A Monitoring System Based on Wireless Sensor Network and an SoC Platform in Precision Agriculture

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***Abstract*—This paper proposed a field signals monitoring system with wireless sensor network (WSN) which integrates a System on a Chip (SoC) platform and Zigbee wireless network technologies in precision agriculture. The designed system was constituted by three parts which include field-environment signals sensing units, Zigbee transceiver module and web-site unit. Firstly we used acquisition sensors for field signals, an MCU as the front-end processing device, and several amplifier circuits to process and convert signals of field parameter into digital data. Secondly, Zigbee module was used to transmit digital data to the SoC platform with wireless manner. Finally, an SoC platform, as a Web server additionally, was used to process field signals. Then, we created a system in which field signal values are displayed on Web page or collected into control center in real-time through RJ-45 with the SoC platform. The experimental results show our proposed field-environment signals monitoring system is very feasible for future applications in precision agriculture.

***Keywords*- Field-environment signals; SoC; Wireless sensor network; Zigbee.

I. Introduction

It is important that using sensors to detect field-environment signals in agriculture is understood since a long time ago. To use more sophisticated sensor devices with capabilities of chemical and biological sensing not only aids the personnel in the field maintenance procedure but also significantly increases the quality of the agricultural product. Precision agriculture is a technique of management of large fields in order to consider the spatial and temporal variability. Several technologies were used in the precision agriculture such as remote sensing, global positioning system (GPS), geographic information system (GIS), microelectronics and wireless communications [1, 2]. Most GPS and GIS with satellite systems provide images of great areas. Alternatively wireless sensor networks (WSNs), used for precision agriculture, additionally give better spatial and temporal variability than satellites, they are also permitted to collect soil and plant data, as temperature, moisture, pH, and soil electrical conductivity [3, 4].

Wireless connection based smart sensors network can combine sensing, computation, and communication into a single, small device. Because sensor carries its own wireless data transceiver, the time and the cost for construction, maintenance, the size and weight of whole system have been reduced. Information collected from these sensor nodes is routed to a sink node via different types of wireless communication approaches. Currently three main wireless standards are used namely: WiFi, Bluetooth and ZigBee. Of these, ZigBee is the most promising standard owing to its low power consumption and simple networking configuration. The prospective benefits of using the WSN technologies in agriculture resulted in the appearance of a large number of R&D projects in this application domain. The job of the sensor network in this paper is to provide constant monitoring of field-environment factors in an automatic manner and dynamic transmitting the measured data to the farmer or researchers with WSN based on Zigbee and Internet. The real time information from the fields will provide a solid base for farmers to adjust strategies at any time.

In the initial effort, Alves-Serodio *et al.* [5] showed several concepts on technique for the supervision and control of agricultural systems such as greenhouse and animal live stocks-claim for the use of computer systems. The method basically focused on control of the environmental parameters in a low-cost way to generate the best agricultural product or animal living conditions. In [6] a web server based strategy was used where sensor nodes were setup with a web server to be accessed via the internet and make use of wireless LAN to provide a high speed transmission. The application of a web server assists to analyze distant agricultural fields over long periods of time whereby the whole dataset is accessible to general public. The main goal of this paper is to develop a low cost, high performance and flexible distributed monitoring system with an increased functionality.

In the proposed strategy, wireless sensors send data via a Microprocessor Control Unit (MCU) and a ZegBee transmitter. The receiver unit receives data from a ZigBee receiver and an SoC platform. And, these data are transmitted to the Internet through the RJ-45 connector. A remote data server stores the data. Any web browser, smart phone or PC terminal with

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access permission can view the data and remotely control the wireless network.

II. SYSTEM ARCHITECTURE

Figure 1 shows the architecture of the proposed wireless-network monitoring system that includes sensor units, Zigbee transceiver, an MCU, an SoC platform, and Web server. The MCU is a communicator and controller between sensors and Zigbee transmitter. The SoC platform in monitor system worked as a web server to receive the field-environment signals from a Zigbee receiver. In order to get stable signals, some amplifiers are added into acquiring circuits. Finally, the field-environment signals can be displayed on Web page or collected into control center through RJ-45 of the SoC platform.

III. WIRELESS-NETWORK ACQUIRING UNIT AND RECEIVER UNIT

The main part of the wireless-network acquiring unit is mainly including the sensors of temperature and moisture in air and soil, CO_2, and illumination. In order to amplify the field-environment signals, amplifier circuits are also added into acquiring unit. For the purpose of processing these signals and transferring them to ZigBee wireless transmitter, an MCU named SPCE061A [7] is used. Firstly, the A/D converter bound on the MCU converts the analog signal into digital manner. And, MCU calculates and organizes the data to desired format, and writes them to ZigBee wireless transmitter. Then, the ZigBee Transmitter sends these field-environment signals to the ZigBee receiver through a handshaking protocol. Finally, these signals are transmitted to the Receiver Unit.

