Wireless Sensor Network Application for Precision Agriculture

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Abstract

To accommodate the large global population and to combat with the alarming climate change and scarcity of water, the modern day farming demands new and improved methods, technologies and solutions for modern agricultural fields to enhance productivity. Consequently, the need for automation and intelligent decision making is becoming more important to accomplish this mission. This article outlines the recent applications of wireless sensor networks (WSN’s) in precision agriculture research to improve agricultural quality including the provision of adequate nutrients for crops and the wastage of pesticides for the effective control of weeds, pests, and diseases. An intelligent and smart WSN system can collect and process large amount of data from the beginning of the monitoring and manage air quality, soil conditions, to weather situations and in many other applications such as military, health care, industrial this technology is also applicable. These approaches may also increase the number of opportunities for processing Internet of Things (IoT) data.

Introduction

For enhancing agricultural productivity, improving natural resources, competitiveness, and better rural growth in agriculture domain, technologies such as cloud computing, wireless ad-hoc and sensor networks, Internet of Things (IoT), Radio Frequency Identifier (RFID), satellite monitoring, are becoming increasingly popular now a days. Among all these technologies, the agriculture domain is mostly explored concerning the application of wireless sensor networks (WSNs) in improving the traditional methods of farming. The self-organized together with ubiquitous nature, small sized nodes, scalable and cost-effective technology, enables the WSNs as a potential tool towards the goal of automation in agriculture. In this regard, precision agriculture, smart irrigation system, optimization of plant growth, farmland monitoring, smart fertilization system, greenhouse gases monitoring, smart pest control and disease monitoring system, agricultural production process management and security in crops, are a few potential applications. However, WSNs have few limitations such as limited computation capability, low battery power and small memory of the sensor nodes invites challenges in the design of this technology in agriculture.

In the Indian scenario, to fulfil the demand of food-grain for the increasing population, the WSN-based farming solutions need to be of very low cost to be affordable by end users. As, India is one of the largest exporters of food grains, and thus, researchers demand to boost production by incorporating advanced technologies. Consequently, new and modern technologies comprises of WSNs, General Packet Radio Service
(GPRS), Global Positioning System (GPS), remote sensing, and Geographical Information System (GIS) application are being considered in many agricultural applications to achieve the target.

Figure 1: A typical wireless sensor network deployed for agricultural applications.

Potential applications of WSN in Agriculture

In agriculture, most of the WSN-based applications are. The performance of an existing WSN-based application can be improved to monitor more parameters by only including additional sensor nodes to the existing architecture. For an example for irrigation scheduling with WSNs with use of soil moisture sensors the soil moisture and weather conditions regarding parameters needs to be gathered. WSNs for environmental condition monitoring gather the information of soil nutrients applied for predicting crop health and production quality over time. The issues present in such applications are the determination of optimal deployment strategy, measurement interval, energy-efficient medium access and routing protocols. For example, if the field area is separated by obstructions then it will lead to attenuation of signal, thereby affecting the inter-node communication. Contrary, a sparse deployment of nodes with a long data collection interval is helpful for enhancing the lifetime of a network.

Here listed the possible agricultural and farming applications which can be implemented using WSNs.

1. **Smart irrigation system**

Modern day agriculture requires an improved irrigation management system to optimize the water usage in farming. The alarming reduction of ground water level is another motivation for the requirement of an advanced system. In this context, micro-irrigation techniques are cost-effective and water-usage efficient. However, micro-irrigation efficiency can be further improved based on the environmental and soil information. In this regard, WSNs are applied as the coordinating technology.

2. **Farming systems monitoring**

Currently, various improved systems and devices are used in farming. In this regard, an improved system to manage these devices eases the overall operation, and enables automation in farming. Also, such remote monitoring systems help towards enabling improved management in large agricultural fields. Further, with the input of additional information such as satellite images and weather forecasts, the system performance can be improved.

3. **Smart Pest control and disease monitoring system**

Controlled usage of pesticides and fertilizers helps increasing the crop quality as well as minimizing the farming cost. However, for controlling the usage of pesticides, we need to monitor the probability and occurrence of pests in crops. To predict this, we also need the surrounding climate information such as temperature, humidity and wind speed. A WSN can autonomously monitor and predict these events over a field of interest.

4. **Smart fertilization system**

Plant growth and crop quality directly depend on the use of fertilizers. However, optimal supply of fertilizers to proper places in fields is a challenging task. The use of fertilizers for farming may be controlled by monitoring the variation in soil nutrients such as Nitrogen (N), Phosphorous (P), Potassium (K), and pH. Consequently, soil nutrition balance may also be achieved and hence, crop production quality is also maintained. Gonçalves et al. (2015) studied the effectiveness of mobile nodes to improve agricultural productivity in a smart system with precision sprays.

