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Development and Deployment of Wireless Sensor Network in Paddy Fields of Kuttanad

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Abstract—***The evolution of wireless sensor network technology has enabled us to develop advanced systems for real time monitoring. In the present scenario wireless sensor networks are increasingly being used for precision agriculture. The advantages of using wireless sensor networks in agriculture are distributed data collection and monitoring, monitor and control of climate, irrigation and nutrient supply. Hence decreasing the cost of production and increasing the efficiency of production. This paper describes the development and deployment of wireless sensor network for crop monitoring in the paddy fields of Kuttanad, a region of Kerala, the southern state of India.***

Index Terms— **Crop Monitoring, Precision Agriculture, Wireless Sensor Networks, Zigbee.**

I. INTRODUCTION

Kuttanad, the rice bowl of Kerala, is unique among the rice ecologies of the world; the biggest wetlands of the country, located 0.5 – 2.5 meters below mean sea level (msl). Rice is grown by construction of bunds and dewatering the so formed polders mainly during the puncha (rabi) season from Oct. – Nov. to Jan. – Feb. The soils of Kuttanad are low to medium in fertility. Soil is enriched by annual silt deposition during the monsoon floods. The soils are alluvial with salty clay texture and are acid sulphate in nature with excessive iron content. The major problems faced by Kuttanad rice are flood and lack of drainage, intrusion of saline water and soil acidity. The major occupation in Kuttanad is farming. Rice is the important agricultural product, giving Kuttanad the moniker of "The Rice Bowl of Kerala". Three crops are grown every year now instead of the traditional two per year. Large farming areas near Vembanad Lake were actually reclaimed from the lake. Rice is the one of the most widely grown crops in the world and is one of the major food crops grown extensively in India. The most important rice producing states of India are West Bengal, Andra Pradesh, Bihar, Tamil Nadu, Assam and Kerala. In Kerala, Palaghat, Trichur and Kuttanad are the main rice producing regions. The vast area of paddy fields in Kuttanad extends from 90 17' N to 90 40' N and 76019' E to 76033' E. These are divided into "padasekharams" literally meaning groups or blocks of paddy fields and are separated by canals, bunds and water-logged masses. The puncha lands of Kuttanad are classified under three categories based on elevation, geographical formation and soil characteristics, into Karappadoms, Kayal lands and Kari lands. The Karappadoms are generally situated along with the waterways and constitute the lower reached of the eastern and southern periphery of Kuttanad, usually 1-2 m below mean sea level. Vembanad Lake for agricultural purpose and the elevation ranges from 1.5 to 2.5 m below the mean sea level. The Kari lands situated in Ambalappuzha, and Vaikom taluks is peaty and marshy in nature and are overgrown in many areas with wild weeds and grass and most of the Kari lands lie below mean sea level. The soil of the paddy fields of Kuttanad is salty and is extremely acidic. The acidity is due to the production of sulphuric acid by microbiological oxidation of sulpher compound present in the soil. High amount of iron, manganese, aluminum and sulphides are present in the soil. This acidity of the soil is a major constraint which retards the production of rice in the Kuttanad area. Regular rinsing of the soil by water can reduce the acidity and increase the production. Rice is a crop which needs high amount of water for its growth. The main factor to be considered here is that the water should not be too much or too low. Periodic monitoring and controlling water level is essential for the healthy growth of the rice plant. Due to the socio-economic states prevailing in the state of Kerala the labor community is getting narrower. The paddy field owners are not able to recruit sufficient labors for these processes. The initial activities like plowing, seeding etc and the final activities like harvesting are done as a group and hence can be easily coordinated. The periodic monitoring of needs, controlling the pests and water level monitoring is a tedious process. Majority of the paddy field farmers are employed in some other activities or are considering this cultivation as a secondary business. Hence their involvement on a daily basis should be greatly reduced. Since the pumping of water to and from the field is the major activity from plowing to harvesting, automating the process can greatly reduce the load on farmers. Automated systems may monitor the water level and regulate the levels by sophisticated systems and can send messages to the farmers.

