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A Survey on Wireless Sensor Network based Technologies for Precision Agriculture System

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Abstract: *This paper provides the information related to previous work that has been done in the field of agriculture using the wireless sensor network technology over a period of past few years. We also studied the wireless protocols that were used previously. These protocols have limitation of short range which requires multi hopped network as in Zigbee and Bluetooth communication technologies. The multi hopping can be avoided by the use of appropriate long range wireless protocol such as WiMaX, GSM and medium range Wi-Fi protocols.*

Over recent years, there have been important advances in several technologies related to wireless communications and networking applications in the agricultural practices. Based on survey results, a more research can be done for providing best technological solution to the common challenges in agriculture. This research would be helpful to develop a device having flexibility, local intelligences and decision power. Hand held device option can be useful in precision agriculture for various commercial crops in Indian scenario.

Keywords: *Wireless Sensor Network; Precision Agriculture; Random Topology; Wi-Fi network.*

I. INTRODUCTION

Agriculture in the Indian economy has played vital role. It accounted for 15.7% of the GDP in 2009-10, employed 52.1% of the total workforce [1].

Information related to previous work that has been done in the field of Precision Agriculture (PA) is very necessary before going to develop a best solution for precision agriculture. Over a period of past few years, a system which is useful in monitoring as well as controlling the data which provides the flexibility, is realized. The communication and networking technologies that were used previously have limitation of short range which requires multi hopped networks. So this multi hopping can be overcome by the use of appropriate long or medium range wireless protocol such as WiMAX, GSM and Wi-Fi.

Researcher have devoted their time to develop important advances in several technologies related to wireless communications and in network processing, a steady increase of processing capacity, the appearance of mature wireless sensor network (WSN) hardware and software platforms, and the widespread adoption of smart-phones. All these innovations offer a wide set of novel alternatives which could potentially address unsolved problems in PA and offer more convenient alternatives to existing solutions.

II. LITERATURE SURVEY

Santhosh Simon and K Paulose Jacob proposed that the wireless sensor network for crop monitoring in the paddy fields of Kuttanad (india) can be applied because the soil of the paddy fields is salty and is extremely acidic. This acidity of the soil is considered a major problem which retards the production of rice in the area. A best solution to overcome this problem is to regular rinsing of the soil by water which can reduce the acidity and increase the production. So, the pumping of water to and from the field is the major activity from plowing to harvesting. Further, they added that Electro-mechanical sensors in the mesh networking and through ZigBee communication can be automated systems which monitor the water level and regulate the water. It can send messages to the farmers. They suggested Zigbee technology because of its 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. [2]

Kazunobu and Mitsuho developed a site-specific nitrogen management system "RiceNiSMo" for paddy rice for estimating the appropriate rate of fertilizer nitrogen application. This software can simulate the growth stages, nitrogen uptake, yield and the degree of lodging based on the parameters from soil nitrogen release and the weather. [3]

S.K. Balasundram et al reviewed On-the-go soil sensor technologies and find out that soil sensors can be used to generate real-time soil data, such as pH, electrical conductivity, salinity, dissolved oxygen and nutrient concentration, which are subsequently turned into geo-referenced maps to facilitate site-specific nutrient management. They suggested that numerous 'on-the-go' sensors have been manufactured to measure mechanical, physical and chemical soil properties. These sensors have been based on electrical and electromagnetic, optical and radiometric, mechanical, acoustic, pneumatic and electrochemical measurement concepts. [4]

N. G. Shah et al. developed a system for precision irrigation using sensor network mainly aimed for monitoring soil moisture and estimating vaporization by considering soil moisture, soil temperature and relative humidity as the critical parameters for measurement. [5]

A system was developed by Q. Wang et al using microcontroller, universal asynchronous receiver transmitter (UART) interface and sensors while the transmission was done by hourly sampling and buffering the data, transmit it and then checking the status messages. But they find out that its cost and deployment of sensor under the soil which causes attenuation of radio frequency (RF) signals was the major drawbacks. [6]

I. Aziz et al developed a remote monitoring system in agricultural greenhouse using wireless sensor and short message service (SMS). System was divided into four parts namely data acquisition, data communication, data presentation and alert notification which also allowed the reverse communication i.e. from farmer side to the base station. The system was cost effective and reliable. They considered that this system can be made more cost effective by taking other environmental parameters and by using recent technologies such as artificial intelligence, neural network, etc. [7]

