PRELIMINARY DESIGN FOR CROP MONITORING INVOLVING WATER AND FERTILIZER CONSERVATION USING WIRELESS SENSOR NETWORKS

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***Abstract* - The main aim of this paper is to propose a state of art wireless sensor technology in agriculture, which can show the path to the rural farming community to replace some of the traditional techniques. In this project, the sensor motes have several external sensors namely leaf wetness, soil moisture, soil pH, atmospheric pressure sensors attached to it. Based on the value of soil moisture sensor the mote triggers the water sprinkler during the period of water scarcity. Once the field is sprinkled with adequate water, the water sprinkler is switched off. Hereby water can be conserved. Also the value of soil pH sensor is sent to the base station and in turn base station intimates the farmer about the soil pH via SMS using GSM modem. Obtaining the soil pH value in his mobile the farmer selects the necessary fertilizer and crop for his next season. Hereby the amount of fertilizer can be reduced. In order to overcome the lack of information and technical support and to increase the rice production, a development of rice cropping monitoring using WSN is proposed to provide a helping hand to farmers in real-time monitoring, achieving precision agriculture, and thus increasing the rice production.Thus automated control of water sprinkling and ultimate supply of information to farmers is done as a result of this project using wireless sensor network.**

Keywords-Wireless Sensor Networks; precision agriculture; crop monitoring; MICAz mote

I. INTRODUCTION

India being an agricultural country needs some innovation in the field of agriculture. This can be achieved through modern technologies which assist computing, communication and control within devices.WSN suit for this purpose. Wireless sensor networks (WSN) technologies have become a backbone for modern precision agriculture monitoring.[1] WSN in agriculture helps in distributed data collection, monitoring in harsh environments, precise irrigation and fertilizer supply to produce profuse crop production while diminishing cost and assisting farmers in real time data gathering. This paper presents the preliminary design on the development of WSN for crop monitoring application. The proposed WSN system will be able to communicate each other with lower power consumption in order to deliver their real data collected to the farmer's mobile via GSM technology and to actuate the water sprinklers during the period of water scarcity.

II. REQUIREMENTS OF WSN BASED MONITORING

According to paper [2~4], research on the modern agriculture are becoming increasingly concentrated on monitoring and controlling the entire greenhouse yielding process. The requirements in the aspect of WSN based crop monitoring system functions can be mainly summarized as the following points:

i. Hardware – sensors, actuators, connectors, interface boards, input and display panels, routers, computers, generators, transformers, etc.

ii. Software – communication, data filter and fusion,

III. SYSTEM REQUIREMENT AND ARCHITECTURE

The requirements that adopting a WSN are expected to satisfy in effective agricultural monitoring concern both system level issues (i.e., unattended operation, maximum network life time, adaptability or even functionality and protocol self-reconfigurability) and final user needs (i.e., communication reliability and robustness, user friendliness, versatile and powerful graphical user interfaces). The system, shown in Fig. 1, comprises an overall self-organizing mesh WSN with sensing capabilities, a Gateway, which gathers data and provides information to the final user capable of monitoring and interacting with the instrumented environment.

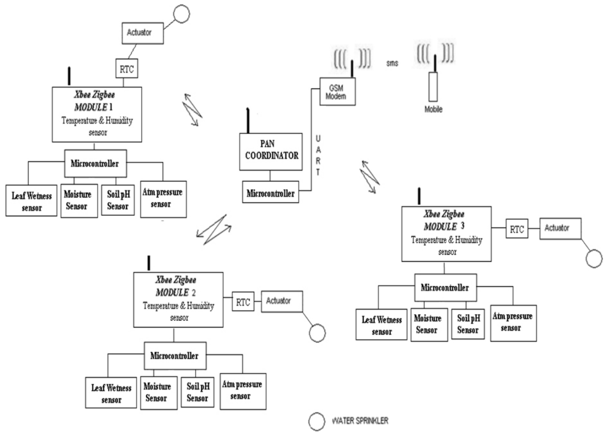

Figure 1. Overall Architecture of system design

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The crop management system using Wireless Sensor Network (WSN) is a kind of an autonomous solution to enhance the agricultural technology. Precision agriculture could raise the crops yield, labour cost saving and environmental protection against over pesticide or fertilizing. Therefore in this project we would like to propose a wireless sensor system that will communicate each other with lower power consumption. This is served with the help of Micaz motes from crossbow technologies. The architecture then to be implemented in the sensor nodes will construct a wireless networking data collection at crop field likely to replace the conventional manually data collection system. A general Micaz mote with MDA300 data acquisition board has standard measurement parameters sensors such as ambient air temperature and humidity and also has external terminals for soil pH, soil moisture, leaf wetness and atmospheric pressure sensors all to be integrated in all nodes. All the deployed nodes will collect the parameters and report to the central co-ordinator /sink. The coordinator will coordinate the data collection. The individual nodes based on the soil moisture sensor content attached to it will excite the water sprinklers in that particular region. Meanwhile the soil pH sensor value will be reported to the central coordinator, and then the soil pH value is reported to the farmer using SMS system via GSM modem intimating him to fertilize the particular region. There by we can conserve water and fertilizer using this project.