II. WSN FOR MONITORING WATER LEVEL

Paddy field is a large area and is nearly flat in nature. Normally the water level in a field will be uniform throughout the field. Water wells can be made as per the need and the water level in each well can be monitored. Water level sensors can be used for sensing the levels. Even though electronic sensors are available due to the environmental conditions electro-mechanical devices are more applicable. The mechanical part in the devices will float on water and the electrical part will produce the signals based on the portion of the floating device. These values or signals generated by the sensor needs to be transmitted to the farmers. Due to the issues like transmission media, power consumption, security etc, conventional communication techniques cannot be used. Low cost communication devices which needs low power

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and less maintenance, which can operate on a wireless architecture is the solution. The new generation wireless sensor networks can be considered for the situation. Wireless sensor Network (WSN) is a major technology used for real time monitoring of environmental assets. WSN has the advantages of large scale deployment, low maintenance, scalability, adaptability, less power needs etc. with the disadvantages of low memory, low power, low bandwidth etc. They can be employed in hostile environments and the features like use of low power and low maintenance makes them the most suited technology for real-time environmental monitoring. They can be highly useful in monitoring the water level in the paddy fields. ZigBee is the most commonly used network standard today and it is a low-cost, low-power consumption, low data-rate, two-way wireless networking standard that is aimed at remote control and sensor applications which is suitable for operation in harsh radio environments and in isolated locations. It is built on the IEEE standard 802.15.4-2003 which defines the physical layer and medium access control sub layer. Above this, ZigBee defines the application and security layer specifications enabling interoperability between products from different manufacturers. There are several different network topologies that a wireless sensor network can form: star, tree, bus, ring, and mesh. All these topologies have their own individual benefits but the mesh network topology is best suited in our case.

III. Sensors for Monitoring Water Level in Fields

In our system the sensor network is deployed as a three tier system. The bottom level is the end sensor devices which are in sleepy condition most of the time. The water level sensors are connected to these nodes. They collect the values of water level from the electrical sensors and transmit them. The second tier is the routers or the cluster heads. The end sensor nodes are grouped according to their geographical positions and for a group of end sensors a cluster head is allocated. The end sensor node sends their data to their respective cluster heads periodically. The cluster heads are connected to the sink node or the coordinator node which form the third tier. The overall monitoring and controlling is done by the FCC (Field Control Center). FCC is a software program residing in the user computer. The sink node transmit the data to the FCC and FCC issues the necessary commands for network monitoring and other operations like pumping in and out of water. Periodic monitoring of the water level in the paddy field is essential because the water supplied to the plants is different at different times for optimum or maximum crop production. For deploying the sensor network system, a paddy field named Panackal was selected. It is a small strip of paddy field of about two hundred acres, located at Kavalam, uttanad, Kerala, India. The paddy cultivation of panackal paddy is jointly done by about fifty local farmers. Since we need to erect the sensor columns nearer to the coordinator node, a strip of field of about one acre with a nearby farm house was selected for sensor column erection. Fig.1 shows the layout of the panackal paddy field. The outer boundary of the field is a strong mud bund of about three meters in width. It has many internal canals for pumping in and draining out the water from the fields. All the internal canals are connected each other. The pump house located near the outer bund has an electric water pump for pumping out the water from the internal canals.

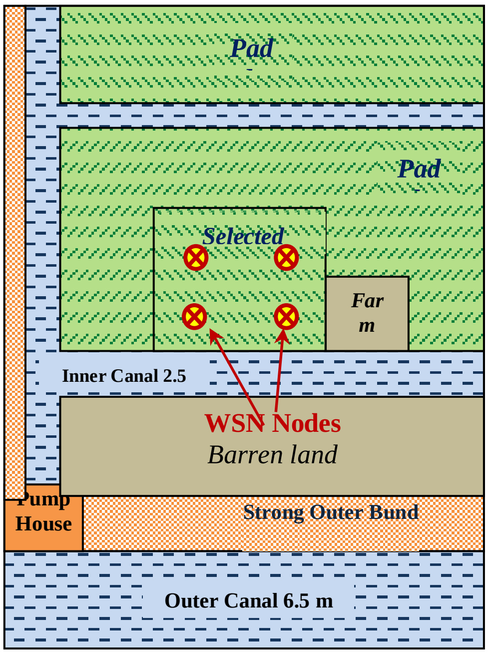

Fig 1. Layout of Panackal Paddy Field

IV. Sensor Column Design

Paddy fields are large in size covering many hectors and are nearly flat. Regular irrigation is done and hence the platform will be like lose clay. Paddy plants are grown very closely with a gap of nearly 10 centimeters. Hence it is a thickly cultivated crop and the plants height is nearly 1 meter. Conventional commercially available sensors do not have water level sensors. They normally have humidity sensors only. The humidity sensors cannot be directly applied here because the Kuttanad area is mostly humid and paddy field have stagnant water always. For measuring the water level of particular area small water wells are pored and sensor columns are installed. The water well are of the size of 2 inches wide and with a depth of 0.5 meter. Three levels of water were considered for the experiment; high, normal and low. The normal water level was considered as the ground level or the average level of the top of the clay. The low level is 6 inches below the normal level and the high level is 6 inches above the normal level. These levels will be periodically monitored by the sensor column.