A Wi-Fi based smart sensor network for agricultural environment was developed by G. Mendez et al. They considered temperature, humidity, light intensity, air pressure and soil moisture as main parameters. The objectives were to reduce cost and effort of incorporating wiring, to enhance flexibility and mobility for the system. The system was useful for transferring and logging the data from various nodes. [8]

M. Haefke et al. developed a ZigBee based smart sensing platform for monitoring environmental parameters such as temperature, relative humidity, pressure and sunlight with the use of microcontroller which serve as a smart weather station. The research was based on characteristics such as use of low cost equipment, accurate sensors and flexibility in data handling. Use of XBee module provided the wider range and reduced the current consumption of the circuit. [9]

M. Dinesh and P. Saravanam proposed a FPGA based embedded system which could monitor and control microclimatic parameters on regular basis so as to maximize the production of crop with reducing human intervention research. They considered temperature (wet and dry both), humidity and light intensity as their main parameters. The system was low cost, automated and can be made effective by considering other environmental parameters and real time fault detection. [10]

A remote sensing and control irrigation system using distributed wireless sensor network aiming for variable rate irrigation, real time in field sensing, controlling of a site specific precision linear move irrigation system to maximize the productivity with minimal use of water was developed by Y. Kim et al. [11]

M. Dursun and S. Ozden developed a drip irrigation automated system using wireless technology. The objectives were to monitor water content of soil in real time and remove the need for workmanship for flooding irrigation. The designed system has three unit namely base station unit, valve unit and sensing unit which were applied for controlling drip irrigation of 1000 dwarf cherry trees. In this sensors were placed 20cm deep and 50cm away from the trees. The analysis of the system produced the circa linear graph between volumetric water content and time for which system was analysed. It was a low cost and reliable system having advantages such as preventing moisture stress of trees, minimising excessive use of water and ensuring of rapid growing weeds. [12].

Gopala Krishna Moorthy .K et al. developed a monitoring system to measure the water level in agriculture using sensor network which offers precision irrigation. They developed a routing algorithm which provides information related to water level as well as useful in computing threshold values based on transmission range. The algorithm was based on distances of wireless information from source to sink node as well as on minimum angle between source and destination. They also proposed that system can be optimized by the use of algorithms based on genetics and neural network. [13]

T. Pearson proposed "Paprika greenhouse management system" which had WSN environmental sensors and CCTVs at inside/outside of paprika greenhouse. These devices collect the growth-environment related information of paprika. He investigates that Zigbee-based agriculture monitoring system serves is a

reliable and efficient system to monitor the environmental parameters. Wireless monitoring of field not only allows user to reduce the human power, but it also allows user to see accurate changes in it. [14]

Jose I. et al reviewed the principles of biosensor fabrication and operation, their existing and potential applications in the food and agricultural industries, and recent research and future trends. [15]

III. OSERVATION FROM SURVEY

On the basis of survey of the literature, the following findings have been observed.

TABLE 1. FINDINGS FROM ABOVE SURVEY

Agricultural parameters measured by WSN technology	Field capacity during irrigation, dissolved oxygen, nutrient concentration, soil moisture, soil temperature, relative humidity, atmosphere temperature & humidity, light intensity, air pressure etc.
Working principle of sensors used in WSN	Electro-Mechanical, electrical and electromagnetic, optical and radiometric, mechanical, acoustic, pneumatic and electrochemical measurement concepts, Biosensors etc.
Local computation, Networking & Communication techniques in WSN	Mesh networking and Zigbee IEEE standard802.15.4, Simulation software, artificial intelligence, neural network, Wi-Fi based smart sensor network, FPGA based real time monitoring system , Microcontroller and universal asynchronous receiver transmitter (UART) interface , A remote sensing (GPS enabled) and control irrigation system , genetics and neural network etc.
Benefits of using WSN technology in agriculture	cost effective, low-power consumption and long distance data transmission, 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 , reliability on real time data collection, reduce effort of incorporating wiring, flexibility , mobility, maximise the production & quality of crop with less manual efforts, FPGA based WSN platform is energy efficient and more useful for farmers for decision making.
Challenges in using WSN technology in agriculture	Deployment of sensor under the soil which causes attenuation of radio frequency (RF) signals, power supply, measurement of accurate data in open field, environmental protection issues are the major challenges

