WSNs must consume very less power & can sustain for longer durations. The proposed new MAC protocol based on Orthogonal Frequency Division Multiplexing (OFDM) technique. This paper also discusses various OFDM techniques & have made simulations on SMAC & ASMAC & ELE-MAC using Ns-2 simulator. D. D. Chaudhari et. al. [9] proposes and analyses the use of Programmable System on Chip Technology (PSoC) as a part of Wireless Sensor Networks (WSN) for monitoring & control of various greenhouse related parameters. The sensor nodes classification can be made in three types A, B and C, where type A climate sensor for outside, type B is climate sensor for inside greenhouse and C type sensors are soil sensors. As the layout plan of crop plantation, the greenhouse climate control is an event-based control system with level crossing sampling technique as asynchronous control based on adaptive sampling or send –on-delta method. Furthermore authors have suggested to develop sensor node

using low power RF kit by Cypress Inc. using programmable system on chip CY3271 works with CY Fi wireless system. Ibrahim Al-Adwan et. al. [10] suggested WSN based ZigBee technology using PIC microcontroller 16F877A. By locating different local stations in greenhouse for sensing temperature, humidity, and light related data is transmitted after processing by PIC microcontroller via ZigBee transreceiver connected to it. This data is received by central station hosted by a personal computer (PC). The central station monitors all network nodes in real-time, maintaining the network information database. A solar powered WSN is the innovative power supply technique has been adopted to measure humidity and temperature as greenhouse parameters. Greenhouse control design is achieved by using fuzzy decoupling control algorithm. WSN is composed of cheap micro-sensor nodes are deployed in monitoring area. A sink node is developed by CC2430 system on chip microcontroller. GSM network is used for communication between sink node, mobile and PC using GSM module (TC35i) [11]. Greenhouse conditions can be efficiently controlled by ANN using already saved information of its related parameters. For this three types of ANN including feed forward neural networks with multiple delays in the i/p of ANN system, two and three layer neural network with two feedbacks from hidden layers and input delay was used for prediction of humidity and light index of greenhouse [12]. Fuzzy logic can efficiently monitor and can also manage the control of humidity, temperature, CO_2, illumination intensity inside greenhouse. This system also assures adoption of multilevel energy memory management of solar collected energy to battery storage which work as energy source for sensor nodes. A rectangular greenhouse is virtually divided into equal size area called a virtual grid. A number of sensor nodes are deployed in virtual grid and forms a cluster. Each cluster includes a cluster head (sink node) and some cluster member nodes. The data which is collected form sensor nodes to cluster head is transmitted further to a base station. WSN node mainly comprised of ATmega 128L microcontroller and wireless trans-receiver chip CC2420 [13]. Many research worker studied different type protocols. Micro electromechanical system (MEMS) facilitates the development of smart WSAN effectively. This paper discusses different types of WSAN architecture and explains about Agricultural WASN. It also specifies AG-WSAN design parameters and its physical aspects along-with AG-WSAN based application areas. It is based on design and implementation of a WSN that uses two different wireless technologies in combination. System design consists of monitoring of air temperature and humidity in greenhouse. Wireless communication is established using ZigBee and GSM technique with unique specialization that only a cell-phone is used by avoiding computerized base station with consideration of farmer's role and power management in rural places. A basic sensor node consists of temperature and humidity sensors along-with ATmega 16L microcontroller and ZigBee module. Another node is a coordinator node which acts as gateway node used to provide transmission of data to GSM module. GSM provides information to a cellular phone by short message service (sms) using SS7 protocol [14-28].