Sensing the water level with electronic circuits and electrical head points were easy but due to the acidic nature of the water of this area they were not producing correct result after a period of time. Hence electro mechanical were used for sensing the level. They consist of a floating device and contact switches. These floating devices will be floating above the water and moves up and down according to the level changes. These electro mechanical devices are placed

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inside a PVC pipe of 2 inches in diameter. The bottom end of the pipe is closed and holes were drilled on the sides of the pipe for water to enter inside the pipe. A thick covering was given above the holes by wrapping coir. This was for preventing mud and other solid substances entering into the pipe and damaging the mechanical float. The leads from the contact switches were fed to the zigbee sensor boards. Periodically the zigbee module senses these levels and transmits them to the cluster head. The design details of the sensor column are illustrated in Fig.2. When the water level is very low, i.e below the lower sensor all the switches will be in OFF state. When the water level is normal, the low switch will be ON and high will be OFF. When it is high the low and high switches will be ON. When the water is in the normal level, that is, as per our design not below 6 inches or above 6 inches from ground no attention is necessary. In the other two states the water level is too low or too high, hence remedial action should be initiated at the earliest. The sensor column erected at the Panackal paddy field is shown in Fig.3.

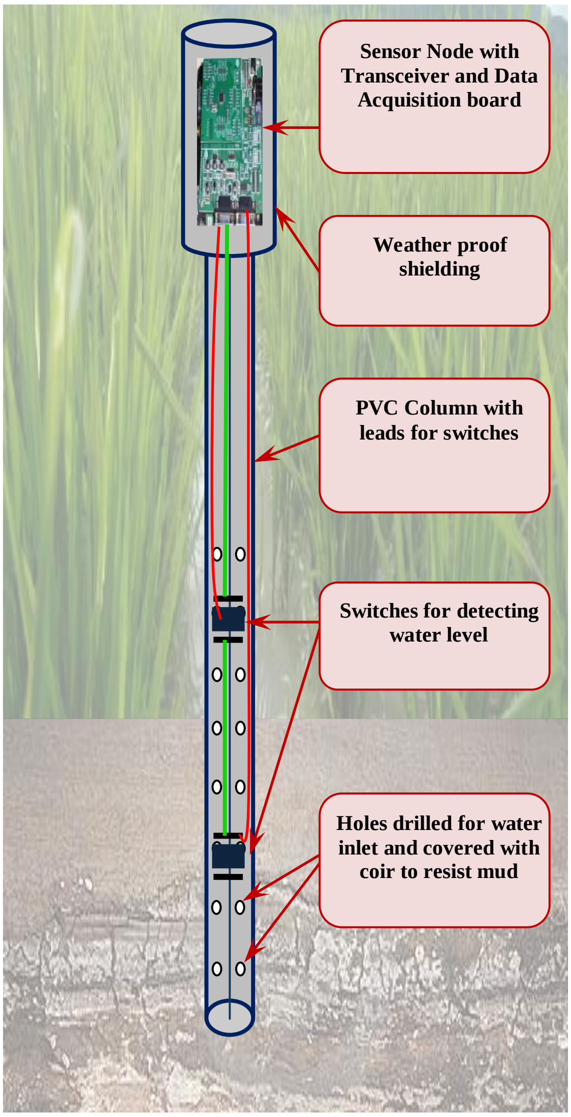

Fig 2. Sensor Column Design

Fig 3. Sensor Column

V. WIRELESS SENSOR NETWORK ARCHITECTURE

In our experimental setup we installed four sensor nodes for collecting the water level data. These sensor nodes are in a mesh structure and are approximately 50 m apart. The architectural details of the Wireless Sensor Network system developed for the panackal paddy field is shown in Fig 4.

