A Pervasive system for optimizing water utilization in Agriculture using wireless Sensor Networks

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Abstract

Wireless Sensor Networks (WSN) are playing vital role in precision agriculture. In the current era, many sensor variants are being used in the agriculture sector for different process, production and precision monitoring system. Apart from this, Wireless sensor Networks are used for decision support systems in agriculture for various processes. This paper provides an insight of an automated drip irrigation decision support system for optimum utilization of available water to be distributed over a specified cultivation land with multiple crops. This system works with a network of wireless Sensor for data acquisition. All sensor nodes collect data from various geospatial locations and send it to sink node to provide decision support for water distribution. The main focus is to reduce the cost of a working system using less number of the Sensor node in comparison with other methods studied for a survey. Many novel methods are used for automated drip Irrigation. The presented system narrows the focus on soil moisture data collection between two sensor nodes using piece wise Interpolation. A multi hop transmission is used in data transmission from a source node to sink node.

**Keywords:** Wireless Sensor Network, Decision Support system, precision on agriculture, Multi hoping transmission, Drip Irrigation
I. INTRODUCTION

The advent of Wireless Sensor network has improved the wireless resource utilization in agriculture sector. Use of wireless sensor network for environmental parameter monitoring has given a new methodology for framers to increase their farm production by optimum utilization of available resources. The versatile environmental parameters, geographical location and uncertain climatic conditions has made farmers decisions more cumbersome and tedious [1]-[3]. There is considerable growth of parameter monitor using the sensor in previous few years and hence agriculture sector is in transformation phase from conventional to modern practices [4].

A wireless sensor network is a ubiquitous system of sensors to monitor physical or environmental conditions, like soil moisture, soil properties such as texture, color, the capacity of water content, temperature, Humidity and much more. To concomitantly pass parameter values through the main location ZigBee wireless communication technology (IEEE 802.15.4) is adapted over other technologies for the implementation sensor nodes and its communication. Low cost and low power consumption features of ZigBee, so it is widely used [5]. The wireless sensor networks can provide an easy access of real-time field data to farmers for decision support [6]. The agriculture sector is a very potential field where WSN can be used with ease.

The presented system uses soil moisture property as a parameter to be transmitted over a network and it will be used to verify conversions of current needs of crop and according to the decision are made. The decision is made through automated process based on a comparison of parameter values between pre-set threshold and sensor values transmitted by sensor nodes which are deployed at the different point in the cultivating land. The scope of the project can be extended to green house environmental parameter, Industrial use, Power plants and Chemical plants. Here it is limited to agriculture sector for monitoring process and decision support system.

II. LITERATURE SURVEY

Wireless Sensor Network is formed by distributed sensor nodes where each node consists of various sensors to read physical phenomenon such as Light, Heat, Soil Moisture, Temperature, Humidity, pressure. These sensor nodes are regarded as revolutionary data collection methods to transmit information at geographical apart locations. It has great reliability and efficiency of a working system. United States Military pioneered the use of Sensor node networks in Civil War II to detect submarines and air defense. It was called Distributed sensor networks which were used to process data collaboratively [7]-[10]. Previously, many researchers worked on WSN application in precision Agriculture. Following are few remarkable works done by researchers.
Robert W. has presented a novel method for valve control method. He has developed valve control hardware and software. These hardware and software modules are compatible with commercial WSN nodes. The valve control units are available to deploy in fields to control and monitor different necessary parameter. The valve relay system appends sensor node firmware, actuator hardware, an internet gateway with control, communication and web consolidation [11]. Bhagat focused on drought vigilance in tea plantations. He worked on environmental parameters such temperature, humidity and soil water content. These parameter values are transmitted remotely to the sink node or server. Based on these sensor readings, server proffers the idiosyncrasy of working adherence and reliability in the system [12]

Paventhan worked on IEEE standard used in wireless data transmission. The IEEE 802.15.4 (IEEE Std 802.15.4, 2006) Low-rate Wireless Personal Area Networks standard is anticipated at applications with limited power and tolerable throughput exigency. The Internet Protocol (IP) is adapted over Ethernet links that produce colossal good put. He ensures transmission of IPv6 packet over LoW PAN links. There were many challenges of resource constraints. However, concludes the benefits in enabling IPv6 over 802.15.4 links such as (1) large IPv6 address space and stateless auto configuration (2) Network vigilance (3) Feasibility of application layer protocols (4) seamless and end-to-end integration with a connected network. IETF 6LoWPAN working group has defined RFC 4944 specification (6LoWPAN, 2012) to efficiently move IPv6 data grams over IEEE 802.15.4 links. [13]

Aurelio Cano developed a network abide with a number of automatic measurement stations, stereo typically placed soil congruity and land utilization criteria. In this system, a base station performs acquisition, conditioning, and communication through nodes. To achieve uninterrupted power supply, the solar panel was used to activate sensor nodes. The gathered parameter values are then routed through long radio links to cover a larger spatial range. The presented system used computer system connected to the web in contemplation to control the entire network, to deposit information, and to access remotely monitored real-time data [14]

