Review Article

WIRELESS SENSOR NETWORK DESIGN FOR PADDY CROP MONITORING OF CHHATTISGARH

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ABSTRACT

Chhattisgarh is a rice-producing land that is why it is called the 'rice bowl'. Farmers here are not inclined to cultivate crops other than paddy as they are completely dependent on the rains. Till now Chhattisgarh comes under a mono-crop belt. Only one fourth to one fifth of the sown area was double cropped so in order to improve the production proposed system will become helpful for farmers. In proposed system we are embedding wireless moisture sensors at different locations in field in order to check the moisture level of earth as Wireless sensor networks (WSN) are increasingly been used in precision agriculture for years. They are used in convergence with other technologies like the Global Positioning System (GPS), Geographic Information Systems (GIS), miniaturized computer components, automatic control, remote sensing, mobile computing and advanced information processing and telecommunications for modern precision agriculture monitoring. WSN offers several advantages; these includes suitability for distributed data collecting and monitoring in tough environments, capable to control an economical way of climate, irrigation and nutrient supply to produce the best crop condition, increase the production efficiency while decreasing cost and provide the real time information of the fields that enable the farmers to adjust strategies at any time. This paper presents the basic design on the development of WSN for paddy crop monitoring application. The proposed WSN system will be able to communicate each other with lower power consumption in order to deliver their real data collection. The main objective of the new design architecture is to cater the most important and critical issue in WSN, that is power consumption. The design will attempt a sensor node board systems consist of a low power microcontroller so called nano-Watt technology, low-power semiconductor based or MEMS sensors, Zigbee™ IEEE 802.15.4 wireless transceiver and solar energy source with optimal power management system.

KEYWORDS: Wireless Sensor, precision agriculture, environmental monitoring, agriculture management

1. INTRODUCTION

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to cooperatively monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion, or pollutants, at different locations. Wireless technologies especially wireless sensors and sensors network, which integrate sensor technology, MEMS technology, wireless communication technology, embedded computing technology and distributed information management technology, has been under rapid development [16] Wireless transmission can reduce and simplify in wiring, allow deployable the sensor at remote, dangerous, and hazardous location, easy installation, and integration for extremely low cost, small size and low power requirement and mobility. In recent years, new trends have emerged in the agricultural sector. The demand for remote measuring, automation and control in agriculture is rapidly growing. Environmental monitoring using wireless sensors technology has become more important especially in agriculture because wireless sensors technology is very suitable for distributed data collecting and monitoring in tough environments [4] Environmental monitoring in agriculture is essential for controlling in economical way of climate, irrigation and nutrient supply to produce the best crop condition, increase the production efficiency while decreasing cost [2]. The real time information of the fields will provide a solid base for farmers to adjust strategies at any time. WSN will revolutionize the data collection in agricultural research. However, there have been few researches on the applications of WSN for agriculture.

2. RESEARCH BACKGROUND

Previous research on the development of wireless monitoring system for greenhouses focus on reducing the electricity cost by designing low power consumption of the node for the application and prolonging the actuator life but keeping promising performance results [1]. They proposed architecture and application of ZigBee-based mesh network combine with event-based control technique. They found that the architecture shows low power consumption of the node for the application in the average of 17.4μA while event-based control reduced the number of changes by more than 80 % in comparison with a traditional time-based controller. [14] achieved measurement and control with lower power, lower cost and lower latency by using improved LEACH clustering algorithm as a tool for analyzing latency and energy consumption for three-level network model of the wireless monitoring and control system based on the multi-span in the same architecture. Hyun-Joong Kang et al., 2008 simulate the performance of sensor node running with low power operation in greenhouse environment to the impact of crop's growth when obstacle exists in inter-node's communication point. They found that, different performance respectively depending on the routing protocol. Sliva, I.J., 2008 [6] give an overview of technologies used in WSNs. He concludes that, the recent developments in WSN are in energy conservation; improve communication protocols, self-organization, size of nodes, computer power and motion of nodes. In specific, protocols tend to be more general while nodes will be smaller, more powerful, more energy efficient, universal, and cheaper in the future. Tao Chi et al., 2008 [11] study of energy efficiency on sensor nodes for WSN in greenhouse environment. They develop low power sensor nodes with energy saving of communication protocol. Therefore, they gain higher power efficiency of WSN. Xuemei Li et al., 2008 proposed real deployment of WSN for greenhouse management. The sensor nodes show low energy wastage, short communication range and self-organized. Wei Cao et al., 2009 [13]test experimentally WSN system in greenhouse environment. With the success of the system, they move to the future into VPN and video transmission, remote control panel and robots remote control.

