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Wireless Sensor Network in Agriculture: A Primer

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Abstract: Agriculture is one of the industries which have recently diverted their attention to wireless sensor networks. Wireless sensor networks have been widely used in monitoring agriculture and collecting data such as agricultural irrigation, fertilization, pest control, greenhouse cultivation, and livestock breeding. This paper presents a primer on the applications of wireless sensor networks technology in agriculture.

Keywords: *Precision Agriculture, Green/Sustainable Agriculture, Digital Agriculture, Smart Agriculture*

I. INTRODUCTION

Agriculture plays an important role in many countries and is the backbone of the economy in most countries. It has played an crucial role in the development of human civilization. Modern agriculture requires technological tools that can improve production efficiency, meet the increasing demand of food, and reduce their environmental impact. To achieve this goal, new technologies and solutions are being applied in agriculture. One of the key solutions is precision agriculture. As its name implies, precision agriculture is precise in both the size of the crop area it monitors as well as in the delivery amounts of water, fertilizer, etc.

Wireless sensor networks (WSNs) are the enabling technology for efficient and inexpensive precision agriculture (PA). WSNs are used to collect, monitor, and analyze data. They can help monitoring fields, thus helping farmers to increase crop production and prevent damages to their crops. A wireless sensor network consists of a series of small low-cost, low-energy, easily-deployable sensors. A WSN system (wired or wireless) may be used to monitor and collect data such as light, humidity, air/water temperature, air pressure, sprinkler water flow, soil acidity, and soil moisture parameters in the agricultural domain.

II. OVERVIEW OF WSN

A wireless sensor network (WSN) usually consists of a large number (hundreds or thousands) of sensor nodes deployed over a geographical region. The wireless sensor nodes are compact, light-weighted, and battery-powered devices that can be used in virtually any environment. The sensor nodes monitor physical or environmental conditions such as temperature/heat, humidity, sound, vibration, pressure, light, object motion, pollutants, presence of certain objects, noise level or characteristics of an object such as weight, size, speed, direction, and its latest position. A typical sensor node is shown in Figure 1 [1]. The sensor node is made up of four components: a power unit, a transceiver unit, a sensing unit, and a processing unit. The node may also have some application-dependent components. Specific sensors commonly used include air temperature, relative humidity, light, soil moisture, and soil temperature.

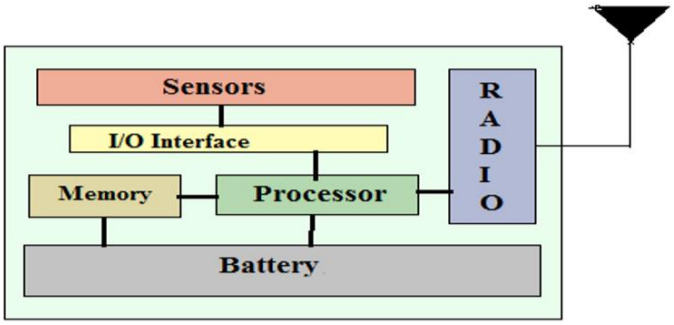

Figure 1: Typical sensor node [1].

WSNs belong to the general family of sensor networks that employ distributed sensors to collect information on entities of interest. In general, there may be both sensing and non-sensing nodes in a WSN; i.e. all sensors are nodes but not all nodes are sensors. A sensor has four operating modes: transmission, reception, idle listening, and sleep. Collision occurs when two or more nodes transmit at the same time. A sensor node is designed to use an operating system (OS). TinyOS (developed at UC Berkeley) is perhaps the first operating system specifically designed for WSNs. Most WSNs are application specific and are designed to meet the challenges for that specific application. Applications of WSNs typically involve some kind of monitoring, tracking, or controlling. A number of WSNs have been deployed for agricultural and environmental monitoring [2]

A wireless sensor network for agriculture is similar to those used in other applications of WSN including homes, offices, military, environmental monitoring, industrial monitoring, natural disaster prediction, health care, vehicle tracking and detection, security systems, and many others [3]. Some of these applications are displayed in Figure 2 [4].