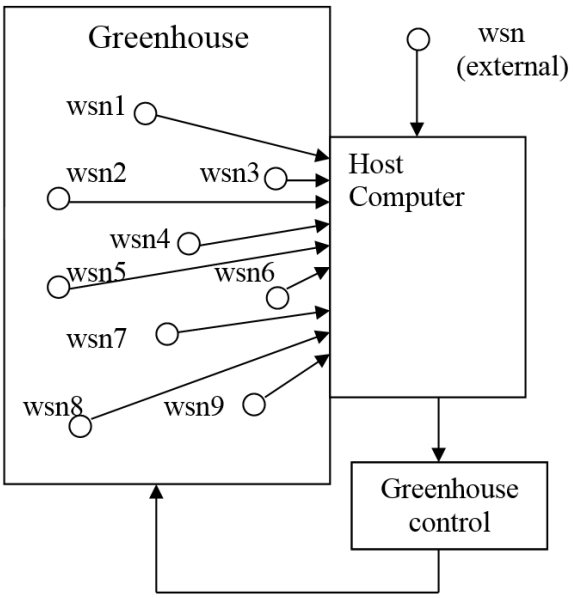

Fig 1: Typical Setup for wireless sensing concept

2. PRACTICAL APPROACH

Development of a wireless embedded system design consists of seven wireless sensing nodes (wsn 1 to wsn 7) and each node is an independent wireless embedded system located anywhere inside the greenhouse (one wsn node is located outside also) is shown in figure 1. Each of these wsn node collects localize current information of area under measurement for various parameters like humidity, temperature, CO_2 level, Light intensity, Oxygen level etc. These nodes directly communicates with the host computer system simultaneously [29]. The host computer analyses the transmitted information. This information tabulates and creates graphs as per the measured parameters by sensing nodes using high level language programming technique. This processed information useful for instant adjustment in inside the greenhouse in either localized area of a particular wsn node or over complete area of greenhouse for better result. This information can be send anywhere using internet technology available with the host computer system [30].

3. PROPOSED SYSTEM

Project development includes the use of MSP-EXP430G2 Launch Pad board which is used to write the code in high level language for MSPez430-RF2500T target board and is used as mcu (microcontroller unit) for wireless sensing node(wsn) [31]. The eZ430-RF2500 uses a complete IAR Embedded workbench IDE or code compressor essential software to develop application. The eZ430-RF2500T target board is a wireless system that can be used as a standalone system with or without external sensors or it can act as debugging interface, that can enable the system to establish wireless data communication to and from PC using the

MSP430 application UART. Using this microcontroller based target board, localized physical parametric information for humidity, temperature, CO_2, O_2, light intensity, soil temperature, air velocity etc. is collected and transmitted using RF link setup provided by RF2500. MSPez430-RF2500T contain 8 analog channels along with 10 bit SAR (Successive Approximation Register) ADC. Wireless communication link is established by SimpliciTI™ [32]

proprietary network protocol developed by TI (Texas Instruments). It is a low power radio frequency (RF) protocol which is implemented for multiple RF trans-receivers.

System Features:

System discussed here has distinctive features as follows.1) Using closed loop wireless multimodal sensing approach a round the clock data collection of all important parameters form various locations inside greenhouse . 2) The data collection can furthermore useful for deep understanding of entire crop cycle from which ideal environment crop standards can be achieved. 3) The system can be utilized for different crops which can grow inside greenhouse. 4) System under discussion can also be utilized to measure selected environmental parameters such as Humidity, Temperature, Wind speed, etc.

WIRELESS SENSING REALITY

Wireless sensing is becoming more popular data communication systems as it avoids physical connection between a source and destination. Some of the important network protocol includes WiFi, Bluetooth, Zigbee etc. are useful for low power and short distance communication for wireless personal area networks (WPAN) [33]. A similar network protocol known as SensitiviTI™ has been developed by TI. It is a low power radio frequency (RF) protocol useful for simple and small RF networks. This network protocol can easily be implemented with minimum microcontroller resource requirements and with CC2500 processor which transmits 2.4 GHz radio frequency (RF) trans-receiver with low current consumption and programmable data rate up to 500 kbps with lower the cost of network design. It supports a wide range of low power applications such as alarms, security applications, automated meter reading and home automation and also in RFID designs. This protocol is provided as source code under a free license without royalties for Texas Instruments TI™.