The other researchers discussed about short message service (SMS) as an effective and economical solution of communication protocol in his developed wireless sensor network (Hui Liu et al., 2007[3,4]). Xiuhong Li et al. (2006) [15] used free embedded operation system (μc/OS-II) and free source codes (Linux) to improve the system's real-time, reliability and expansibility. The architectures based on networking and inter-networking is possible to establish long-term management plans that will increase profitability and quality in term of low-cost, flexible, transparent, friendly and intuitive Graphical User Interface (GUI) for a distributed data acquisition and control system for computerized agricultural management systems (Carlos et al., 2001 [2]). Konstantinos et al., 2007 [8] proposed an optimize topology in WSN for precision agriculture applications. The methodology can determine the optimal sensor topology, thus lowering the implementation cost. Siuli Roy and Bandyopadhyay, 2008 [10] developed architecture for precision agriculture based on WSN because they found very limited work has been done so far on the technologies to be used to transfer sensor data wirelessly from crop field to the remote server.

The sensor design is made based on four parameters, the soil pH, the Electrical conductivity, the soil temperature, and the soil moisture. Jzau-Sheng Lin and Chun-Zu Liu, 2008 [7] proposed a WSN field signal monitoring system for the precision agriculture by using SoC platform. SoC platform is used to reduce cost and the physical size significantly. Hui Liu et al., 2009[3] had designed WSN for cropland environmental monitoring. They found that antenna height was proven an important factor for reliable communication performance. Therefore, the applications of WSN in agriculture are widely developed throughout the world especially on greenhouse environment. However, less research on application of WSN in agriculture crop field. In addition, this technology is relatively new in Chhattisgarh especially on paddy rice cropping. Rice is a staple food for majority of the world population especially in Asia. Although Asia is a largest consumer, rice yield efficiency in Asia countries is still low compared to their population. In Chhattisgarh, an average level farmer can produce just only 3 tons per hectare and this local production can only cater approximately 60 to 65% of domestic requirements. The challenges to increase rice production are including low management capability of farmers and cultivation technique usage, water management, shortage of labor power and lack of information and technical support. In order to cater these problems and increase the rice production, a development of rice crop monitoring using WSN is proposed to provide a helping hand to farmers in real-time monitoring, achieving precision agriculture, and thus increasing the rice production.

3. OVERALL ARCHITECTURE OF SYSTEM DESIGN

3.1. System Architecture and Platform Design

The crops management system using Wireless Sensor Network (WSN) is a kind of an autonomous solution to enhance the agricultural technology. Precision agriculture could raise the crops yield, labor cost saving and environmental protection against over pesticide or fertilizing. Sensor system must utilize the minimal possible energy while operating over a wide range operating scenarios and leading key technology for low energy distributed micro sensors. A long node lifetime under diverse operating conditions demands power aware system design. In a power-aware design, the node's energy consumption displays graceful scalability in energy consumption at all levels of the system hierarchy, including the signal processing algorithms, operating system, network protocols, and even the integrated circuits themselves. Nodes depend mainly on energy source. In most cases the source is a battery cell, in specific cases it could be a solar, mechanical (vibration) pr thermical source. Low power consumption is reached by high integration on chips and powering off not needed circuits. Besides saving energy by powering off unnecessary circuits there exist certain phenomenon inside the batteries. It is called charge recovery effect. Shortly it means that if the time of battery task is very short (pulsed discharge) and period between tasks is relatively long, the capacity of the battery is partially recovered. (Ing. Jakub Sliva, 2008 [6]). Therefore in this project we would like to propose a wireless sensor, system that will communicates each other with lower power consumption and also better power management system architecture for sensor node. The power consumption becomes the most important and critical issue nowadays. In order to design a wireless sensor system, a low power processor with green power source is preferable than using conventional energy harvesting hardware such as microprocessor, sensors, AC adaptor, or large battery for their life supporting. Therefore we attempt to design a sensor node board systems consist of a low power microcontroller so called nano-Watt technology, low-power semiconductor based or MEMS sensors, Zigbee™ IEEE 802.15.4 wireless transceiver and solar energy source with optimal power management system. This architecture then to be implemented in the sensor nodes that will construct a wireless networking data collection at paddy field likely to replace the conventional manually data collection system. Fig. 1 describe the overview of the proposed system consisting a nodes coordinator/ gateway and few sensor nodes routed via PAN (personal area network) that can be added or reduced depending on the requirement of the farming areas. The same color of nodes means they are in a same PAN but different node IDs. A general-purpose node, which has standard measurement parameters sensors such as ambient air temperature and humidity, soil pH and moisture are integrated in all nodes. While these nodes will, does routing to their neighborhood node(s) until the beacon reach at coordinator destination? The coordinator will coordinate the data collection from each existence PAN addresses within the network system. Then there are two direction the data will go, which is first linked to server data based system to be recorded and revealed on internet web page and real-time alert system using SMS system via GSM modem to person in charge cell phone. However, now we are interested to set up the nodes PAN addressing with static addressing and ID with point-to-point networking system.

