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Wireless Sensor Networks for Paddy Field Crop Monitoring Application in 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 application of wireless sensor network for crop monitoring in the paddy fields of kuttand, a region of Kerala, the southern state of India.

Keywords–Crop monitoring, Precision agriculture, Wireless sensor networks, Zigbee**.**

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 metres 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 mansoon floods. The soils are alluvial with silty 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. In spite of the sharp decline in area under rice; Kuttanad rice bowl (53600 ha.) accounts for 18 per cent of the rice growing area and 25 per cent of total production of the State.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.

I. The Kuttanad Region

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, Assamand Kerala. In Kerala, Palaghat, Trichur and Kuttanad are the main rice producing regions. Kuttanad popularly known as the rice bowl of Kerala, located in central Kerala, is a large wetland habitat comprising of paddy fields, marshes, lakes and rivers. Kuttanad consists of 54 revenue villages spread over 10 taluks in the districts of Alleppey, Kottayam and Pathanamthitta. It is separated from the Arabian sea by a narrow strip of land and is deltaic formation of four river systems, namely Meenachil, Pampa, Manimala and Achenkovil, together with the lying areas (marshes) in and around the Vembanad lake. Most of the vast expanse in this region is laying 1 – 1.5 m below mean sea level, water-logged throughout the year, subjected to continued flood submergence during monsoon and saline water ingression during the summer month.

The vast area of paddy fields in Kuttanad extends from 9^0 17' N to 9^0 40' N and $76^0$19' E to $76^0$33' 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 Vaikomtaluks is peaty and marshy in nature and are overgrown in many areas with wild weeds and grass and most of the Kari lands lie at or below mean sea level.

'Puncha' is the mean paddy crop in Kuttanad sown in November or December and harvested by the end of March. The 'virippu' is the additional crop grown from May to the end of June and harvested in September or October. High yielding varieties of rice are sown in all the areas of Kuttanad. The gap between demand and local production of rice in Kerala is widening primarily because of the continuous pace at which rice are giving way to urbanization.

II. Automated Water Level Regulation

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 activation as a secondary business. Hence their insolvent 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.

III. SENSORS 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. These sensors can monitor the level according to the user needs. Normally there can be three levels, normal, high and low. These sensors are electro-mechanical devices. 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. Transmitting the electrical signal from the device in the field to the farmer through copper wire is not practical, since it is so long and we many wells and sensors at different locations in the field. A farmer may have hectors of area as paddy field and need hundred of sensors for monitoring. Hence wired devices are not practical. Use of commonly used wireless communication technology is also not advisable due to complexity of the communication system and the high power needs of such systems. Proving power supply or having a solar panel is also not economical. High battery power may be needed by such devices and regular charging or replacement of the batteries is highly costly. Alternative solution is to provide power from a solar panel. The solar panels are of high cost and hence are after prove to theft. The paddy fields are of large area and ensuring security to each solar panel is also not possible. Low cost communication devices which needs low power 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.

IV. WIRELESS SENSOR NETWORKS FOR COMMUNICATION

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 wirelessnetworking standard that is aimed at remote control and sensor applications which is suitable foroperation in harsh radio environments and in isolated locations. It builds on the IEEE standard802.15.4-2003 which defines the physical layer and medium access control sub layer.Above this, ZigBee defines the application and security layer specifications enablinginteroperability 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 themesh network topology is best suited in our case.A ZigBee WSN is shown in Fig 1.It consists of three types of nodes: a ZigBeeCoordinator, ZigBee Routers , and ZigBee End-Devices.

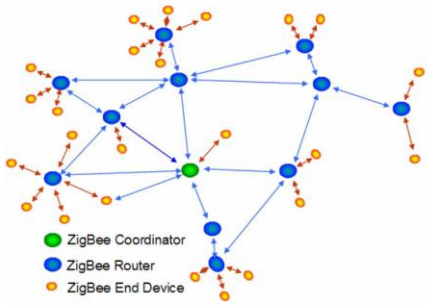

Figure 1-Typical ZigBee WSN – Mesh Architecture

V. WSN SYSTEM ARCHITECTURE

In our project the water wells are constructed at suitable location in the field and sensor columns are attached. The electro-mechanical sensors will measure the water level and the valves can be transmitted through the WSN for this the entire paddy field can be divided into a number of clusters and these clusters can have number of water wells or sensor wells. Each cluster will have a cluster head and all sensor nodes in that cluster will communicate the data to the cluster heads. The water level sensed by the sensor can be low, normal or high. These valves are sent to the cluster head then the cluster head aggregates these valves and compare them. If all the valves are normal then it need not send any data to the user. If any valve is high or low then it needs to be communicated to the user.For this the cluster head transmits the data to the sink node. The sink node is the node which is connected to all the cluster heads or in other words the cluster heads can communicate to the sink node in one hop.

