WIRELESS DATA COMMUNICATION IN AGRICULTURAL ENGINEERING. TRENDS AND PRACTICAL EXPERIMENTS

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Abstract: *The new wireless technologies emerged on the markets in the last few years have changed the field of agricultural engineering too. The present paper aims to make a critical comparison of the most popular technologies and methods used today for implementing wireless data communication in agricultural engineering and machines. Furthermore the paper presents first practical experiments with Bluetooth-based wireless sensors.*

Key words: *Sensors, Wireless communication, Bluetooth.*

INTRODUCTION

In the agricultural domain, the past few years have brought new technological achievements which led to the development of a new research field called precision agriculture. This field of interest concentrates on providing the means for observing, assessing and controlling agricultural practices, covering a wide area of agricultural concerns. Precision agriculture is based on the achievements in the field of wireless data communication and particularly wireless sensor networks.

EXISTING IMPLEMENTATIONS

The existing implementations of wireless data communication for agricultural engineering rely, in most of the cases, on an architecture composed of one or more sensors for environmental data (temperature, humidity etc), a signal conditioning block, a microprocessor/microcontroller with an external memory chip and a radio module for wireless communication between the sensor nodes and/or a base station. One of the first and also one of the biggest wireless networks for agriculture was built in the frame of the Dutch Lofar Agro research project [7], where 150 sensor boards based on the Mica2 Crossbow wireless sensor platform were deployed in a field for gathering temperature and humidity data used for fighting phytoptora in a potato field. The data received by the sensors is handled by a microprocessor implementing the TinyOS operating system, is transmitted via radio in the band 868/916 MHz to a so-called field-gateway and from there via Wi-Fi to a PC for data logging. The on-board processing capacity of these devices is high due to the embedded operating systems, which permits these sensors to receive and send data, dynamically build routes and avoid data collisions. This “smart” architecture is used also by other implementations which have in common the Crossbow sensor platforms, like the systems presented in [6] and [8], the difference being the use of the ZigBee wireless communication standard for radio transmission.

The Bluetooth radio transmission standard is also used in test like those presented in [4], based on a similar architecture, which, beside a microcontroller uses an optional FPGA circuit. Finally, Wireless LAN implementations can be found in Japanese implementation [1] of so-called field monitoring servers, hardware platforms equipped with sensors, solar cells and Wireless LAN boards (converters) communicating with each other (ad-hoc mode) or with an Access Point (infrastructure mode).

WIRELESS CONSIDERATIONS

As seen in the last paragraph, several methods and standards are currently implemented for wireless data communication in agriculture. The goal of this work, of building a small-sized, low-cost wireless sensor, reduced the number of suitable digital radio standards to three choices: Wireless LAN (IEEE 802.11), ZigBee (IEEE 802.15.4), and Bluetooth (IEEE 802.15.1).

Wireless LAN (WLAN) is the most popular standard used today for wireless data transmission, offering a good throughoutput and coverage, but having also a high power consumption. Peak values arrive at 400 mA, totally unacceptable for sensing platforms operated autonomously in a natural environment without a constant power source.

The ZigBee standard, was designed on purpose for sensor applications with very low power consumption at low data rates. Hardware based on this standard is increasingly available on the market, making ZigBee a valuable alternative.

The Bluetooth standard was also designed for low power consumption, offering short range radio communication (maximum 100 meters) using low-cost transceiver microchips. The Serial Port Profile (SPP) can be used in combination with digital data received from sensors. The Bluetooth device acts as serial interface and therefore the data connection is very easy to implement, both on the software side and the hardware side (connections with microcontrollers or other digital devices).

Based on the above-mentioned considerations, as well as positive previous testing results [3], the Bluetooth standard was chosen for the experiments in the agricultural environment. The radio module used while conducting these experiments was built by Amber Wireless (Germany) using a the LMX9820 Bluetooth transceiver chip. The small size of the device permitted a good deployment in the natural environment.

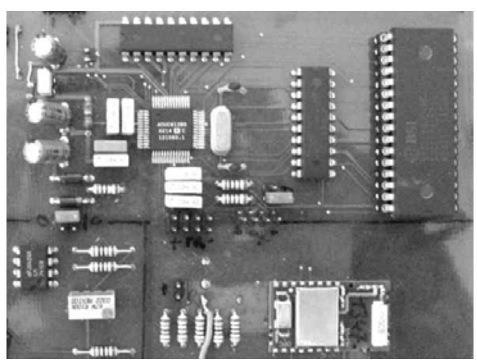

Fig. 1. Experimental board – Bluetooth module (down right) connected with microcontroller (middle) and memory chip (up right)

HARDWARE DESIGN AND OPERATION MODES

The hardware design of the wireless sensor node was split in four functional blocks: the signal conditioning and A/D converter block, the logic unit, the memory and finally the power management block. These blocks perform the acquisition of the sensor's output and the serial transmission of the sampled data to the Bluetooth module directly or using the memory as a data buffer. The necessary voltages for all functional blocks had to be supplied by the power management block. The power management considerations will be detailed in the next paragraph. A picture of the experimental board containing the above-mentioned blocks can be seen in Figure 1.

