CHANGES OF DATA SAMPLING PROCEDURE TO AVOID ENERGY AND DATA LOSSES DURING MICROCLIMATES MONITORING WITH WIRELESS SENSOR NETWORKS

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ABSTRACT

Wireless sensor networks are gaining importance in agricultural applications, such as monitoring crops microclimates. Precision agriculture is one of the areas that can most benefit from this technology in the sense that wireless sensors networks allow data collection with high resolution, enabling better decision making. Such networks have restrictions on their deployment in a real environment, for example, on energy. Thus, several studies have been conducted in order to optimize the use of this technology. Depending on the application, it is desirable that the available energy on sensor nodes batteries allows operation for months or even years. One proposed solution to extend the lifetime of sensor nodes, so as to avoid unnecessary data collection, is the implementation of a routing protocol that allows a differentiated data sampling. An application that can benefit from this approach is vineyard microclimates monitoring, which is very important to monitor temperature and relative humidity, and can apply precision agriculture techniques to the crop. Thus, in the program to be installed into sensor nodes, rules for data collection are defined, so that the value collected by the sensor at a given time is in the rule that defines normal conditions, the rate of sampling data used will be higher; however, when the value collected by the sensor is out of this rule, the sampling rate will automatically be reprogrammed to a higher value. This differentiated data collection allows savings in power consumption under normal conditions, and generates less data to be analyzed.

Keywords: Wireless sensor network, microclimates monitoring, vineyards differentiated data sampling

INTRODUCTION

Precision agriculture (PA) is a working philosophy that differs from the traditional approach in order to divide the land into parcels and treat it differently, providing economic advantages and benefits to the environment (Bongiovanni and Lowenberg-Deboer, 2004). Spatial variability within a field related to climatic conditions, soil and plants requires the use of new technologies for their management, applying the best concepts of PA (Bramley and Hamilton, 2004). The emergence of a new technology, known as Wireless Sensor Network (WSN), allows for applications that could not be accomplished through the use of conventional technology (Yick et al., 2008); the contribution of this technology in PA is important, allowing monitoring of agricultural crops, given their spatio-temporal variability (Wang et al., 2006).

In the agricultural environment, the importance of climate and its influence on the phenological development of a culture are known. In the particular case of grapevines cultivated under plastic overhead cover, this microclimate undergoes different changes, which influence plant physiology (Chavarria et al., 2009). Wireless Sensor Networks (WSNs) applications on vineyards are increasing, due to the advantages perceived in studies (Mariño et al., 2008; Morais et al., 2008; Burrel et al., 2004). Among these advantages, it is important to aid in managing the microclimate variability in crops, allowing the farmer to act proactively on possible problems that could affect them, using the necessary resources, which will lead to an increase in the quality of grapes produced.

However, a WSN has particular features, among them, energy available for the operation of sensor nodes. Generally, these are powered by batteries, making that energy a limited resource, affecting the network lifetime (Roundy et al., 2004). Comparing the energy consumed by different modules of the sensor node (sensing, computing and communication) for sending a data packet, the communication module is primarily responsible for energy consumption, followed by the sensing module (Anastasi et al., 2009). Aiming to save energy and storage of unnecessary data, an architecture for a microclimate monitoring system in vineyards is proposed, the data collection of which is performed by changing the sampling rate. This can be reprogrammed automatically from rules implemented in the firmware of the sensor nodes.

This work was structured as follows: the following section presents hardware and software features that were used, experiments planned with the WSN, the experimental vineyard in which the experiment was performed and the proposed architecture. After this section, the results presented were obtained from experiments and discussions. Finally, conclusions and references that were used are presented.

MATERIALS AND METHODS

Experimental scenario: vineyard cultivated under plastic overhead cover

Experiments were conducted in a vineyard owned by Mr. Jose Milani, located in the Vale dos Vinhedos, Bento Gonçalves, Rio Grande do Sul - Brazil.

Geographic coordinates are: latitude 29º12'S, longitude 51°32'W and altitude of 603 m. The vineyard is six years old, with plants of *Vitis vinifera* L., cultivar Italia grafted on rootstock ‘SO4’. Seedlings were planted with 1.8 m spacing between plants and 3 m between rows, giving a density of 1.852 plants per ha. The vineyard area is 1.8 ha but the experimental area is 0.125 ha, with six rows of plants of approximately 67.30 m each (as shown in Figure 1), arranged north-southwards. The slope of the land is approximately 15°, with the conduction system in trellis, and the canopy height from the ground is 2.10 m.