The Receiver Unit is consisted of a ZigBee wireless receiver and an Soc platform. The field-environment signals, received by the ZigBee wireless receiver, were directly sent to the field information database on the Internet through a RJ-45 connecter and Web server built on the SoC platform.

A. Sensors in the Wireless-Network acquiring system

WatchDog 3667 [8], products of Spectrum Technologies Inc., including a 6 foot cable is connected to an external port on a WatchDog Data Logger. It was used as the sensor of soil temperature. Watermark 6450WD [9] (Spectrum Technologie, Inc.) was used to measure soil moisture. It consists of two concentric electrodes embedded in a reference matrix material, which is surrounded by a synthetic membrane for protection against deterioration. A stainless steel mesh and rubber outer jacket construct the sensor more durable than a gypsum block. The measured temperature range is -30 ~ $100^\circ C \pm 1^\circ C$ for the WatchDog 3667 while the detected moisture range is 0 ~ 200 cbars for the Watermark 6450WD.

The module RHU-300M, products of Decagon Devices Inc. was used in order to measure the temperature and moisture in the air. The range of measured temperature is 0 ~ $60^\circ C \pm 1^\circ C$ while the range of detected moisture is 10 ~ 95 %RH. For the purpose of detecting CO_2, the sensor REHS-135 [10] was used in which the operating humidity range is less than 95% Rh. And, the illumination was measured by using of the CDS photo-resister [11]. The completed hardware for these sensors to measure signals in the field-environment was enclosed in a box for wireless-network acquiring system is shown as in Figure 2.

B. MCU and ZigBee Units

The final part of the wireless-network acquiring system is the MCU in which the Sunplus SPCE061A was used. The SPCE061A features 2K words of SRAM and 32K words of Flash ROM data memory, 32 programmable input/output ports, 2 ports of 16-bit timer/counter, 7 channels of 10-bit Analog-to-Digital (A/D), 2 channels of 10-bit Digital-to-Analog (D/A) converters, and an In-Circuit-Emulation (ICE) port. In the MCU SPCE61A, we used analog input ports I/O A0 ~ A5 to extract the moisture, temperature and CO_2 in the air, soil temperature and moisture, and illumination. A crystal is mounted on pins of oscillator 1 (XI/R) and oscillator 2 (XO) as the system clock of the MCU. Then, the digital signals of field-environment are forward sent to the ZigBee transmitter through programmable I/O ports outputs I/O B7 and B10 respectively.

The used ZigBee transceiver module in the proposed system is module 3160 produced by Ready International Inc. [12]. The 3160 module provides a point to point connection much like a standard serial cable. Connections are made dynamically and can be established between server 3160 module and sensor module or between several sensor modules and a server module. ZigBee utilizes frequency hopping in the radio band and hops at a relatively pace with a raw data rate of about 250Kbps and a transmitting distance of about 200 m.

IV. WEB SERVER UNIT

Owing to the wide application of Internet, to access field-environment signals by using Internet through an embedded system is popular more and more. Using an embedded system not only can realize the equipment remote control, but also the system size can significantly be reduced. An external interface is essential to carry on the monitoring through the network. The users can manage and monitor the far-end system through Web browser which can simplify the design of human-machine interface.

We use an SOC platform built in XILINX SPARTAN-3 (SP3) [13] as a Web server and digital signal processing (DSP) unit which was implemented by using *C* language in order to transmit the field-environment information to Web page or control center through the TCP/IP with a connector RJ-45. The SP3 FPGA uses eight independent I/O banks to support 24 different single-ended and differential I/O standards. In the SP3 SOC platform, a built 10 base-T/100base-TX/FX IEEE 802.3u fast Ethernet transceiver named BCM 5221 is used as Ethernet PHY to transmit data to the Internet through RJ-45. This development platform integrates many IP (Silicon Intellectual Property) modules including RS-232, RJ-45, USB, expand I/O pin etc. The detail SOC platform with Xilinx SP3 chip and ZigBee receiver is also shown in Figure 3. Finally, the SoC platform combines ZigBee receiver to receive digital signal from wireless-network acquiring unit and calculate the field-environment signals in the platform to transmit them to the Web page or control center.

