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IOT & Wireless Sensor Networks in Precision Agriculture

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Abstract: ***Internet of Things (IoT) enables various applications (crop growth monitoring and selection, irrigation decision support, etc.) in Digital Agriculture domain. Precision agriculture is set to provide higher productivity and a better use of resources when compared to traditional methods and this will result in lower costs with higher yields. As water supplies become scarce because of climatically change, there is an urgent need to irrigate more efficiently in order to optimize water use. In this context, farmers' use of a decision-support system is unavoidable. Indeed, the real-time supervision of microclimatic conditions are the only way to know the water needs of a culture. Wireless sensor networks are playing an important role with the advent of the Internet of things and the generalization of the use of web in the community of the farmers. It will be judicious to make supervision possible via web services. The IOT cloud represents platforms that allow to create web services suitable for the objects integrated on the Internet. In this paper we propose an application prototype for precision farming using a wireless sensor network with an IOT cloud.***

Keywords: Precision Agriculture (PA), Wireless Sensor Networks (WSN), Internet of Things (IoT), Application Prototype

1. Introduction

India is agriculture oriented country. 69% of Indian population has agriculture as their main occupation or side business. The production or cultivation of useful crops in the Ecosystem produced by the people is known as agriculture. From another point of view, the farmers are the ecosystem engineers who find new ways for cultivation of crops. The water management practices are also adapted by many villages which provided water for drinking and other purposes in the dry season. In present time, in Indian agriculture still faces the challenges: Dependence on monsoon, fragmented land farming and holding, traditional farming practices, poor infrastructure in rural areas and less usage of technology applications. The advancement in the technology will help farmers increase the crop gain.

The new concepts in the technologies now a days are (i)Internet of Things (IoT) (ii) Wireless Sensor Network (WSN) (iii)Precision Agriculture (PA).

1.1 Internet of Things (IoT)

The internet of things is the network in which the real world objects are connected to each other which tends to form many embedded system including fields such as electronics and sensors through which the data can be transferred and received reliably. A real world thing/object in Internet of Thing in terms of animal farming can be an animal with Biochip transponder which when assigned an IP address and an ability to reliable data transfer over the network can be helpful to the farmer. Also with the use of sensor, application on the mobile phones and the transfer of useful data generated by the system will make it easy to use. The system has wide area of applications like Open Farm, Greenhouse Farming. In Open Farming, irrigation, water level etc. can be managed with this system whereas in Greenhouse Farming, temperature control, moisture control are the applications of this system. The system is also useful in the field of Gardening.

1.2 Precision Agriculture (PA)

Precision agriculture (also known as smart farming) uses internet of things (IoT) solutions together with Big Data methods to provide for more efficient management of resources. It is a significant vertical market [1] that includes the management of crop yields, livestock, seeding, fertilizer use and water. The benefits of precision agriculture (PA) include increased profitability and reduced environmental impact [2].

In the early years, PA consisted mainly of map based technologies using geo-statistical methods like GIS and satellite remote sensing and the main application of PA was to manage fertilizer use [2]. Sensor use was not widespread since sensors were either too costly, too inaccurate or unavailable for the applications required. Surveys during the early 2000's showed that few farmers used PA technologies and the main barriers to the adoption of these methods were the lack of technologies to deal with the large amounts of information, the lack of scientific validation, high costs and no training or technology transfer [2].

This has changed with the development and testing of prototype PA systems, the rapid development of IoT [3] and Big Data [4], and the decreased cost of sensors. IoT solutions in agriculture now form a cycle of i) monitoring through sensors, ii) analysis and planning, and iii) smart control, all linked by a wireless network connected to a cloud service (as shown in Figure. 1) [5]. Big Data analytics [6] and machine learning [6], [7] can be applied to the data to help make informed decisions [8] and the create intelligent control.

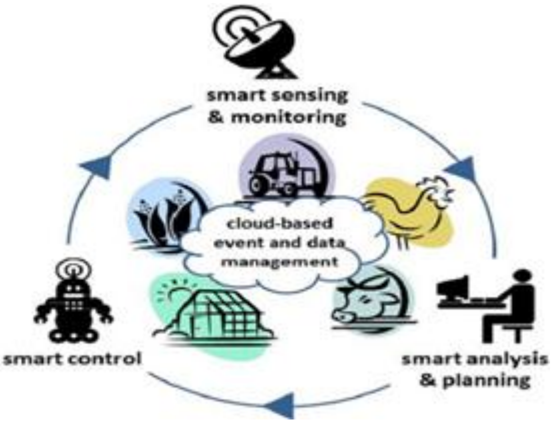

Figure 1: Precision agriculture IoT wireless system

1.3 Wireless Sensor Networks (WSN)

A wireless sensor network is a network composed of a set of nodes integrating the functions of acquiring, processing, communicating. Once deployed, the nodes cooperate with each other autonomously to collect and transmit data to a base station in order to monitor and / or control a phenomenon. Nowadays, the use of WSN knows a great boom in areas as diverse as the military, medicine, the environment and precision agriculture.

