Computers and Electronics in Agriculture 109 (2014) 287–301

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

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

A hybrid mobile environmental and population density management system for smart poultry farms

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ARTICLE INFO

Article history:
Received 5 May 2014
Received in revised form 29 September 2014
Accepted 5 October 2014

Keywords:
Hybrid architecture
Evaporative cooling
Smart farming
Mobile cloud computing
Mobile management system
Wireless sensor network

ABSTRACT

Due to advances in technology and size reduction of portable mechanical and electronic devices, sensors have been involved in many sectors, including in agriculture, where sensors and their unique functionalities are extremely useful for both productivity gains and reducing operating costs. These benefits are attained by utilizing their real-time sensing capability over environmental stages affecting the animal breed to enable on-time decision support but with some limitations, i.e., mobility, coverage, ubiquitous access, and energy. Thus, this research focuses on the integration of wireless sensor and mobile system networks with a well-known sensor integration platform toward cloud offloading scalability services via a hybrid architecture used to collect sensing data, such as temperature, humidity, light intensity, and population density, for data analytics and then issuing on-time decisions to adjust the environmental behavior accordingly. Based on a smart poultry farm concept for evaporative cooling environments, the instrument and components of the system design are discussed in detail with the experienced selection criteria, including a discussion of practical topology and deployments, enhanced transmission logics, external environmental tuning control logics integrating mobile user management interfaces, and image processing units. Aside from the proposed prototype of the integration of mobile phones, sensors, and controllers, an experimental investigation was also performed on data sensing and transmission procedures regarding power consumption characteristics, especially on high-cost image data transmissions, including an illustration of the outstanding performance, i.e., 80% in accuracy with low computational complexity, of the image filter over other well-known image classification techniques.

1. Introduction

One of the key roles involved in the development of human civilization is in the area of agriculture. With the continuing increase in the world's population, the demand for food supply is extremely required. Thus, not just farmers nor agriculturists but also researchers have put considerable effort into a wide variety of techniques to increase food production with an efficient return-of-investment methodology (Zhang et al., 2002; Suprem et al., 2013). Aside from scientific technologies, to increase efficient productivity, information technology has been heavily explored in this sector, especially in terms of managements and controls integrating automatic real-time decision supports, e.g., Precision Agriculture, Smart Agriculture, and Precision Farming (Srinivasan, 2006; Wang et al., 2006). Recently, the concept of Smart Farming has influenced several sectors, especially in the food industry (Grogan, 2012). Similar to other production technologies supporting agriculture-related areas, the main objective is to improve productivity and operational cost-cutting measures with environmental concerns. The smart process involves all production stages ranging from product acquisition to distribution. With the smart concept, various scientific techniques and technologies are employed to improve the production line efficacy considering the specific breeding and farming criteria with various geographical environments such as Animal and Pastures Monitoring, Irrigation, and Horticulture (Rehman et al., 2011).

Evaporative cooling systems (EVAPs) are one of the smart indoor equipment systems used to control and adjust the environment suitably for world-wide animal breeding sectors, especially in the food industry, in particular, poultry including chicken, in agricultural countries such as Thailand (Fahmy et al., 2012). The environmental monitoring and control of the system is critical because it is independent of natural agents. In general, in EVAPs, a water-cooling fan-pad and a fan-controller with optional vent box and curtain controller are the main features used to alter the air volume flow for temperature and humidity adjustments in

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http://dx.doi.org/10.1016/j.compag.2014.10.004
0168-1699/

environments, including light intensity controls depending on the breeding requirements. In addition, in practical fields, various other requirements are recommended, such as a population density distribution control, especially for poultry brood. In addition to air and light mechanical controls, including feeding and cleaning processes, typically, wired environmental sensors are also required to observe the farming condition and then report back to managers and farmers to adjust the environment controls accordingly.

To interface with environmental behavior leading to information technology support including smart farming (Wang et al., 2006; Lehmann et al., 2012), one of the promising approaches with worldwide deployability is the use of multi-functional wireless sensor networks (WSNs). WSNs can be utilized in a large number of applications ranging from civil to military aspects including agriculture which their key functions are based on the monitoring and sensing capabilities (García-Hernández et al., 2007; Yu et al., 2013). The IEEE 802.15.4 standard (IEEE Std. 802.15.4, 2003), ZigBee, is the de facto standard for commercial WSN technology, integrating micro-electromechanical systems (MEMS) based on multi-sensors, transmission logics, and computing capabilities into *motes* with low cost and low power consumption. MEMS has made motes available to the world market in both fully-equipped packages and manually customized user-made packages at reasonable prices. Apart from the various distinctive features of WSNs, the support of mobility is also a key feature. The mote can be positioned in a variety of locations to monitor and/or collect on-the-go environmental behaviors. In general, the mote is also placed in a distributed manner leading to the decrease of the overall system failure probability (Yick et al., 2008). With wireless connectivity and coverage, the cost of extreme wiring-based connection and improbable access to environments have been reduced in additional to the overall operation cost (Sensors Magazine, 2004).