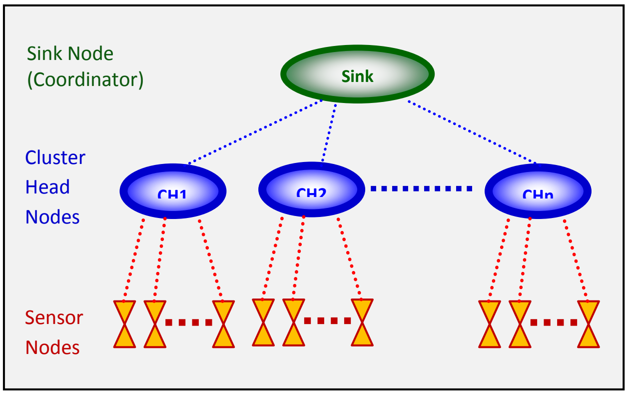

Figure 2 – WSN Architecture

Different topologies can be adopted in the WSN. In our project we are using a mesh topology. The WSN architecture used for the project is shown in fig 2. The sensor nodes in on region will form a mesh structure and each of these mesh structure will be a cluster. These nodes will together have a head node called the cluster head.For example in a wireless sensor network with hundred nodes, the nodes can be divided region wire ten to twelve nodes can form a cluster which operate in a mesh topology. Each of these meshes will have a head node called the cluster head node. Similarly another ten to twelve nodes form another mesh cluster. Totally we may have eight to ten clusters and their cluster heads. Then cluster heads are operating in the mesh topology so we have a mesh with two levels. These cluster heads communicating to the sink node which is on top of the network architecture.

Sudden increase in the water level or decline in the water level is not often occurred hence real-time monitoring or a full time monitor is not necessary. The monitoring can be done on a six hour basis,that is four times a day and its remedial measures can be taken. The remedial measure in the sense, pumping in water if water level is low and pumping out water if water level is high. As stated earlier in the introduction, Kuttanad area is lying below the mean sea level. The water level in the surrounding water bodies of the paddy field are higher than that of the paddy fields so pumping in water is easy by just opening the inlet valves located at the outer boundaries of the paddy fields. At situation where water level is high the excess water needs to be pumped out for this to happen there are electrical pump stations at different locations. The paddy fields are connected each other through water canals and these canals will have the pumping station. These pumps can be operated and the water can be pumped out.

Normally the low level sensor nodes will be in the sleep state and will be active only on the sixth hourly basis. When active they sense the water level and send it to the cluster head. After sensing and transmitting it goes to the sleep state for power usage optimization and will be active in the next sixth hour slot or otherwise instructed by the cluster head.

VI. DATA AGGREGATION

Initially when the network gets booted up each low level sensor node will measure the water level through the electro mechanical sensors and this valve will be sent to the cluster head. The cluster head upon receiving the data packet from all its subordinate nodes will start analyzing the data. It compares the valves of water level with the predetermined values. These predetermined values are fed to the system by the farmer. These values will be different according to different seasons and processes initiated by the farmer, for example, the field needs to be dry for some days after de-weeding and more water needs to be present for applying fertilizer.

On analysis if the cluster head is finding the value to be higher or lower than the predetermined value, it enters into a state from *normal* to *alert state*. Otherwise it continues to be in the *normal state*. On *alert state* the cluster head sends the data packets to the sink node and the remaining processes will be done by the sink node. It also instructs the subordinate sensor nodes to *sniff state*. The sensor nodes are having two states, *sniff state* and *sleep state*.

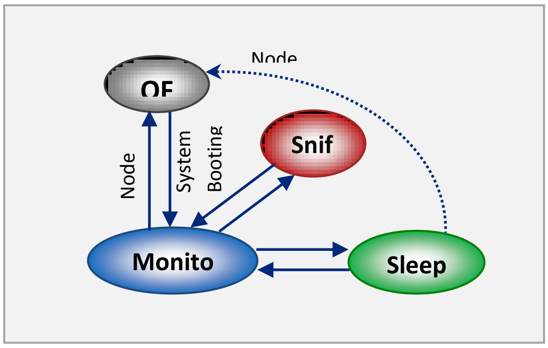

Figure 3 – Sensor Node State Transition

State	Description
OFF	Initial State of the system, Once booted up the node reaches this state when the node is shutdown or fails
Monitor	Normal operation - sensing and transmission at longer intervals
Sniff	Sensing and transmission at shorter intervals
Sleep	No sensing and transmission, a state of low power usage.

During *sniff state*, the sensors will be measuring the water levels at a high rate i.e. at short intervals of time Tsniff. It measures the valves and sends these valves to the cluster head. During *sleep state* the sensor nodes will be idle most of the time. Here the sensing intervals will be longer with a larger valve for time, Tsleep. The sensor node will initiate a counter for Tsleep and goes into *sleep state*, until the counter valve is reached. It wakes up after Tsleep and repeats the process by sensing and transmitting data to cluster head.

The state transition from*sleep* to *sniff* and reverse of the sensor nodes is instructed by the cluster head. The cluster head does this after receiving an *alert* value from any of its sensor nodes. Then the cluster head enters into *alert state* and instruct the nodes to enter into *sniff state*. Along with this the data will be reported to the sink node by the cluster head. The sink node will not perform any analysis of the data. It just forwards the matter to the Field Control

Centre (FCC). The Field Control Centre is a program which is running on the user computer. The FCC will receive the data from all the cluster heads through the sink node. The FCC will process these data and decides the remedial actions. It accesses the regions which are affected and then issue commands to the pumping stations of that region to either pump in or pump out the water.

Once the situation of the water level changes it will be reflected on the values received by the cluster heads from the sensor nodes. But it continues to be in the *alert state* until all the sensor nodes are sending values within predefined limit. When this situation is arrived it sends the message to the sink node and instructs all the sensor nodes to go to sleep state and enters into normal state. This state continues for a period of Tsleep and the above processes are repeated. Once the situation of the field is under control the full network will be in a sleep state for a period of Tsleep.

VII. CONCLUSION AND FUTURE WORK

India is developing at a faster rate but 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. This paper discussed the environmental and socio economical back ground of Kuttanad, the problems faced in agriculture and proposed use of wireless sensor networks for overcoming some difficulties. In the future this proposed system will be fabricated, deployed and tested.

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