TABLE 2. COMPARISON BETWEEN COMMUNICATION TECHNOLOGIES FOR THE FIELD SENSOR NETWORK

Bluetooth	**ZigBee**	**Findings**
Protocol IEEE 802.15.1	Protocol IEEE 802.15.4	Zigbee advance in protocol
Frequency Hopping Spread Spectrum (FHSS) modulation technique	Direct Sequence Spread Spectrum (DSSS) modulation technique	DSSS use low power in Zigbee
Protocol stack size 250k byte	Protocol stack size 28k byte	Low size of protocol suites in Zigbee
Intended for frequent recharging	No charging	Long battery life for Zigbee
1M bit/sec network speed	250kbits/sec	High speed for Bluetooth
1-10 meter network range	10-100 meter line of sight range	Long range for Zigbee
3 s network join time	30ms network join time	High selectivity
Bluetooth is more oriented toward user mobility and eliminating short-distance cabling	ZigBee aims more for grand-scale automation and remote control	Remote control in Zigbee

TABLE 3. COMPARISON BETWEEN COMMUNICATION TECHNOLOGIES FOR SENSOR NETWORK TO REMOTE SERVER

Wi-Fi	**WiMAX**	**Findings**
Standard: IEEE 802.11x (802.11b, 802.11g, 802.11n)	Standard: IEEE 802.16y (802.16a, 802.16d and 802.16e)	WiMAX is advance in protocol
ISM band	ISM bands or licensed band	For long range, subscriber can pay for license in WiMAX
100metres as it maximum range	80-90kilometers in terms of range	Long range in WiMAX
speeds up to 54mbps	speeds upto 40mbps	Wi-Fi better
channel bandwidth of 20MHz	bandwidth option which ranges from 1.25MHz to 20MHz	Chanel choosing facility in WiMAx
Wi-Fi uses Extensible Authentication Protocol (EAP) Wired Equivalent Privacy (WEP) security algorithms	WiMAX uses X.509 or PKMv2 as authentication algorithms	Both secure

IV. NEW PROPOSED SOLUTION

Considering all above findings, we propose a new solution for agricultural practices which would use WSN technology. Followings are the observations which are considered to use in proposed system.

TABLE 4. COMPONENT WISE OBSERVATIONS

Sr. No.	Components	Observations
1.	Agricultural parameters	Soil nutrients and moisture; atmospheric temperature and sunshine
2.	Working principle of sensors	Electrical conductivity
3.	Computation device	FPGA
4.	Communication techniques	Zigbee and WiMaX
5.	Networking	Random topology
6.	Benefits	Local and real time decision, compatible for any agriculture sites (greenhouse and open filed)

The proposed system would consist of couple of sensors to sense various soil and atmospheric parameters such as nutrients, moisture, temperature and sunshine. The result of sensed parameters would be transmitted via zigbee on a embedded device. The device would be installed at the farmers' premises. In this device, FPGA (Field Programmable Gate Array) may be used to give the system local intelligence power. The device would be able to use the sensor algorithm to accurately predict the health of the crop. This would alert the farmer in the form of textual and audio alarm through local display and alarm system. For public extension system, this device would transmit the signal to centralized server without any interference or interception of signal via WiMAX. In this topology, we may take wireless antenna, router, and gateway and centralized server.