Despite WSNs' facilities and features, they come with trade-offs, especially a small battery-operated power source and no guarantee of service. Thus, numerous studies have been conducted (Huang et al., 2013; Pantazis et al., 2013), and with one of the main limitations, short transmission range and limited bandwidth, the advancement of mobile computing and networking technology has played a key role and has recently become ubiquitous worldwide access. The number of mobile or cellular phones has rapidly increased in parallel with their drastic decrease in cost, while maintaining existing or greater functionalities (Global Mobile Statistics, 2011), e.g., small, portable, and wide coverage, but still with energy consumption issues, including recent mobile cloud computing as an offloading concept to help alleviate scalability and accessibility constraints (Dinh et al., 2013). In fact, the influence of mobile computing has been deployed to interact with real-time mobile phone applications (Montoya et al., 2013; So-In et al., 2013; Sallabi et al., 2011) including agriculture-related applications. The existence of mobile technology results in user-friendly and ubiquitous systems with the enhancement of wireless transmission speeds and wide range coverage. Although applying Web architecture (Antonopoulou et al., 2010) may be convenient universal accessibility, many customized features toward mobile applications are fruitful, such as user-friendly interfaces, multi-sensor capabilities, real-time notification services, and global positioning functions via GPS.

As a result, the primary objective of this research is threefold: (1) to embed the concept of smart farming to enhance the productivity of EVAP poultry farms, focusing on the management and communication of human usages and the interaction among sensors, administrators, and controllers aiding mobility and manageability; (2) to investigate integration issues of multi-platform applications such as utilizing a mobile phone integrated with cloud services as a computational offloading mechanism to support long-range monitoring and control systems, including alert notifications and global-positioning of sensor node perimeters; and (3) to investigate practical uses of motes for both environmental sensing and data fusion, including wireless mechanical control embedded external logic boards with the purpose of reproducibility. Apart from a proposed system prototype, two more implicit objectives are based on the evaluation of the proposed architecture validated in terms of energy consumption, especially for high-cost data transmissions as well as the measurement of image classification precision.

This research article is organized as follows: In Section 2, a comparative survey is discussed regarding applications and frameworks employing WSNs and mobile and cellular architectures for control and monitoring schemes, as well as sensor transmission techniques including mobile usage integration specifically into agriculture sectors in a concept of smart farming. Section 3 presents the detailed architecture and in Section 4, a comparative performance evaluation is discussed in terms of energy consumption for data transmission, including image classification precision. Finally, the conclusions and future work are drawn in Section 5.

2. Related work

For years, there have been a number of studies and applications in various areas employing wireless sensor and mobile system networks, especially for the purpose of monitoring and acquiring environmental data as well as location information in several sectors ranging from environmental control and monitoring to health care services (García-Hernández et al., 2007; Yick et al., 2008; So-In et al., 2013; Riquelmea et al., 2009; Li et al., 2011; Huircána et al., 2010; Kwong et al., 2012; Díaz et al., 2011; Nadimi et al., 2012; Garcia-Sanchez et al., 2011; Dearden et al., 2011; Jiuxi et al., 2013; Kim et al., 2011; Wan et al., 2008; Murad et al., 2009; Okada et al., 2010). Several techniques were also developed directly to enhance their capabilities, e.g., quality of service, transmission reliability, and media access control (Huang et al., 2013; Pantazis et al., 2013; So-In et al., 2013); however, in this research, the focus is on recent proposals and applications in the agriculture sector, especially in geographically practical deployments with the use of experiments for various requirements and motes with specific optional sensors, rather than theoretical or simulation solutions.

Several practical deployments have employed WSN integration into precision agriculture especially for crop farming and monitoring animal behavior. For example, in 2009, Riquelmea et al. (2009) employed WSNs in precision agriculture by investigating practical issues when they deployed a sensor network testbed in the semi-arid region of Murcia. This study focused on different types of sensor nodes to measure various soil characteristics. A real implementation was carried out on a crop of ecological cabbage along with discussions of hardware and software components, based on a customized microcontroller from Texas Instruments. A few years later, Li et al. (2011) investigated a practical deployment based on soil property monitoring systems in a wheat field as a two-tier architecture, i.e., WSNs using IRIS platforms and cellular networks. Short range in-field WSNs was formed to acquire real-time soil property data. With cellular modems and Internet services, a long-range cellular network was used to relay the field data to a remote database web server. Considering the applications for monitoring animal behavior, in 2010, Huircána et al. (2010) introduced a WSN localization design for cattle monitoring in grazing fields. One of the main contributions was to investigate the link quality indication measurement in a customized sensor platform, Jennic JN5139, to enhance the precision. Two years later, Kwong et al. (2012) investigated WSN applications based on individual cattle monitoring targeting for cost reduction and low power