V. APPLICATION SCENARIO

ZigBee technology based wireless sensor can be used in a diverse, high volume sensor system. It can significantly save space and improve the reliability. Figure 4 shows an application scenario in precision agriculture. As we know, to monitoring the real-time status of a wide field needs high-density sensors. As shown in the figure, each ZigBee receiver has quite mounts of sensors installed. MCU can poll each sensor quickly to get the sensing data. Since every sensor has a unique identification number, MCU can easy know the sensing data comes from which sensor and do respective operation.

The whole system has been successfully designed and tested. The field-environment signals can then be accessed and stored into the field information database in the information management system of the control center by a terminal or a computer in the Internet like shown as in Figure 4. For each field in Figure 4, A is represented as a Wireless-Network acquiring unit with a ZigBee transmitter while B is a Web server with a ZigBee receiver. The researchers or farmers can easily set the acquiring interval and duration time for each field on the Web page anytime and any place.

VI. CONCLUSION

A wireless-network field signal monitoring system in the precision agriculture was proposed in this paper. We have finished monitoring temperature and moisture in air and soil, CO_2, and illumination signals in the field. We used ZigBee technique to solve wireless transmission problem and to finish field-environment signals transceiver between acquiring unit and Web server that might be useful in replacing cables of field signal monitoring system. Most of field monitoring system applications use mobile device and PC as main monitoring device in their system. We used an SOC platform as the Web server that can effectively to reduce cost and the physical size significantly. Because of the popularization of the Internet that displays the field-environment signal values on the Web page in real-time through RJ-45 of SP3 platform, the researchers or farmers can easily take care of the product's status in the precision agriculture anytime and any place through the Web page.