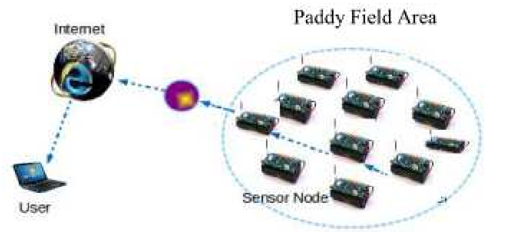

Figure 1: Wireless Sensor Network routing via PAN both ad-hoc or planned network

3.2. Node Board Architecture System

The node architecture and hardware is driven by a MCU produced by Microchip™ chip, which is PIC16F684 Nano Watt processor core, features low current, and voltage consumption. This chip is a 14 pin 8-Bit FLASH CMOS MCUs, with 12 I/O and 8 ADC channels at 10-bit maximum resolution. It is consuming current less than 500µA at 2.0V and 20 MHz clock cycle. Another series of PIC16F88X chip also can be used as an alternative for more I/O pins (28/40) with dynamic CPU clock start-up and ultra low power at sleeping mode (approximately 50 nA). Fig. 2a describes the system architecture that inserting the contribution of power management system that will utilizes two batteries for night and day time operation. The power management system will manage solar power direction for charging the secondary battery while the primary battery will remain works until at certain level of voltage drops, it will triggered alternate charging-working process for these two batteries. This method of power management system to be claimed a better power life for nodes up to 25% due to the improved charging concept. Sharing the solar energy for charging a battery while at the same time drawing current from the same battery will loss much efficiency of the battery life, insufficient charging and lead to hassle at night operation or dim daylight. The charging engine for lithium-ion 3.7V cell is driven by MCP73832 charge-pump chip with programmable charging current at 15mA-500mA. The power supply of the sensor node also will apply the low-drop out (LDO) regulator instead of linear regulator that slash a lot of voltage drops and higher noise for switching regulator. The proposed system has the capability to attach more sensors such as the wind speed, dissolved oxygen, water pH, solar radiation and other analog or digital interface to the MCUs. Fig. 2b describes the algorithm sequence for working-charging batteries in the nodes power management system.

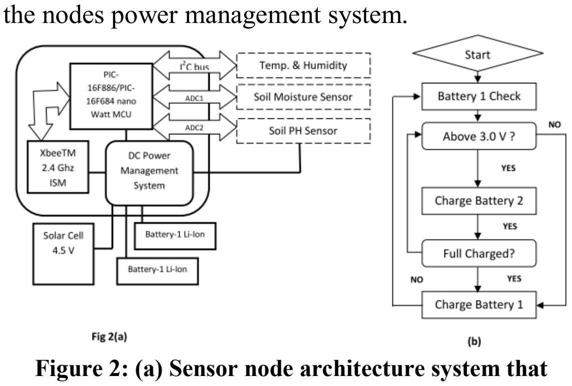

Figure 2: (a) Sensor node architecture system that features optimal power management system and (b) Battery management algorithm

3.3. Wireless RF and Networking

The wireless and networking activities will take place after the MCU reads all the ADCs values from the sensor output voltage and send it to it FLASH memory. While the digital sensors like I2C bus type will send the readings after the acknowledgement bits sent by the MCU. The Xbee™ modules operates Preliminary Design on the Development of Wireless Sensor Network for Paddy Crop Monitoring Application in Chhattisgarh 654 within 2.4Ghz ISM band and working DC voltage 3.3V (2.8-3.4V) at maximum transmission power 0dBm@ 1mW, 45mA while Xbee™Pro gives better transmission range up to 18dBm@60mW at 225mA. This IEEE 802.15.4 compatible module has wide range of 65,000 unique networking addresses, which capable to build peer-to-peer, point-to-point, and point-to-multi point topologies. This module is programmed using both AT command and X-CTU software provided as free software.

3.4. Sink node, gateway and GSM modem application

A network coordinator as the gateway of accessing the outside world will manage the operation of wireless networking sensor nodes. This board has the same architecture as node type except the MCU has external UART communication with the GSM/GPRS 900/1800Mhz (Wavecom Fastrack M2406B) modem to send the alert massages via SMS and RS232 serial communication to the server PC. PIC MCU establish communication together with GSM modem using AT command to gives instant alert via sms, like the over limit or under limit condition for paddy field environmental. The proposed system is also able to display the real-time captured data from the paddy field. Nodes coordinator also becomes a base station that linked with LAN and TCP/IP for data storage and web based server. Fig. 3 shows detail architecture of battery management algorithm.