2. Related Work

IoT frameworks and platforms are still immature for agriculture, but there is a trend now to apply IOT in the agricultural sector. In [12]Duan Yan-e et al proposed an IOT application that provides agricultural information and crop information to farmers on the basis of collected wireless sensor network data. This information is used to ensure that the rate of Fertilizer application and within the recommended limit. In [13]Xiangyu HU et al. Developed an IOT application for remote monitoring and control of agricultural fields, which is based on the analysis of data collected by the wireless sensor network, which has enabled farmers to minimize the cost of hand And the efficient use of water resources. In [14]Andreas Kamilaris et al. Have proposed an application called Agri-IOT allowing the analysis and the processing of data coming from a network of sensors (WSN) while exploiting the semantic aspects. This will make it possible to associate an easy publication of data on the semantic web.

3. Background

Precision agriculture is a principle of management of agricultural parcels appeared in the United States in the 1980s. Already in 1985, researchers from the University of Minnesota vary the intake of calcium amendments on agricultural plots. We then try to modulate the insertion of certain inputs (nitrogen, phosphorus, potassium) in certain high-energy-intensive crops and inputs (maize, sugar beet for example), in the context of race to progress agricultural yields.

Mainly precision farming aims at optimizing yields and investments[4, 5 6] seeking to better account for the variability of environments and improving conditions between different plots. It has influenced tillage, seeding, fertilization, irrigation and pesticide spraying. In practice The aim is to optimize the management of a plot from a triple point of view:

- Agronomic: The agronomic precision aims at improving the efficiency of inputs / yields, including the choice of strains and varieties more adapted to the edaphic or phytosanitary context
- Environmental: It also involves reducing certain risks to human health and the environment (in particular by reducing the environmental release of nitrates, phosphates and pesticides).
- Economic: Increase yields, while reducing energy consumption and chemical inputs.

3.1 WSN

Networks of autonomous wireless sensors is promising technology which is making its place to complement these existing solutions and compensate their shortcomings.
Fig- 2 depicts architecture of WSN.

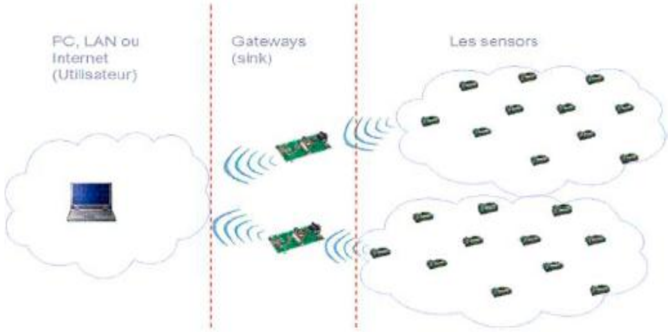

Figure 2: Wireless Sensor Networks Architecture

3.2 IOT Cloud

IoT (Internet of Things) is a scenario in which objects, animals and people are assigned as unique identifiers, IOT makes it possible as the ability to transfer data over a network without requiring any human interaction To-human or human-to-machine. The architecture of the Internet of the objects Fig 3 relies mainly on 4 processes allowing to collect, to store, to transmit and to treat data from the physical world. The role of the different processes presented in Fig 3 is described as follows:

- Collect data: refers to the action of transforming an analog physical magnitude into a digital signal.
- Interconnect: allows you to interface a specialized object network with a standard IP network (e.g. Wi-Fi) or consumer devices.
- Store: qualifies the aggregation of raw data, produced in real time, meta tagged, arriving in an unpredictable way.

Finally, presenting indicates the ability to restore information in a way that is understandable to humans, while offering a means of acting and / or interacting.

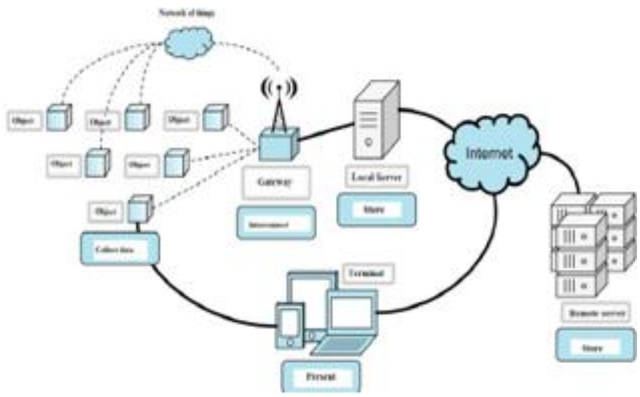

Figure 3: IoT Architecture

4. Sensor Based Irrigation

The success of crop farming relies on proper irrigation. Under-watering reduces nutrient uptake while over-watering causes leaching which poisons ground water [10]. Early water management [11] relied heavily on projected weather patterns, past farming activities and the manual observation of soil conditions; for instance, McKinion et al. [12] used GIS information [13] (based on soil samples and past farm use) as inputs for crop simulation models to optimize water and nitrogen use on a 201 ha cotton farm. Around the same time an automated irrigation system was prototyped using a central computer control centre [14], [15] linked to field irrigation valves [16].