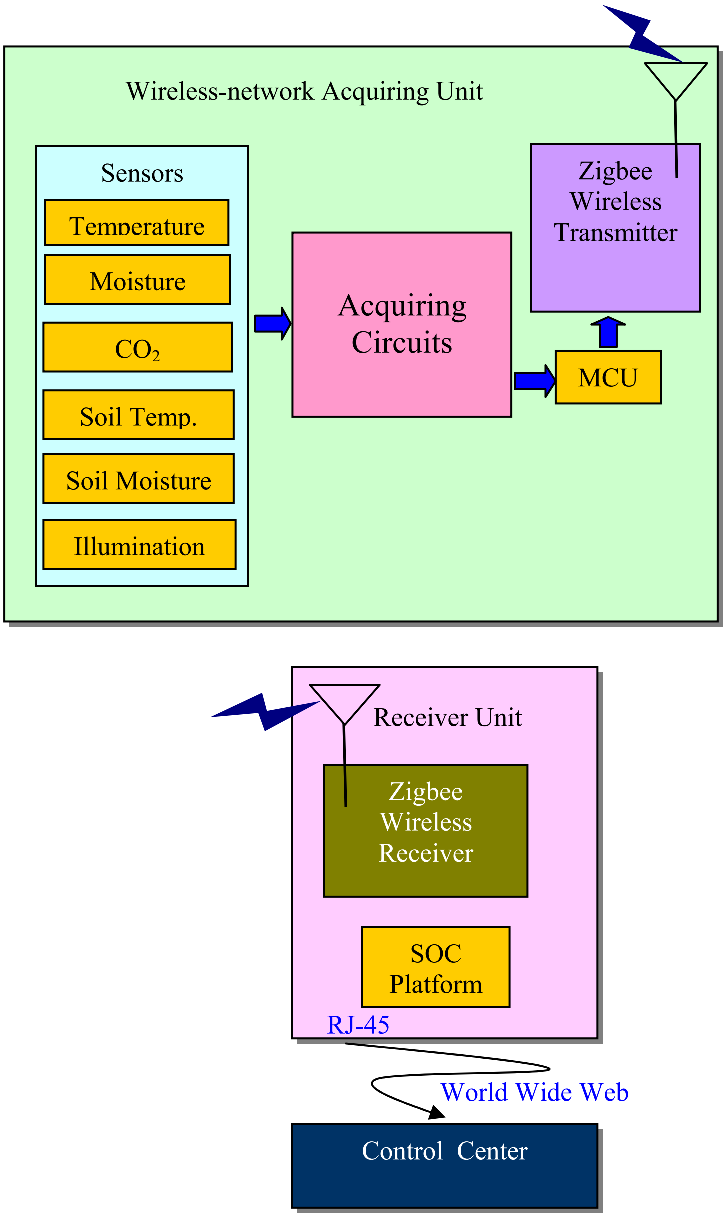

Figure 1. The proposed architecture of wireless field signals monitoring system

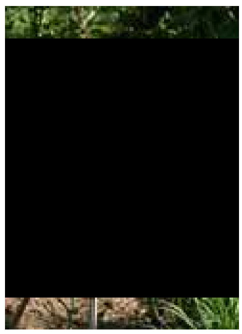

Figure 2. The enclosed box for wireless -network acquiring system in field

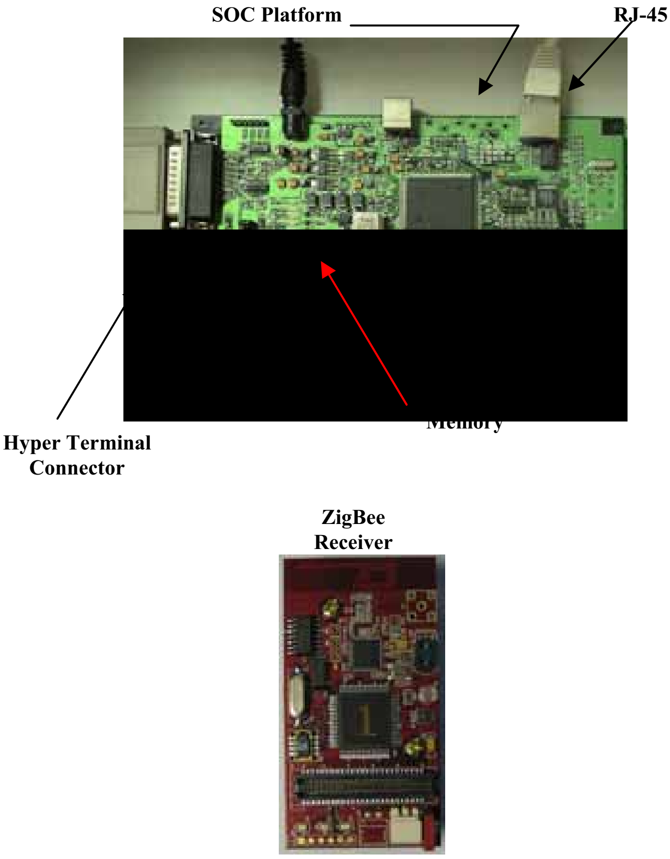

Figure 3. Xilinx Spartan-3 SOC Platform and ZigBee receiver

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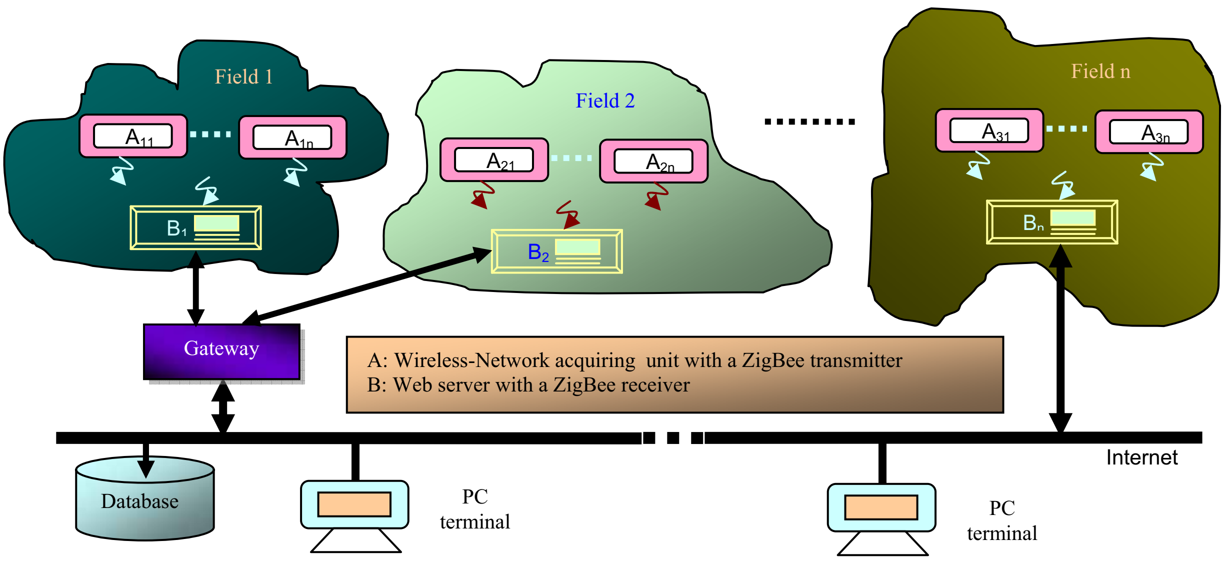

Figure 4 The architecture of Field signals monitoring system in the precision agriculture based on wireless network and Internet.