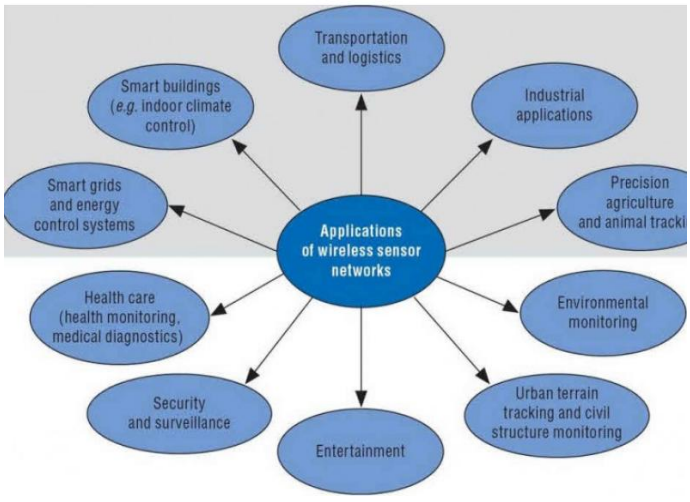

Figure 2: Some applications of wireless sensor networks [4]

III. BACKGROUND ON PRECISION AGRICULTURE

The agriculture is transitioning from traditional agriculture to modern agriculture currently. Precision agriculture (or

precision farming) is the use of information and communication technology (ICT) along with best agricultural practices. Precision agriculture (PA) is the application of precise amount of inputs like water, fertilizer, pesticides, etc. at the correct time to the crop for increasing its productivity while boosting yields. It achieves this objective by using high-tech systems. It allows farmers and soils work better. The basic principles underlying PA are [5]: correct information, correct observation, correct analysis, correct doses, correct place, correct time, correct conditions, and correct equipment. PA follows the site-specific management principle, which has the idea of doing the right thing, at the right time, at the right place. It may boost agricultural production while reducing harmful impact on the environment [6].

IV. APPLICATION OF WSN IN AGRICULTURE

As the cost for sensors and communications infrastructure drops, more growers are implementing WSNs for their crops. Common agricultural application of WSN include environmental monitoring, outdoor monitoring, greenhouse monitoring, agricultural water management, irrigation management, pest management, and crop growth.

A. Monitoring for Precision Agriculture:

The most common implementation of WSN technology in agricultural practices is environmental monitoring. Precision agriculture involves the monitoring of various parameters such as soil pH, soil moisture, soil temperature, and electrical conductivity. The monitoring system may be based on low-power ZigBee wireless communication technology. It is usually made up of four components [7]: sensor node, the sink node, transmission networks, and monitoring terminal. Sensor nodes collect temperature, humidity and other parameters. The sink nodes are the core nodes which are responsible for collecting data and storing data. Three main wireless standards are currently used namely: WiFi, Bluetooth and ZigBee. Monitoring includes crop field monitoring, monitoring the water quality, and monitoring of soil quality parameters. Crop field monitoring is necessary in agriculture to reduce resource waste and to increase yield in activities like irrigation and fertilization. The information generated by the monitoring can be used to predict crop health and production quality [8]. A typical wireless sensor network for measuring environmental factors is shown in Figure 3 [9].

B. Measurement of Agricultural Parameters

Precision agriculture requires some parameters for the improvement of production. These parameter are obtained through WSN technologies. The parameters include soil parameters and parameters of temperature, humidity, and luminosity. Collection of the parameters is done using sensor nodes deployed in the farmland.

C. Irrigation Management

Irrigation is an essential practice in many agricultural cropping systems in arid areas, where agricultural output is low and water is a scarce and vital resource. Adequate irrigation is crucial for improving the crop yield. Traditional field irrigation is often manned and needs massive manpower and material resources. Off-the-shelf irrigation controllers are usually expensive and not effective in managing scarce water resources. On the other hand, irrigation management using WSN can ensure a better crop yield of good quality and accept any desired irrigation scheduling strategy to meet specific environmental requirements. WSN can be applied as a tool for appropriate irrigation tactic to improve the crop yield. Figure 4 illustrates the architecture of the irrigation management system. The use of cellular network reduces the cost of the remote monitoring system [10].