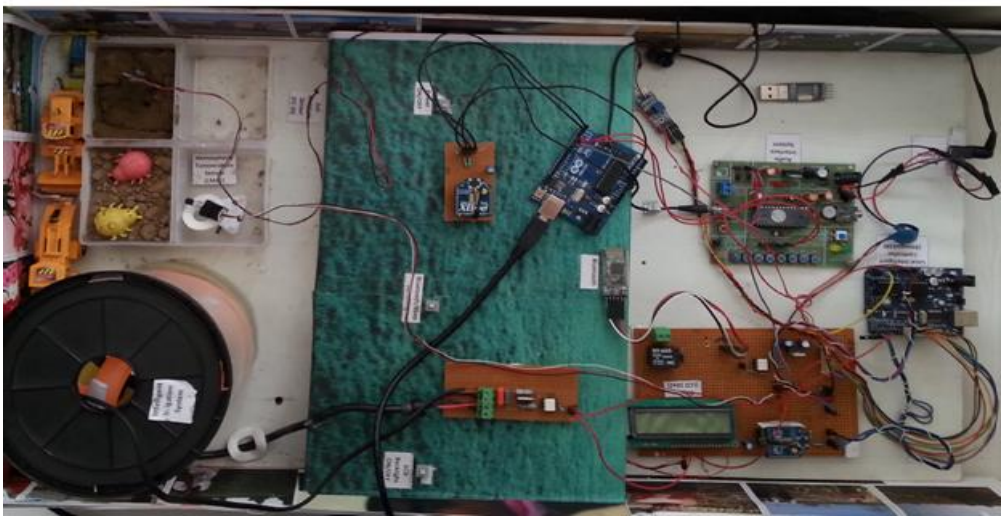

Fig.1. Snapshot of prototype

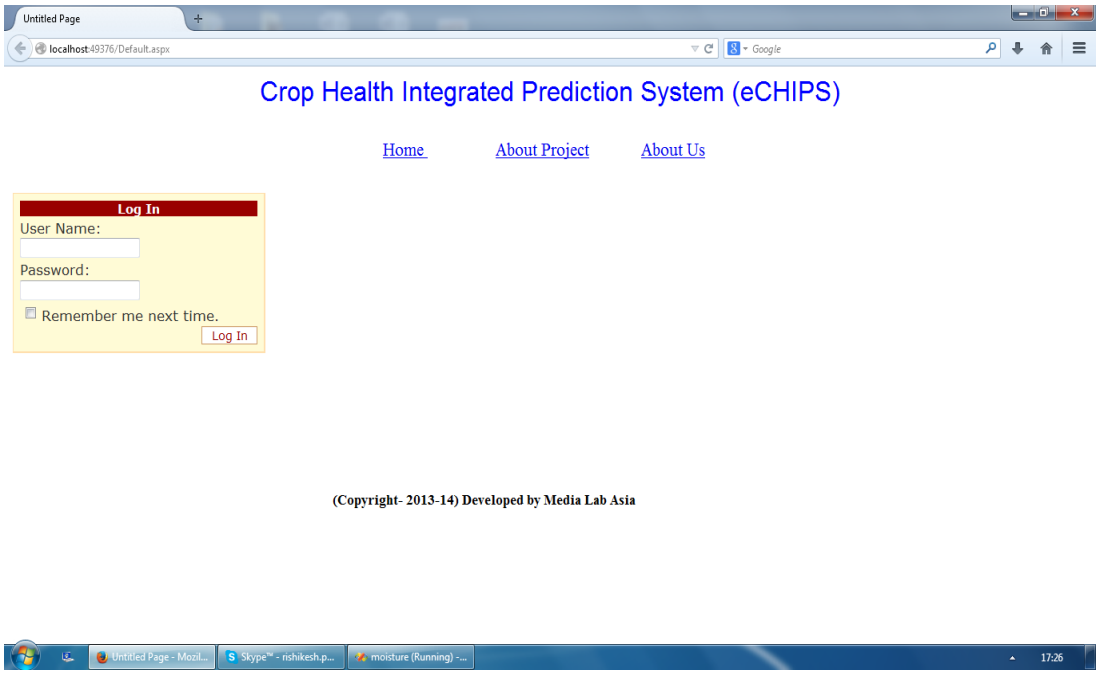

Fig.2. Screenshot of web application for prototpye

V. RESULTS

A prototype is developed at Media Lab Asia to prove the proposed concept and experienced results are shown in fig.3 and fig. 4:

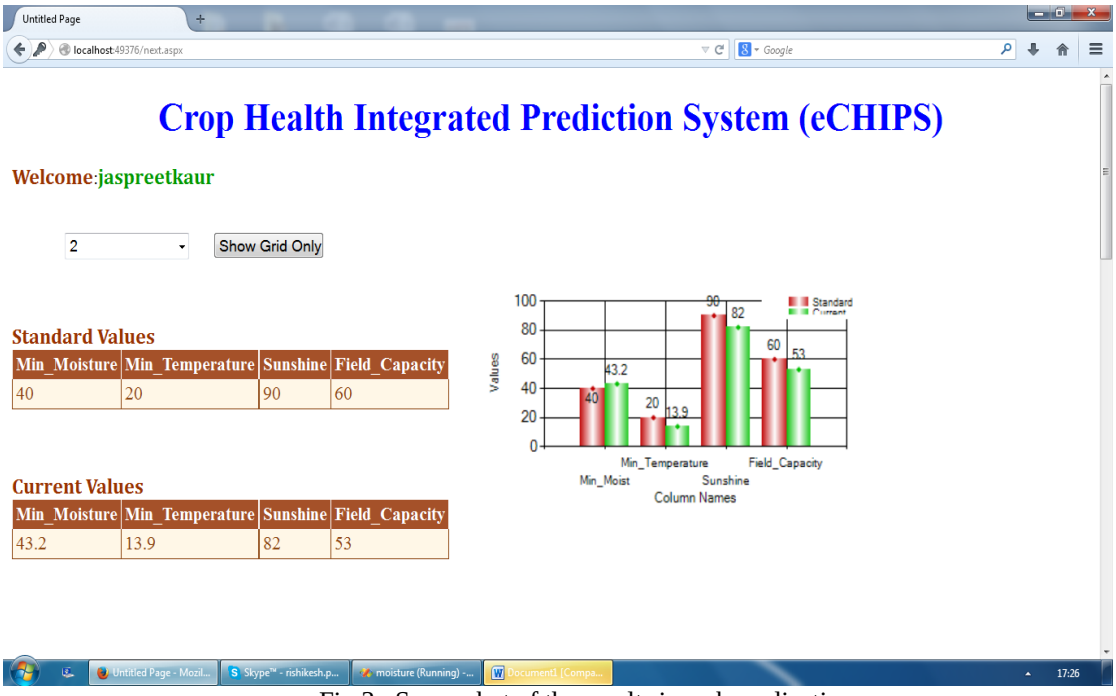

Fig.3 : Screenshot of the results in web application

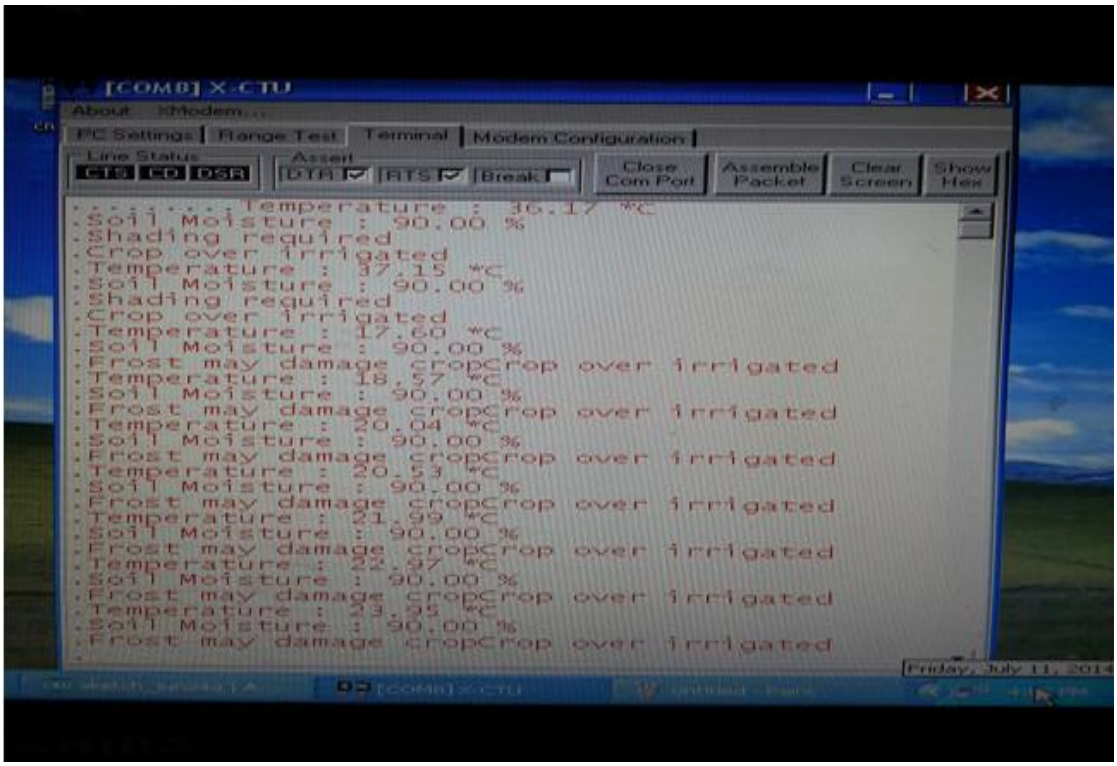

Fig.4: Snapshot of results displayed at remote PC

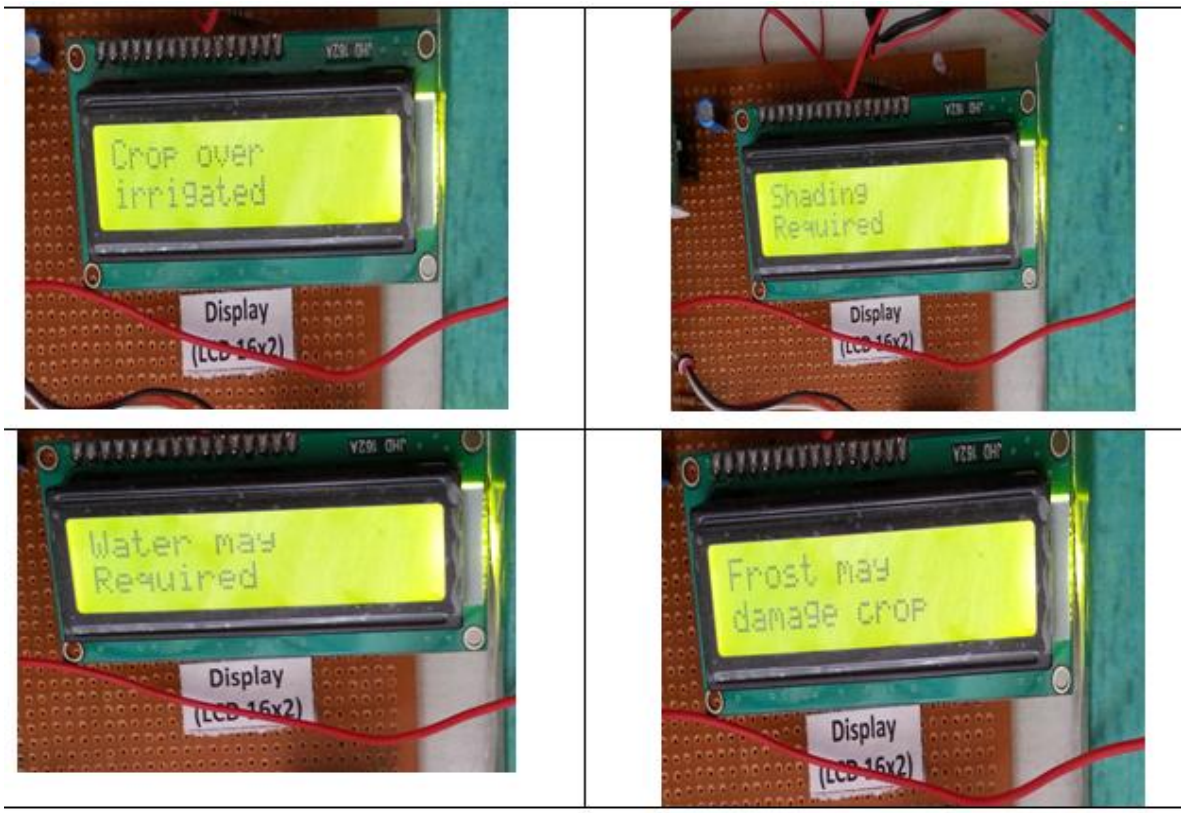

Fig. 5: Snapshot of results displayed at local LCD

VII. CONCLUSION AND FUTURE WORK

Precision agriculture (PA) and WSN applications combined together presents an exciting new area of research that will greatly improve quality in agricultural production especially in area of floriculture where quality is most important because consumer of cut flower are elite group of society. There are potential

applications of Wi-Fi wireless sensor network technology in agricultural systems such as real time field monitoring, automated irrigation control, monitoring, and remote operation.

In this paper, we surveyed the literature available and considering the findings we proposed a new solution in wireless sensor network technology for automatic monitoring and local alarming for the farmers. In our solution, the sensor nodes collect the data such as temperature, soil moisture, sunshine and nutrients from the field . The real-time data is transferred to the FPGA node via zigbee. On the basis of these data, device predicts about crop health. For public extension, this data may be transferred via Wi-Fi/WiMAX to the centralized center which stores and processes the data. Developed prototype gave good results. This would be further extended for the product.

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AUTHORS' BIOGRAPHY

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