This system by Damas et al. had the hallmarks of a modern IoT solution [17], [18] since it was made up of rudimentary sensors measuring water pressure and flow volume, simple solenoids controlling the irrigation valves, and a central computer management system [13], [14] all linked together with a network of omni directional UHF radio antennas. 1500 ha of irrigated land was covered with an irrigation system comprised of 1850 valves, 1850 meters and 32 pressure sensors. The management software monitored the sensors[14], controlled the valves while assessing water use to correctly bill the supplied communities. Although the system could more efficiently distribute water to irrigation users it was not fully automated since it lacked control feedback from the fields. This requires the use of soil and moisture sensors [22, 1].

Such an experimental system was developed to irrigate sage crops in a greenhouse. The main components of the system were sensor units joined to a central micro controller through a ZigBee network. A General Packet Radio Service unit relayed the sensor data over a cellular network to a server with a database. Each sensor unit is comprised of a temperature sensor, a moisture sensor, solar power cells with rechargeable batteries with a ZigBee radio unit. The unit is low-power with a sleep mode to reduce consumption. ZigBee unit was chosen due to its low price and efficient power consumption. The micro controller sends data to the server and receives instructions to activate irrigation. It also directly processes sensor data to implement automatic irrigation. Lastly the irrigation pumping system consists of two pumps activated by relays. A web application is used for monitoring and determination of an irrigation schedule. It is also used to set threshold values on the WIU for the automated scheduling. A SQL database is used for storage.

Testing was done over 136 days to compare it to the traditional irrigation method that used human supervision. Both methods used the same flow rate per drip hole during irrigation. The traditional irrigation schedule consisted of watering 42 production beds for 5 hours three times per week. The automated system watered 14 beds for only 35 min/week for the first 6 weeks then 35 min every three weeks along with automatic watering triggered by the sensor feedback of temperature and soil moisture. Threshold values to trigger automatic irrigation were set based on the producers experience. The total water use (for 14 beds) shown in Figure. 2 show a 90% reduction in water use using the automated system as compared to human supervision.

Advantages of the system are low power consumption, reasonable cost, long power life due to the solar cells and efficient water management. The study showed that a wireless sensor based irrigation system is an effective solution to cut water use.

The system shares many features with the previous greenhouse system such as solar panels and control relays except everything is geared towards outdoor field irrigation. The actuator units contained a micro controller that received sensor data and controlled irrigation valves with latching solenoids. The application software monitored sensor and actuator operation and sent control instructions to the actuators units based on a preprogrammed schedule or irrigation rules based on sensor information. Advantages of this system are long range connectivity, outdoor design, a grid network enabling communication between nodes and long power life due to solar cells. The estimated cost of a working system with 10 sensor nodes with 1 actuator along with the estimated savings per year due to the reduced labor, fertilizer use and water use costs meant that cost recovery would take about 4.5 years.

The system was tested for network and valve actuator robustness. The network tests shown in Fig- 4 show that nodes connectivity depended on line of sight conditions aranged from 100 m to 170 m. It was also noted that once the node successfully joined the network, communication remained stable. The actuator stress tests showed that the system withstood over 11000 normal actuations and over 6000 short circuit events. Short circuit testing was crucial since short circuiting valve wires is a common mistake made in the field. Further field testing done for nursery, landscaping and orchard applications revealed no major mis functions. The system showed that a commercially available sensor network could be used to actuate valves for a large scale irrigation system under normal operating conditions.

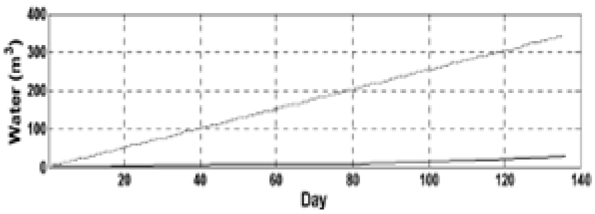

Figure 4: Water volume for the greenhouse irrigation system (bottom line) as compared to traditional methods (top line)

5. Conclusions

As an important constituent part of the IoT, sensor networks enables us to interact with the real world objects. In this project we are dealing with the sensor network design that enables connecting agriculture to the IoT. The connection sets up the links among agronomists, farms, and thus improves the production of agricultural products. It is a comprehensive system designed to achieve precision in agriculture. The studies showed that the wireless sensor networks were feasible with an improvement over traditional methods. Each system generated vast quantities of data which could be analyzed with Big Data analytics to find trends and correlations. In the case of irrigation, data on irrigation events would be integrated into the systems that control agricultural machinery to improve crop yields and fertilizer use. Time trends would be used to plan future farming strategies based on recorded outcomes. These IoT solutions will improve farming methods and result in more productivity and a better use of resources.

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