Ufoaroh worked on GSM based sprinkler irrigation system to monitor water distribution in the farm field. He uses soil moisture and soil temperature parameters to find current conditions of the soil. Depending on the sensor reading, decisions are made for the need for irrigation. A pumping mechanism is used to water the cultivation land as per requirements of the crops. Water levels are monitored and transmitted to farmers through GSM based system [15]

Ahemady, worked on challenging issue of implementing the agriculture monitoring network at colossal and large distributed area. He used multi hop network to implant communication between source and destination. The network sequentially monitors the crops without sensitivity classification to safeguard a high quality of service
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(QoS). For this, he monitored the crops based on respective sensitivity conditions as well as the crops with higher sensitivity. But less sensitive crops are tracked occasionally. This access selects a set of nodes over all the nodes in the network leading the reduction in power consumption and network delay. He preferred classified based approach for comparing nonclassified method in two scenarios such as the back off periods change and numbers of nodes change [16]

Suradhaniwar, designed an interoperable sensing platform that accedes with Open Geospatial Consortium (OGC) Sensor Web Enablement (SWE) framework. He Proposed a system with sensors to estimate point-based soil moisture and temperature observation at different depths of 15, 30, 45 and 60cm each. The research was carried out 2016 in the study area. He concludes with perception for soil moisture and soil temperature delineation at different depths. He analyzed the possibility of deploying dense interoperable sensor networks to capture spatiotemporal changeability of soil moisture over amalgamate landscapes [17]

III. SYSTEM ARCHITECTURE

The core part is on enthralling self-controlled irrigation system using Piece wise Interpolation method. This system is promoting perpetual valve timings of drips fixed on sensor learning from the sensor nodes and it’s tuned timings. A microcontroller is used to store data from nodes. The gathered analog values are persuaded to digital values using ADC converter. The system approves the numerated water distribution. The settlement is made on the basis of readings compiled from sensor nodes. Once the data is collected then Piecewise Interpolation is adapted to vaticinate watering plan for maximum land cultivation and maximum profit sharing. A microcontroller initializes the statute to different pervasive devices such as water pumping motor, valve, to switch ON or OFF. A multi hoping method is used to communicate with the master node. The master node is connected to the server. Server compiles data for computing decisions.

The three parameter values are verified such as temperature, soil moisture, and light intensity. The farm field is divided into small parts and one node is positioned in each part. Each sensor node is carried LM35 for temperature reading and Tensiometer for volumetric soil moisture contents. The sensors are spread out at 6-8 cm underneath the soil level. As soon as moisture level ambit the threshold value then it is communicated to a microcontroller to share a decision over, valve switch ON or OFF.

A. Interpolation Method

The interpolation method is used to predict intermediate values between two sensor
nodes deployed at geographically apart locations. In the presented system, sensor nodes are used to read the soil moisture and temperature data. The collected data is transmitted to the server. As the sensor nodes are deployed at different points, intermediate values need to be calculated. Interpolation is the most suitable method for measuring these values.

B. Algorithm

1. Accept the value of x.
2. Accept the value of y.
3. find local variable.
4. S=x-x(k) ,Where k=0,1,2...
5. Find first divided difference Delta(k) δ (k) =(y (k+1) − y( k)) / (x (k+1) − x(k))
6. find the interpolant
   \[ L(x)= y(k) + (x − x(k))(y(k+1)−y(k))/(x(k+1)−x(k)) = y(k)+ δ(k) . \]

IV. RESULT AND DISCUSSION

In the presented system, a volumetric water content (VWC) is measured for decision support. This system collects the analog values from the required sensor node. These analog values are converted to digital values and then transmitted for the further computational process. The Volumetric water content is based on soil properties such as soil texture, soil particle density, Bulk density, temperature etc but in a presented system only one moisture holding capacity is considered. For VWC a standard formula is used as follows

\[ VWC = 1.17 * 10^{-9} * ADC3 − 3.95 * 10^{-6} * ADC2 + 4.90 * 10^{-3} * ADC − 1.92 \]

(1)

The Volumetric water contents are established on various soil assets such as soil texture, soil particle density, Bulk density, temperature etc, but in this system only moisture holding capacity is mediated.