5. **Cattle movement monitoring**

A herd of cattle grazing a field can be monitored using WSN technology or Radio Frequency Identifier (RFID). Thus, real-time monitoring of any cattle is also achieved. This technology can be implemented further to monitor whether any cattle is moving near the vegetation fields or not.

6. **Ground water quality monitoring**

The increased use of fertilizers and pesticides lead to decrease in the quality of ground water. Placing sensor nodes empowered with wireless communication help in monitoring the water quality.

7. **Greenhouse gases monitoring**

For greenhouse gases emission monitoring the development of a system of solar powered Unmanned Aerial Vehicle (UAV) and WSN to monitor greenhouse gases – CH\(_4\) and CO\(_2\) is being used in WSN.

8. **Asset tracking**

Wireless technology enabled farming equipments attract the possibility of remote tracking of these assets. A farmer can track the position of the
farming vehicles and irrigation systems from his home.

9. Remote control and diagnosis

With the advent of internet of things, remote control and diagnosis of farm equipments such as pumps, lights, heaters, valves in machinery are also possible.

10. Climate monitoring

Climate change have brought many effects such as breaking of sea ice, heat waves, glazier melting and lake temperature warming. Thus, there is a need to control and monitor the climate change. Flood prediction is another example of climate monitoring, where wireless sensors can be used to detect rainfall and water levels to trigger an alarm system.

11. Forest Monitoring

Forests are important sources for biodiversity and ecological balance. Currently, the forest has been interrupted by unethical activities such as illegal logging and development activities. Therefore, it is very important to implement an effective forest monitoring system. The forest monitoring system also includes fire monitoring and detection in forests.

Technologies and Standards Used in Agriculture

In agriculture different wireless sensor nodes and communication technologies are available in the market for use in all agriculture operations.

a) ZigBee

ZigBee wireless communication technology being energy-efficient, low cost and reliable, is preferred for WSN-based applications in the agricultural and farming domains. ZigBee also supports short-distance (10–20 m) data communication over multi-tier, decentralized, ad-hoc and mesh networks. This is suitable for agricultural applications such as irrigation management, pesticide and fertilizer control, water quality management, where periodic information update is required.

b) WiFi

WiFi is a wireless local area network (WLAN) standard for information exchange or connecting to the Internet wirelessly. Currently, it is the most widely used wireless technology found in devices ranging from smart phones and tablets to desktops and laptops. WiFi provides a decent communication range in the order of 20 m (indoor) to 100 m (outdoor). In agricultural applications, WiFi broadens the use of heterogeneous architectures connecting multiple type of devices over an ad-hoc network.

c) Bluetooth

Bluetooth is a low power, low cost wireless technology used for communication between portable devices and desktops over a short range (8–10 m). The advantages of this technology are its ubiquitous nature, and therefore, it is suitable for use in multi-tier agricultural applications.

d) GPRS/3G/4G

PRS (General Packet Radio Service) is a packet data service for GSM based cellular phones. However, it is better suited for the periodic monitoring applications than to the real-time tracking-type applications.

e) WiMAX

WiMAX is the acronym for Worldwide Interoperability for Microwave Access, a wireless communication. The long range support together with high speed communication features place WiMAX as the best suitable technology for agricultural applications involving asset monitoring such as farming system monitoring, crop-area border monitoring, and real-time diagnostics such as remote controlling of water pumps, lights, gates, remote diagnosis of farming systems.

f) Wireless sensor nodes

For better classification, we divide these sensors in three main categorizes soil, environment, and plant related. The soil related sensors along with different soil related measurement parameters such as soil moisture, rain/water flow, water level, soil temperature, conductivity and salinity sensors are suitable for different potential agricultural applications. The environment related sensors such as humidity, ambient temperature, rainfall, wind speed and solar radiation are deployed with the application-specific soil and plant sensors in various agricultural applications. Third one the plant related sensors such as moisture, temperature, hydrogen, wetness, CO$_2$ and photosynthesis are deployed or attached to a plant are also an integral part of modern farming applications. Terms of potential developed between the measuring electrode and reference electrode.

![Figure 2: Block diagram of sensor node](image)

Conclusion

WSN is emerging technology and have wide range of applications. The application of wireless sensor networks to measure the soil parameters and suitably adapt the Irrigation scheduling technique and soil management schemes helps to save a significant amount of water under water scarce situations. The WSN-based farming solutions need to be modified by adding new sensors and to be of very low cost to be affordable by end users in India, to
fulfil the demand of food-grain for the increasing population. The inclusion of WSNs will revolutionize the Indian agriculture for advancing the agricultural and farming industries by introducing new dimensions.

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