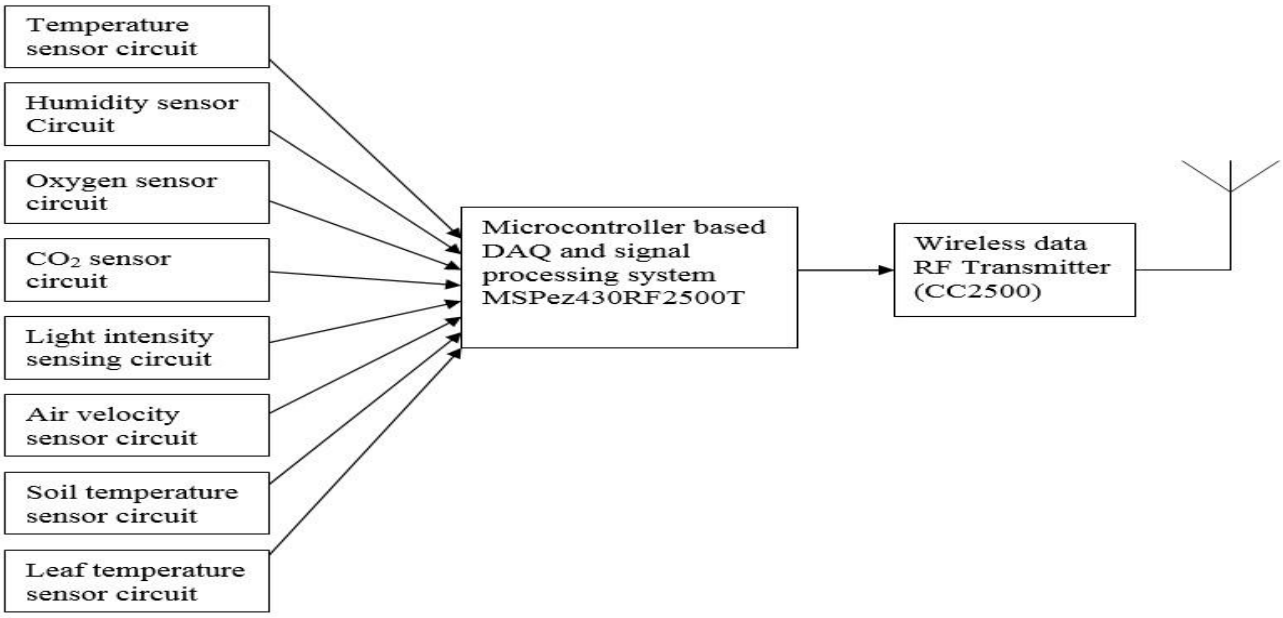

Fig 2: Wireless Sensing Node

THE MICROCONTROLLER MSP430G2XX TI™ PROCESSOR

It is a 16 bit Ultra Low Power RISC (Reduced Instruction Set Computing) type CPU (Central Processing Unit) with 16 MIPS (Million Instructions Per Second), require 3.6 V power supply, 16 bit timer, Watchdog timer, Brownout reset, internally digitally controlled oscillator, 11 GPIO (General Purpose Input and output pins), Value Line Peripherals such as USCI(Universal Serial Communication Interface) with I2C (Inter Integrated Circuit Interference), SPI (Serial Peripheral interface) and UART (Universal Asynchronous Receiver and Transmitter) support, flash RAM support, 8 channel 10 bit SAR (Successive Approximation Register) ADC (Analog to Digital Converter) also a on chip comparators and 16-24 Touch sense enabled I/O pins

EFFECT OF VARIATIONS IN ENVIRONMENTAL PARAMETERS ON PLANT GROWTH

The inside climate of greenhouse must always suitable for an optimum growth of plants in terms of photosynthesis and transpiration. The process of water transport, CO_2 separation and energy intake, along with the creation of chlorophyll and O_2 requires natural or artificial light [34]. The variations in relative humidity (% RH) affects directly on plants transpiration rate. The warmer air increases the driving force for water transpiration. Low levels of light at dawn can cause more stomatal conductance in plant leaves for accessing more CO_2 values for photosynthesis as soon as sun light is received. Increase in wind velocity can cause increase in water transpiration rate in actively growing plants [35]. It is found that variations in CO_2 can greatly affect the stomatal conductance [36]. It is also seen that leaf temperatures were steady state varied by 2˚ C with change in humidity [37].

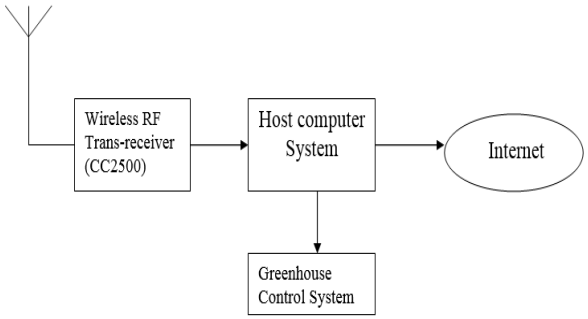

Fig 3: Host Computer System (Base Station)

CONCLUSION

The system discussed assures the accuracy and preciseness not only in terms of its total area coverage of environmental parameter measurements by using localized wireless sensing nodes data collection process but also the representation of data in its simple tabular and graphical form. The system is independent of any one node failure or failure of any one parameter under observation and measurement. So the system helps to identify the faulty sensing node within very less time and initiates necessary corrective action. The complete system can also be called as historian module as it can maintain records of all significant parameters under measurement and displays them in tabular and graphical format which is done by the host computer system

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