All computational part is considered as per the cultivation land used in experiment sand then it is been converted day wise calculations. For all computational part following standard definitions are used to convert necessary conversions as and when needed
1. Cubic foot: A volume of water equal to that of a cube 1 foot in length, 1 foot in breadth and 1 cubic foot in thickness. One cubic foot of water = 28.37 liters or 6.23 gallons or 0.0283 cubic meters or 0.028 ton [18]

2. Acre inch: the volume of water necessary to cover one-acre (43,560 sq. feet) surface to a depth of one inch. One hectare inch = 3630 cubic feet or 101 ton.[18]

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Depth of Soil Layer ( cm )</th>
<th>Moisture % on oven dry basis</th>
<th>Apparent specific gravity g/cc</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Field Capacity</td>
<td>Actual</td>
</tr>
<tr>
<td>1</td>
<td>0 - 15</td>
<td>25.0</td>
<td>16.4</td>
</tr>
<tr>
<td>2</td>
<td>15 - 30</td>
<td>24.0</td>
<td>17.8</td>
</tr>
<tr>
<td>3</td>
<td>30 - 60</td>
<td>22.3</td>
<td>19.2</td>
</tr>
<tr>
<td>4</td>
<td>60 - 90</td>
<td>22.2</td>
<td>20.5</td>
</tr>
</tbody>
</table>

A. Hardware part

Fig.1 Sensor nodes used in experiment
For actual result analysis, water consumption and power consumption parameters are considered. For the result analysis and comparison with experimental values, the standard agriculture environmental parameters are considered from various agriculture universities in and around Pune region, such as College of Agriculture and biotechnology, Mahatma Phule krishi Vidyapeeth, Pune and Maharashtra State Agriculture Marketing Board (MSAMB). All standard values of soil moisture
requirement, water utilization and power consumption in water distribution, compared with actual experimental results [19]-[20]

**Table 1.** Consumption of water and power, day wise plot for one Acre cultivation land up to 12 cm without Piecewise Interpolation

<table>
<thead>
<tr>
<th>Time</th>
<th>Drip Irrigation without Piecewise interpolation</th>
<th>Water in Lit.</th>
<th>Power in watt</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.00-10.00</td>
<td></td>
<td>121.5</td>
<td>243</td>
</tr>
<tr>
<td>10:30-11:30</td>
<td></td>
<td>121.5</td>
<td>243</td>
</tr>
<tr>
<td>12:00-12:30</td>
<td></td>
<td>121.5</td>
<td>243</td>
</tr>
<tr>
<td>12:45-01:50</td>
<td></td>
<td>108.33</td>
<td>216.66</td>
</tr>
<tr>
<td>02:00-03:00</td>
<td></td>
<td>121.5</td>
<td>243</td>
</tr>
<tr>
<td>03:10-04:10</td>
<td></td>
<td>121.5</td>
<td>243</td>
</tr>
<tr>
<td>04:15-05:15</td>
<td></td>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>05:20-06:20</td>
<td></td>
<td>121.5</td>
<td>243</td>
</tr>
</tbody>
</table>

**Fig.4** Consumption of water and power, day wise plot for one Acre cultivation land up to 12 cm without Piecewise Interpolation
Table 2. Consumption of water and power, day wise plot for one Acre cultivation land up to 12 cm with Piecewise Interpolation

<table>
<thead>
<tr>
<th>Time</th>
<th>Drip Irrigation with Piecewise interpolation</th>
<th>Water in Lit.</th>
<th>Power in watt</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.00-10.00</td>
<td></td>
<td>95.34</td>
<td>187.4</td>
</tr>
<tr>
<td>10:30-11:30</td>
<td></td>
<td>92.67</td>
<td>183.3</td>
</tr>
<tr>
<td>12:00-12:30</td>
<td></td>
<td>90.23</td>
<td>179.1</td>
</tr>
<tr>
<td>12:45-01:50</td>
<td></td>
<td>93.56</td>
<td>184.5</td>
</tr>
<tr>
<td>02:00-03:00</td>
<td></td>
<td>92.87</td>
<td>183.3</td>
</tr>
<tr>
<td>03:10-04:10</td>
<td></td>
<td>91.39</td>
<td>182.8</td>
</tr>
<tr>
<td>04:15-05:15</td>
<td></td>
<td>73.11</td>
<td>167.7</td>
</tr>
<tr>
<td>05:20-06:20</td>
<td></td>
<td>92.14</td>
<td>182.9</td>
</tr>
</tbody>
</table>

![Fig.5](image_url)

**Fig.5** Consumption of water and power, day wise plot for one Acre cultivation land up to 12 cm without Piecewise Interpolation

V. CONCLUSION

By estimating the two data tables, it is ascertained that the water consumption with and without Piecewise Interpolation has a huge difference. $937.33 - 721.31 = 216.02$ which is almost 24% water saving in overall water consumption. In power consumption $1874.66 - 1451 = 423.66$ which is again almost 23% power consumption.
saving. All the values are calculated based on one hour continuous running 10 HP (1 H.P. = 745.7 W Energy consumed = Power \times Time) water pump and consuming distributing water through 6 mm pipe [21]

ACKNOWLEDGEMENT

I hereby take the opportunity to say thanks for all valuable support from RKDF, University, Bhopal. Apart from this, I am really grateful to MSAMB, Pune and other Agriculture colleges for their support for data calculations and analysis.

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