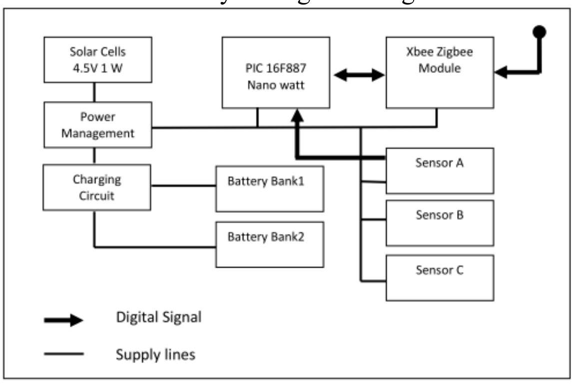

Figure 3: Architecture of Battery Management Algorithm

3.5. Power Management System

A system called µAMPS sensor node architecture has a power subsystem consists of DC-DC conversion to the appropriate voltage required by the system. The power-aware system is sentient of many variables that define energy consumption at each architecture block, from the leakage current in the integrated circuits, to the output quality and latency requirements of the end user, to the duty cycles of radio transmission. However the system is not considering the solar power as the input source for DC supply or battery charging system. While another system utilizes the DC-DC switch mode step-up regulator to convert the voltage level of one or two AA batteries 3.3V to power up their sensor node. They replaced the linear regulator to switch mode regulator to give higher voltage at low start-up supply voltage as low as 0.8V. But the complexity of the circuit and the switching noise generated are the drawback of the system. [9] Their system also not mentioned the practical solution of solar charging issues such as quiescent current loss and energy consumption of nodes, slow charging rated and other drawbacks using single battery system.

The proposed power management system consists of dual Li-ion/Li-Po batteries that will support the nodes life 24 hours a day operation. This architecture will provide better hassle free nodes operation that utilize solar source via separate battery system when charging and consuming at a time. The proposed project will not attempt too much exhausting the power consumption causes by mesh networking, standard XBee™ module transmit mode or other WSN protocol but optimizing the DC supply and power management system. The nominal current consumption for each node circuit board is about 100-150mA at 4.7V with wireless networking operation. By referring to Figure 4, at a starting operation, the Bank 1 battery will discharge the supply to the node while the bank 2 battery will charged by solar source charger. The systems will automatically alternates the Bank 2 becomes discharged after the Bank 1 drops below 3.7V for each cell and at the mean time it will charge Bank 1. Two banks system will provide maximum slow-charging to the battery by solar cell at 4.5V @ 1 Watt (220mA) to the charge pump drive while the other one discharging current to node. Simple it can be said that first battery will serve while the second will charged by solar cell and standby.

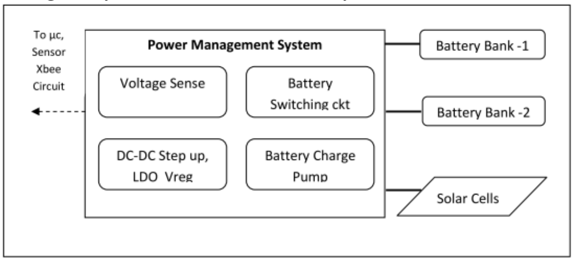

Figure 4: WSN Platform Power Management System

Due to low current consumption of the circuit, each battery expected to run up to 8-12 hours operation with 1000 mAh capability. This concept will gives optimum node lifetime especially during night operation while slower and variation of charging rates by solar cells, different or dimmed sunlight intensity and also node operation will not interrupted. The sunlight intensity variations absorbed by solar cell will also disrupting the output voltage. So, that battery will not efficiently or properly charged at day time because of disruption and power loss during node operation and at night time the node may 'dead'. The higher voltage sensor (10-12V) will use DC-DC switch mode power regulator to ensure the supply batteries can manage the sensor operation in the node.

4. CONCLUSIONS

In this paper a preliminary design is proposed on the real-deployment of WSN for paddy rice cropping in Chhattisgarh. The system focused on low power consumption for the new design architecture to cater the most important and critical issue nowadays in WSN monitoring. From the sensor node hardware to the management system, the whole system architecture is explained. Such a system can be easily installed and maintained. The scope for future work in this study will include fabrication, experimental investigation, data analysis, control solution and complex networks setups. Preliminary Design on the Development of Wireless Sensor Network for Paddy Crop Monitoring Application in Chhattisgarh

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