IV. HARDWARE DESIGN

Focusing on an end-to-end system architecture, every constitutive element in WSN has to be selected according to application requirements and scenario issues, especially regarding the hardware platform. Several criteria have to be considered, involving the energy consumption of the sensor readings, the power-on and power-save status management and a good trade-off between the maximum radio coverage and the transmitted power.

A. *Sensor node*

Each sensor node consists of 2.4GHz MICAz mote, MDA300CA [5] data acquisition board, Irrometer Soil moisture sensor, atmospheric pressure sensor MPX4115A, leaf wetness sensor. The Tiny Operative System (TinyOS) running on this platform ensures full control of mote communication capabilities to attain optimized power management.

B. *Soil Moisture Sensor*

The electrical resistance type Davis soil moisture sensor, which is pictured in Figure 2, converts electrical resistance from the sensor to a calibrated reading of soil water content measured in soil water potential, which is given in bars. The principle of operation is that the resistance of electrodes embedded in a porous block is proportional to its water content. Therefore, the wetter a block, the lower the resistance measured across two embedded electrodes. This implies that the soil water potential is directly influenced by the soil temperature. An excitation voltage of 2500 mV was applied and the analog signals from the transducer were read by the single-ended analog channel of the data acquisition board.

Figure 2. Soil Moisture Sensor

Resistance and temperature maintain a linear relationship when soil water content ranges from 0 to 2 bars. The resistance measurement was normalized to degrees C by

$$R_{21} = Rs / [1-(0.018.dT)] \quad (1)$$

Where

R_{21}=Resistance at 21 ^{O}C,
Rs = measured resistance,
Ts = Soil Temperature,
dT = (Ts – 21).

Soil Water potential, (SWP), was then calculated by

$$SWP = (0.07407.\ R_{21}) - 0.03704 \quad (2)$$

C. *Radio platform*

The radio platform used here is MPR2400CA which is based on the AtmelATmega128L.The ATmega128L is a low-power microcontroller which runs MoteWorks from its internal flash. A single processor board (MPR2400) can be configured to run sensor application / processing and the network/radio communications stack simultaneously. The 51-pin expansion connector supports Analog Inputs, Digital I/O, I2C, SPI and UART interfaces. These interfaces make it easy to connect to a wide variety of external peripherals. The MICAz (MPR2400) IEEE 802.15.4 radio offers both high speed (250 kbps) and hardware security (AES-128).

D. *Data acquisition board*

In order to manage different kinds of sensors, a compliant data acquisition board were adopted namely MDA300CA which is an extremely versatile data acquisition board that also includes an onboard temperature/ humidity sensor. With its multi-function direct user interface, the MDA300 offers a convenient and flexible solution to those sensor modalities commonly found in areas such as environmental and habitat monitoring as well as many other custom sensing applications.

E. *Sink node*

The Sensor –System interface is supported by MIB510 which allows aggregation of sensor network data on a PC as well as other standard computer platforms. A MICAz node can function as a base station when mated to the MIB510 serial interface board. In addition to data transfer, the MIB510 also provides an RS-232 serial programming interface. The overall node stack architecture at the base station is shown in Fig. 3.

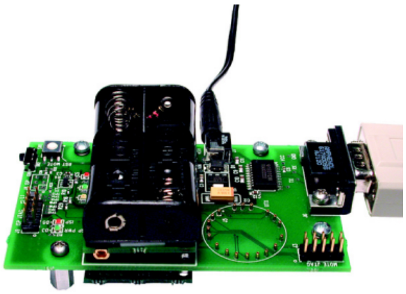

Figure 3. MIB510 with mote

The terminal is a single board computer developed for data displaying and delivering. There are two important reasons that a data terminal is designed in the monitoring network for greenhouse application. The first reason is that we have to view the current environmental parameters while daily management. Another reason is that agricultural facilities are always far from the farm office where the central PC using for data logging and processing is located. It is necessary for the sink node to realize long distance data transmission.

