Computers and Electronics in Agriculture 118 (2015) 66–84

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Review

Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges

Tamoghna Ojha [a,b,*], Sudip Misra [a], Narendra Singh Raghuwanshi [b]

[a] School of Information Technology, Indian Institute of Technology Kharagpur, India
[b] Department of Agricultural and Food Engineering, Indian Institute of Technology Kharagpur, India

ARTICLE INFO

Article history:
Received 16 April 2015
Received in revised form 8 July 2015
Accepted 14 August 2015
Available online 5 September 2015

Keywords:
Wireless sensor networks
Agriculture
Automation
Sensors and actuators
Agriculture in India

ABSTRACT

The advent of Wireless Sensor Networks (WSNs) spurred a new direction of research in agricultural and farming domain. In recent times, WSNs are widely applied in various agricultural applications. In this paper, we review the potential WSN applications, and the specific issues and challenges associated with deploying WSNs for improved farming. To focus on the specific requirements, the devices, sensors and communication techniques associated with WSNs in agricultural applications are analyzed comprehensively. We present various case studies to thoroughly explore the existing solutions proposed in the literature in various categories according to their design and implementation related parameters. In this regard, the WSN deployments for various farming applications in the Indian as well as global scenario are surveyed. We highlight the prospects and problems of these solutions, while identifying the factors for improvement and future directions of work using the new age technologies.

Contents

* Corresponding author at: School of Information Technology, Indian Institute of Technology Kharagpur, India.
E-mail addresses: tojha@sit.iitkgp.ernet.in (T. Ojha), smisra@sit.iitkgp.ernet.in (S. Misra), nsr@agfe.iitkgp.ernet.in (N.S. Raghuwanshi).

http://dx.doi.org/10.1016/j.compag.2015.08.011
0168-1699/

1. Introduction

Modern day farming demands increased production of food to accommodate the large global population. Towards this goal, new technologies and solutions (Chen et al., 2015; Misra et al., 2015; Goumopoulos et al., 2014; Amaral et al., 2014; Ngo et al., 2014; Ullah et al., 2014; Misra et al., 2014; Qu et al., 2014; Misra et al., 2013; Riquelme et al., 2009; Garcia-Sanchez et al., 2011; Camilli et al., 2007) are being applied in this domain to provide an optimal alternative to gather and process information (Behzadan et al., 2014; Dhurandher et al., 2014) to enhance productivity. Moreover, the alarming climate change and scarcity of water (Postel, 1999; Bouwer, 2000; Saleth and Dinar, 2000; Jury and, 2007; Falloon and Betts, 2010; Mueller et al., 2012) demand new and improved methods for modern agricultural fields. Consequently, the need for automation and intelligent decision making is becoming more important to accomplish this mission (ur Rehman et al., 2014; Suprem et al., 2013; Wang et al., 2006; Hart and Martinez, 2006). In this regard, technologies such as ubiquitous computing (Burrell et al., 2004), wireless ad-hoc and sensor networks (Diallo et al., 2015; Srbinovska et al., 2015; Zhao et al., 2013; Karim et al., 2013; Zhang et al., 2013; Krishna et al., 2012; Zhang and Zhang, 2012; Misra et al., 2011; Mirabella and Brischetto, 2011; Lloret et al., 2011; Garcia et al., 2010; Bri et al., 2009; Lloret et al., 2009; Lin et al., 2008; Wang et al., 2006), Radio Frequency Identifier (RFID) (Ruiz-Garcia and Lunadei, 2011), cloud computing (Ojha et al., 2014; Misra et al., 2014; Cho et al., 2012), Internet of Things (IoT) (Atzori et al., 2010; Gubbi et al., 2013), satellite monitoring (Moghaddam et al., 2010), remote sensing (Bastiaanssen et al., 2000; Morais et al., 2008; Ye et al., 2013), context-aware computing (Moghaddam et al., 2010) are becoming increasingly popular.

1.1. Motivation

Among all these technologies, the agriculture domain is mostly explored concerning the application of WSNs in improving the traditional methods of farming (ur Rehman et al., 2014; Zhao et al., 2013; Wang et al., 2006; Akyildiz et al., 2002a,b; Akyildiz and Kasimoglu, 2004; Yick et al., 2008; Ruiz-Garcia et al., 2009). The Micro-Electro-Mechanical Systems (MEMS) technology has enabled the creation of small and cheap sensors. The ubiquitous nature of operation, together with self-organized 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 (Chen et al., 2015; Cambra et al., 2015; Barcelo-Ordinas et al., 2013; Baseca et al., 2013; Díaz et al., 2011; López et al., 2011; Park et al., 2011; Matese et al., 2009), automated irrigation scheduling (Lichtenberg et al., 2015; Reche et al., 2015; Greenwood et al., 2010; Gutiérrez et al., 2014; Moghaddam et al., 2010), optimization of plant growth (Hwang et al., 2010), farmland monitoring (Corke et al., 2010; Voulodimos et al., 2010), greenhouse gases monitoring (Malaver et al., 2015; Yang et al., 2013; Mao et al., 2012), agricultural production process management (Díaz et al., 2011; Dong et al., 2013), and security in crops (Garcia-Sanchez et al., 2011), are a few potential applications. However, WSNs have few limitations (Akyildiz et al., 2002a; Yick et al., 2008) such as low battery power, limited computation capability and small memory of the sensor nodes. These limitations invite challenges in the design of WSN applications in agriculture.

In agriculture, most of the WSN-based applications are targeted for various applications. For example, WSNs for environmental condition monitoring with information of soil nutrients is applied for predicting crop health and production quality over time. Irrigation scheduling is predicted with WSNs by monitoring the soil moisture and weather conditions. Being scalable, 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. The issues present in such applications are the determination of optimal deployment strategy, measurement interval, energy-efficient medium access, and routing protocols. For example, a sparse deployment of nodes with a long data collection interval is helpful for enhancing the lifetime of a network. However, challenges may emerge from the choice of the deployment region. As an example, if the field area is separated by obstructions then it will lead to attenuation of signal, thereby affecting the inter-node communication.

In the Indian scenario, the WSN-based farming solutions need to be of very low cost to be affordable by end users. However, with the increasing population, the demand of food-grain is also rising. Recent reports warns that the growth in food grain production is less than the growth in population (Shanwad et al., 2004). Also, India is one of the largest exporters of food grains, and thus, researchers (Shanwad et al., 2004; Mondal and Basu, 2009) demand to boost production by incorporating advanced technologies. Consequently, new and modern technologies are being considered in many agricultural applications to achieve the target (Mondal et al., 2004). The current state of development in the Indian scenario comprises of technologies such as WSNs, General Packet Radio Service (GPRS), Global Positioning System (GPS), remote sensing, and Geographical Information System (GIS).

1.2. Contributions

In this paper, we surveyed the variants of WSNs and their potential for the advancement of various agricultural application development. We highlight the main agricultural and farming