After considering more microcontroller families such as AVR and PIC, the final choice was the Analog Devices ADuC812 microcontroller, a fully integrated 12-bit data acquisition system-on-a-chip. It features a maximum sampling rate of 200 ksps, 8-channel precision self-calibrating A/D converter. Other advantages of this microcontroller are the integrated UART and SPI serial interfaces with variable baud rates, small footprint and a reasonable price (15$). The integrated A/D simplified the design of the signal-conditioning block, which was reduced to a couple of operational amplifier. An external low-power 512 KBytes SRAM memory chip was used to store the data sampled from the sensor's output. The Bluetooth module was connected to the microcontroller using the RX and TX terminals of the serial interface. Hence, software handshaking is performed using start and stop bits.

The wireless sensor platform was designed to operate periodically based on its internal timers. These timers alternate the functionality of the platform from sleep mode (low power consumption) to operation mode (all blocks are functioning). In operation mode, the sensor platform samples the analogue input (humidity sensor) for an interval of 5 s, writes the data in the external memory and sends then to the Bluetooth module the main value of the sampled data. Meanwhile the Bluetooth module, pre-programmed to pair on power-up with a certain device (in this case a Notebook with a Bluetooth adapter), performs the pairing and then forwards the data received from the microcontroller. The software written for the PC sends back to the sensor an OK code, upon which the sensor gets back into sleep mode. If the microcontroller does not receive the OK code, data is retransmitted for a fixed number of times after which the sensor gets back into sleep mode even without receiving the OK code, logging the failed connection.

POWER MANAGEMENT

First test with the hardware platform were conducted using as power source a 3,7 V Li-Ion rechargeable battery with a capacity of 2700 mAh. The signal conditioning module, microprocessor, memory and Bluetooth module were all fed with a voltage of 3.3 V obtained from a voltage regulator. The power consumption for each block of the sensing platform was measured and the results (peak power consumption) can be seen in Table 1.

Table1: Current consumption of the functional blocks

Block	Peak current [mA]
Signal conditioning	10
Logic unit + memory	70
Bluetooth module	50
TOTAL	**130**

All these values refer to the case when each block is active, in order to calculate the maximum power consumption. The Bluetooth module was configured to enter power saving mode when idle, reducing its power consumption to around 10 mA, the 50 mA being reached only when transmitting/receiving data or making inquiries. The microcontroller has also power-saving features: when idle, it can be powered down into a sleep mode, lowering the consumption of the logic unit together with the SRAM memory to less than 10 mA. Therefore, in idle mode, the power consumption of the entire wireless sensor was maximum 20 mA, the signal conditioning block being decoupled from power via an electronic circuit controlled by the logic unit.

RESULTS

A number of four battery-powered sensor platforms was deployed in an experimental area, monitored by a Notebook PC equipped with a Class 1 Bluetooth adapter (100 m range). Limited by the battery power, the sensors monitored the ground humidity for a time span of 5 days. Pairing with the devices functioned well, the time interval of sending data being set to 60 minutes. No data was lost and the error logs of each sensors were found empty.

CONCLUSIONS AND FUTURE WORK

The first experiments with the sensor platform using the Bluetooth module were successful and showed the versatility of the hardware platform composed of sensors, signal conditioning and microcontroller. Although encouraging, the results with the Bluetooth modules showed the limitation of this data transmission standard which are basically the reduced range and/or the difficulties of building a mesh of sensors forwarding data from node to node, the Bluetooth communication generally having to be supervised by a central unit (PC or Pocket PC) situated close to the sensor platforms.

For these reasons future work will concentrate on using the ZigBee standard for the wireless data transmission and integrating this type of modules in the existing hardware configuration. Appropriate configuration of ZigBee-based sensor nodes in order to build an extended mesh will be studied in detail.

In terms of power management and consumption, the integration of power modules based on solar energy will be taken into consideration, together with optimizing the existing power saving algorithms and lowering the consumed power.

REFERENCES

[1]. Hirafuji M., Fukatsu, T. and Haoming, H. 2004. Full-Wireless Field Monitoring Server for Advanced Sensor-network. *EFITA/WCCA - Joint Congress on IT in Agriculture 2005*.

[2]. Morais, R., Valente, A.and Serôdio, C. 2005. A Wireless Sensor Network for Smart Irrigation and Environmental Monitoring: A Position Article. *EFITA/WCCA - Joint Congress on IT in Agriculture 2005.*

[3]. Popescu, V., Szekely, I. 2005. Wireless Data Acquisition System Using Bluetooth. *In "Proceedings of the REV Coonference 2005", Braşov, România*.

[4]. Postilla, J., Castro, A.,Torre, E. and T. Riesco. 2006. A Modular Architecture for Nodes in Wireless Sensor Networks, *Journal of Universal Computer Science (JUCS), vol. 12, issue 3, pp. 328-339, January 2006.*

[5]. Skafidas, E. 2005. Precision Agriculture Information Networks -Nictor Sensor Network Platform. *http://nicta.com.au/director/research/programs/sn/research_activities/nictor.cfm*

[6]. Stuntebeck, E., Pompili, D., and Melodia, T. 2006. "Underground Wireless Sensor Networks Using Commodity Terrestrial Motes," *Poster Presentation, Proc. of IEEE SECON, Reston, VA, Septemeber 2006.*

[7]. Visser, O. 2005. Localisation in Large-Scale Outdoor Wireless Sensor Networks. *Master Thesis in Computer Sciences, TU Delft*

[8]. Zhu, W, Zhong, X and Shi, J. 2006. The Design of Wireless Sensor Network System Based on ZigBee Technology for Greenhouse. *Journal of Physics: Conference Series 48, 1195 -1199.*

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