V. WIRELESS RF AND NETWORKING

XMesh is a full featured multi-hop, ad-hoc, mesh networking protocol developed by Crossbow for wireless networks. In the XMesh routing algorithm [6], the cost metric is one that minimizes the total number of transmissions in delivering a packet over multiple hops to a destination and is termed the Minimum Transmission (MT) cost metric. The multi-hop network is initially formed when motes broadcast periodic beacon messages to all other motes within radio range. When the beacon messages are sent, they contain a cost value, which indicate to other motes the energy required to transmit a message to the base station. Higher cost indicates more energy required to make the transmission. The purpose of the cost metrics to minimize the total cost it takes to transmit to the base station mote (i.e. node zero). Each node in the mesh network will broadcast its cost value which is derived later in this section. The beacon message includes the number of hops to send a message to the base station mote and a packet sequence number. The packet sequence number is a 16 bit integer and is incremented every time a message is transmitted from the base station mote or other motes. The beacon message also contains a neighbourhood list (NL). The NL contains information about all other motes in the vicinity that the mote or base station mote can hear. The NL information has two parts:

* The ID of the neighbourhood mote (NM).

* A received estimate on how well the mote can hear neighbour motes.

The received estimate value is based on monitoring the sequence numbers of the received messages from the NM. For each link, the MT cost is estimated by the inverse of the product of link qualities in the forward (SendQuality) and backward (RecieveQuality) directions[7] . The link's cost to its parent or the Minimum Transmission cost is written as

$$MT_{ToParent} = (1/linkquality_{forward}) \text{ X } (1/linkquality_{backward}) \quad (3)$$
$$= (1/SendQuality) \text{ X } (1/ReceiveQuality)$$

For example, if the SendQuality between node one and node

zero is 23% and the RecieveQuality is 29%, the link cost to node zero is 15.

The parent's cost would be the total cost of all hops to the baseStation.

$$Parent'sCost = \sum (MT) \quad (4)$$

Hence, the node's cost value is calculated as:

$$Node\ cost = Parent's\ cost + Link\ cost\ to\ Parent \quad (5)$$
$$= \sum (MT) + MT_{ToParent}$$

XMesh Setup is given in the Figure 4 as

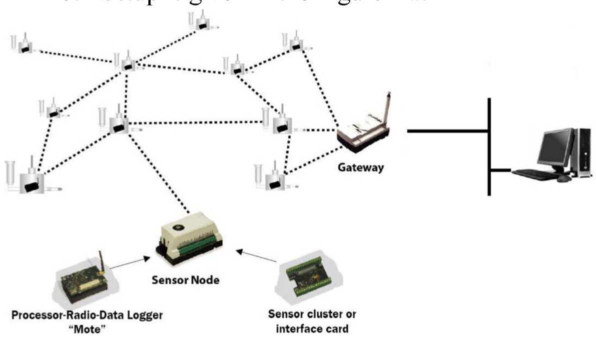

Figure 4. Practical XMesh setup

The Base Station mote serves two purposes:

1. It acts as the Gateway between the Mote Tier and Server Tier. The base station communicates with other motes over the radio, and with the server using serial communication. In this way, the base station forms a bridge to send and receive messages between a host system (PC and/or data logger) and the rest of the mesh network.

2. It forms the network and directs all data messages from the Motes to itself. To other Motes in the network, this base station Mote can forward messages to the PC (host) with zero energy cost. The base station Mote is always identified as "node 0" in a single base station system.

VI. PROGRAMMING AND DATA MANAGEMENT SOFTWARE

MICAz motes could be programmed with TinyOS, an open source, object-oriented, event-driven operating system developed by the UC Berkeley [8]. These sensor nodes were programmed with TinyOS before deployment according to application requirement. An application called "TestSensor", which is depicted in Figure 5, was developed to test the driver. All red components are part of the TinyOS operating system whereas the blues components were implemented for this particular application.

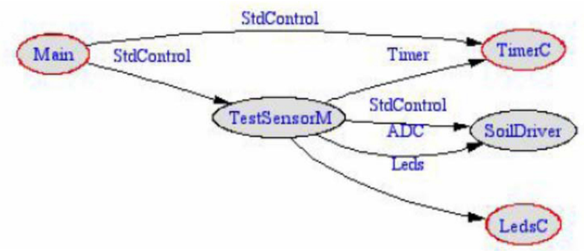

Figure 5. TestSensor Wiring Application

For simplicity, the application only scheduled a timer, which read the channel every timer the timer expired and blinked the LEDs as it was executing. The application consisted of the configuration wires together with the "TestSensorM" module, the "SoilDriver" driver, and two TinyOS components termed "TimerC" and "LedsC". The module controlled the initialization, start and stop of the components, the start of the clock and the activation of an event to measure the sensor.