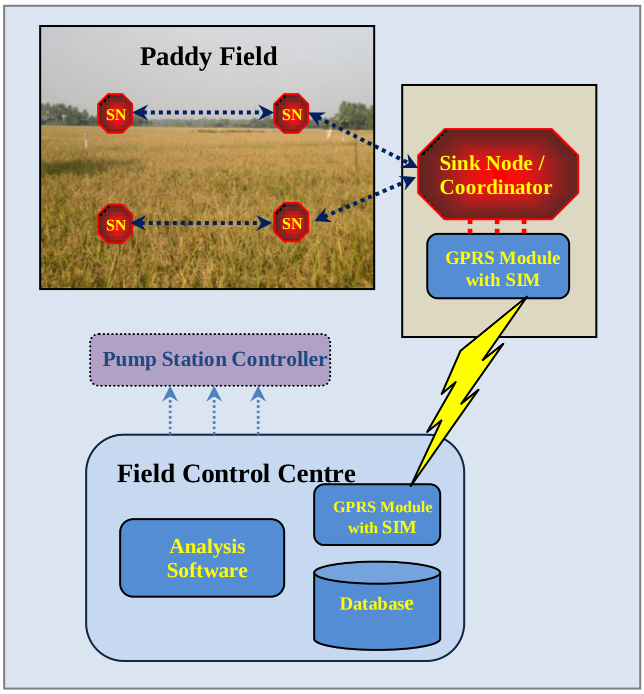

Fig 4. Wireless Sensor Network System Architecture

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These nodes can sense the water level and can communicate each other. These lower level wireless sensor nodes are attached to the sensor columns discussed earlier. They will collect the data from the electro mechanical sensor and the data packets are being send to the upper layer. The immediate upper layer consists of the cluster heads and the layer above this is the sink node. The sink node transmits the data to the field control center (FCC). The side node is a gateway node and is connected to FCC through a GPRS connection.

VI. Sensor Network Deployment

As an experimental setup to access the capability of the system it was deployed in a paddy field. The total area under consideration was about 1 acre. At the time of irrigation paddy cultivation was on the process. The plants were grown up and it was about 20 days for harvesting. The experiment was to install the network and take the values for 5 days. These five days the sensor nodes should monitor the water level and transmits them to the cluster head and ultimately it reaches the Field Control Centre.

VII. WSN Sensor Column Deployment

The main problem we found for sensor column deployment in a live paddy field was to achieve the support from the local farmers. The specialty of the farm / fields of Kuttanad area are that most of the fields are large in size and will be owned by many farmers. The plowing, watering, dewatering and harvesting is done together. So any change affected in one field will naturally spread to other fields also. Hence when we were about to erect the sensor columns we had to face many questions from the nearby farmers regarding the use of this machine, objective of this project, benefits that they will receive, problems that can occur etc. We were able to explain everything in detail to them and achieve their support. The main complaint they had was huge amount is being spend for the research and development activity but the farmers are not benefited by that. The only condition that they put forward was to do something beneficial to them and thereby protecting the paddy cultivation of that area. We were able to convince them that by our project the human labor need for cultivation can be greatly reduced and proper monitoring of the crop can be done, there by achieving high yield and profit. Once they were convinced they also extended their support for the installation of the sensor columns. The sensor columns were checked and devices were powered on. The sensor columns were initially programmed to be active every sixth hour basis. So on every six hours the devices becomes active, senses the data, sends them to the cluster head and then goes into sleep state till the next time slot. As a favorable support from the nature's side the paddy field was nearly dry. We could see water at about 2 inches depth while digging the pit for sensor column creation. We were prepared to enter into clay like field and erect the columns, but proper guidance was only needed as we received full handed support from the local farmers. The four sensor column erected at the field is shown in Fig.5.

Fig 5. WSN nodes deployed as a network

VIII. Network Deployment

One among the four sensor columns which was nearer to the land was programmed as the cluster head. The sink node is a gateway and needs high power. It was installed in a nearby house owned by the paddy field owner. The sensor column is directly connected to the wireless sensor node and is integrated with the transceiver. The distances between the sensor columns were approximately 50 meters. All sensor outputs and its own values are received at the cluster head and are transmitted to the sink node. The sink node was also at about 50 meter distance. A laptop computer was used to run the program and work as field control centre. It was installed at the owner's house which is about 300 meters away. To avoid maximum exposure to the outside world the connection between the sink node and FCC was a GPRS connection.

IX. Conclusion and Future work

Due to urbanization crop fields are getting converted to new forms of the urban world. Also farming community is becoming narrower day by day due to better opportunities. The gap between need and production is increasing at a rapid rate. These problems get elevated when production is decreased. By automating many of the farming procedure and use of advanced machines farming can be made more profitable, thereby attracting more persons into farming and increasing the production. This paper discusses the development and actual field deployment of a wireless sensor network system. As an initial step, a heterogeneous network with four sensor nodes, coordinator node and a GPRS connection was deployed at panackal paddy field, kavalam, Kuttanad, Kerala, India. The data collection at the Field Control Centre was successfully performed. The analysis software should be improved. This improvement and integrating motor operation is our future work

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