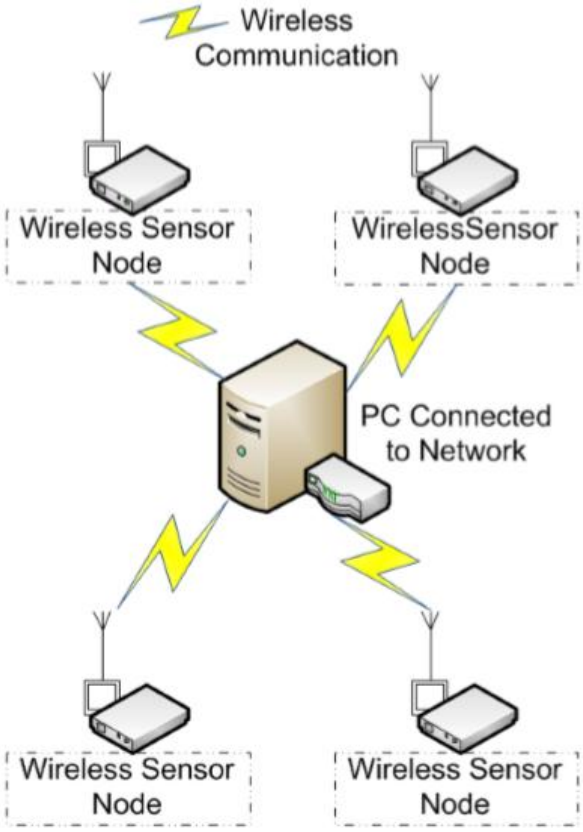

Figure 3: A typical wireless monitoring of agricultural environment [9].

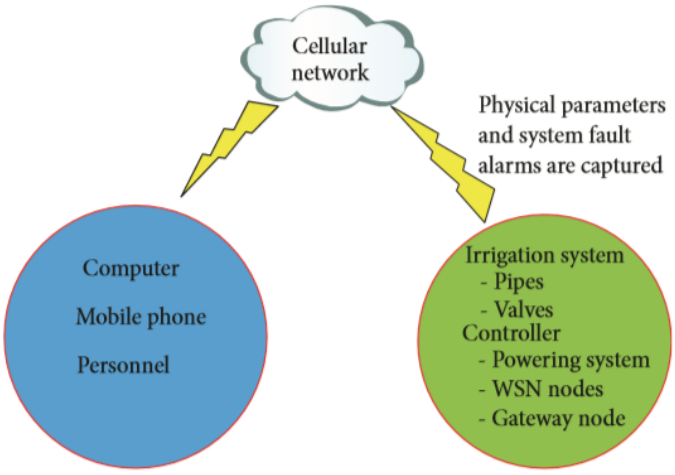

Figure 4: The architecture of the irrigation management system [10].

V. BENEFITS AND CHALLENGES

WSN technology makes it practical and cost effective to implement precision agriculture regardless of the growing area and size. It has the potential to improve crop field monitoring and raise the efficiency, productivity, and profitability. It can lead to a highly effective, green agriculture. With the help of WSNs, it has been possible to transform the traditional farming system into a more pervasive control of the cultivation.

Due to large-scale agricultural production, the sensor network has a large number of nodes. The high initial investment in the form of electronic equipment for sensing and communication implies that only large farms could afford precision

agriculture. Another challenge aspect for a WSN is having prolonged network lifetime because of the limited power of sensor nodes. WSNs are still under development; as such, they are sometimes unreliable, fragile, and power hungry and can easily lose communication.

CONCLUSION

Precision agriculture seeks to regulate or realize precision control of irrigation, fertilizer, diseases, and insect pests prevention in the growing of crops. It focusses on providing the means for observing, assessing, and controlling agricultural practices. Today, wireless sensor networks are regarded as an enabling technology for precision agriculture. Precision agriculture combined with WSN is an exciting new area of research that will greatly improve quality in agricultural production. WSNs can be a valuable decision-support tool for farmers. WSNs are still under development, while many issues in agriculture are still open. Wireless sensor network in agriculture is showing promise and progress. More information about the applications of WSNs in agriculture can be found in [11].

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