The "SoilDriver" driver, written in nesC, mapped the I/O lines of the soil moisture transducer into TinyOS software commands and controlled the sensor using TinyOS components that composed the driver. The "SoilDriver" configuration wired two components termed "SoilDriverM" and "ADCC". The "SoilDriverM" module contained the code written for the implementation of the driver. The "ADCC" component controlled the A/D converter. The SoilDriver component could be decomposed into more internal components. The SoilDriver configuration wiring is illustrated in Figure 6

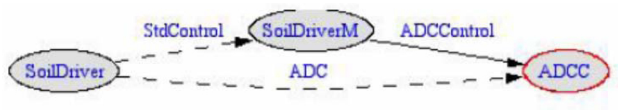

Figure 6. SoilDriver Configuration Wiring

Each sensor node was programmed to perform time-triggered sampling of their sensors and data transmission. Every 5 minutes the sensor nodes took a temperature reading, a humidity reading and a soil moisture reading, then transmitted a packet containing the sensor readings to the sink node. The sensor nodes were programmed to be in a sleep state while not sensing or communicating. nesC (nested embedded systems C) is an extension to the C programming language designed to embody the structuring concepts and execution model of TinyOS.The final user may check the system status through graphical user interface (GUI) known as MoteView.

MEMSIC's MoteView software is designed to be the primary interface between a user and a deployed network of wireless sensors. MoteView provides an intuitive user interface to database management along with sensor data visualization and analysis tools. Sensor data can be logged to a database residing on a host PC. MoteView provides the tools to simplify deployment and monitoring. It also makes it easy to connect to a database, to analyse, and to graph sensor readings.

The Moteview running on the central PC is developed based on database in Microsoft Visual C++6.0 IDE.

It includes three modules:

A. *Data receive*

The short message is received from serial port and parsed into different data fields according to custom data protocol.

B. *Data log*

These data are written into corresponding fields representing environmental parameters in the table of database respectively.

C. *Data display*

Historical data are read from database to creating different types of charts or curves, which makes it clear and easy for the administrator to comprehend and analyse sensors data monitored by the monitoring network.

VII. RESULTS

In order to analyse and optimize system performance, we have conducted some rudimental experiments. This section will show some experiments results.

A. *Sensors data*

The monitoring network was installed in our demo farm. Temporal and spatial variations in temperature, humidity and soil moisture are measured continually and sent to the central PC located in farm base station. Figure 7 shows the temperature and humidity data of a node placed in a farm.

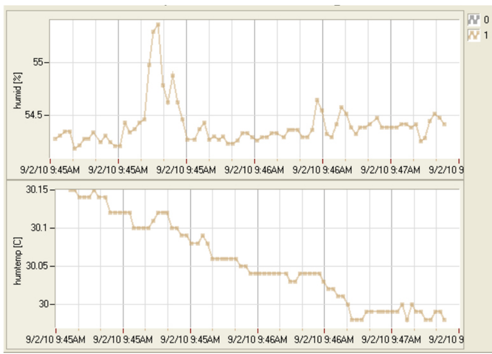

Figure 7. Output Graph Showing the temperature and humidity data of a node placed in a farm using MoteView Software.

Figure 8 shows the soil moisture content value of the node placed in the farm.

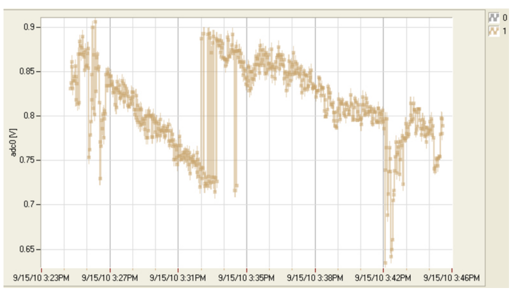

Figure 8. Output Graph Showing the Soil Moisture data of a node placed in a farm using MoteView Software.

Figure 9 shows the entire laboratory setup of the preliminary design

Figure 9. Laboratory setup of the preliminary design

VIII. CONCLUSION

In this paper, we proposed real-deployment of WSN based crop monitoring which is designed and implemented to realize modern precision agriculture. End Users can tailor the mote operation to a variety of experimental setups, which will allow farmers to reliably collect data from locations previously inaccessible on a micro-measurement scale. Such a system can be easily installed and maintained. This paper successfully applies the wireless sensor networks on agro-ecology fields by investigating environmental situations. The complete real-time and historical environment information is expected to help the agro-ecological specialists achieve efficient management and utilization of agro-ecological resources.

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