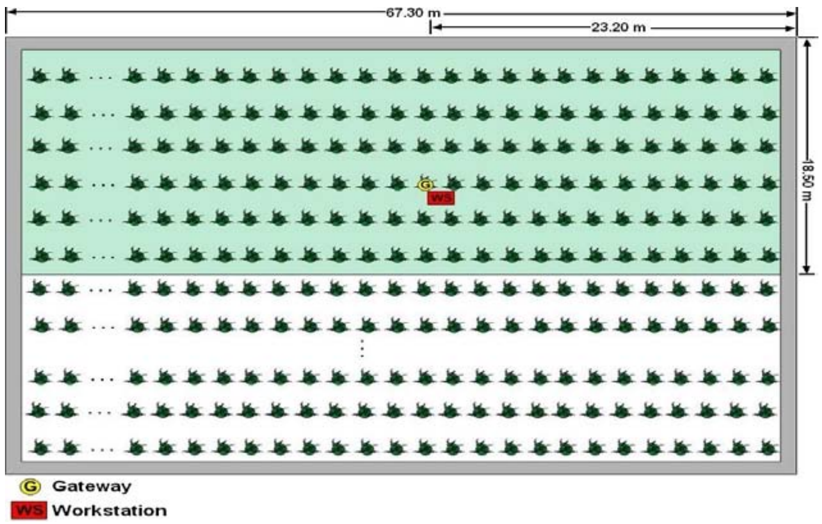

Fig. 1. Experimental vineyard area in Bento Gonçalves, Rio Grande do Sul – Brazil.

The vineyard is cultivated under plastic overhead cover, which is composed of plastic sheeting of woven polypropylene (PP), transparent, sealed with low density polyethylene (LDPE - 160 µm) and anti-UV additives to prevent dripping. The experiments were performed during the grape ripening, in the 2009/2010 harvest, between January and February. Figure 2 presents some photographs taken in the field where the experiment was performed.

Fig. 2. Experimental vineyard cultivated under plastic overhead cover in Bento Gonçalves, Rio Grande do Sul – Brazil.

Hardware and software used

A WSN commercially distributed by Crossbow Technology Inc. (Crossbow, 2010) was used. The network consisted of 10 sensor nodes (MicaZ motes with MTS400 sensor board), with MTS400 sensor board to measure five types of variables (relative humidity, temperature, barometric pressure, light and dual-axis acceleration). MicaZ mote (MPR2400) works at 2400 MHz band, uses a Chipcon CC2420 radio with an RF transceiver based on IEEE 802.15.4, achieving a data rate transmission of 250 Kbps. It has an ATMEGA128L microcontroller, and uses two AA batteries for its operation. As a gateway, a MIB520 was used, which allows the interface between the WSN and the computer, enabling data to be stored in the database and displayed in the computer. Model MIB520 provides USB interface for MICA motes family, making communication and sensors reprogramming possible.

Collected data management was possible by using MoteView 2.0F software, provided by Crossbow Technology Inc. This software allows storing data in a PostgreSQL database, their visualization on computer, as well as exporting data to different formats for their further analysis (xml, sql, cvs) (Moteview, 2010). XMesh was used as network protocol, based on the specifications of the standard ZigBee, which enables self-forming, multi-hop and ad-hoc networks. Firmware that makes possible the normal functioning of motes is an application developed in nesC (Nesc, 2010), an extension of C language, utilized to develop applications for the TinyOS operating system (used by sensor nodes in the network). Crossbow offers different types of firmware as part of the software MoteWorks™; for this work, XMTS400 is used, which provides the option of programming XMesh protocol in High Power (HP) or Low Power (LP) modes. To program motes in the different operation modes, as well as to install the firmware and the changes made in it, MoteWorks™ software was used, which runs on a cygwin environment (Cygwin, 2010).

Experiments performed

A WSN consisting of 10 MicaZ motes with MTS400 sensor board was deployed to collect ambient temperature and relative humidity data within an experimental vineyard cultivated under plastic overhead cover. Two sampling data rates (5 and 10 min) were tested, with motes programmed in LP mode to extend the network lifetime. Both sensor nodes and gateway were placed at canopy height of the vines (1.85 m from the ground). In Table 01 distances between sensor nodes and gateway are shown, which were chosen to ensure network connectivity. Figures 3 and 4 show topologies used in the field for both sampling rates tested (5 and 10 min). Some modifications were made to the firmware used by the motes to collect only the necessary data regarding the application implemented (ambient temperature and relative humidity). Three types of batteries were used for motes operation (DURACELL alkaline, rechargeable typ. 2100 and 2500 mAh).

Table 1. Distance between sensor nodes and gateway for both topologies used.

Distance to gateway (m)		
node id	topology 1 (data sampling every 5 min)	topology 2 (data sampling every 10 min)
node 1	6.60	7.71
node 2	2.60	10.10
node 3	14.90	2.60
node 4	6.90	6.90
node 5	3.70	3.40
node 6	7.89	14.90
node 7	10.20	4.04
node 8	3.50	8.26
node 9	4.61	12.47
node 10	3.40	13.15

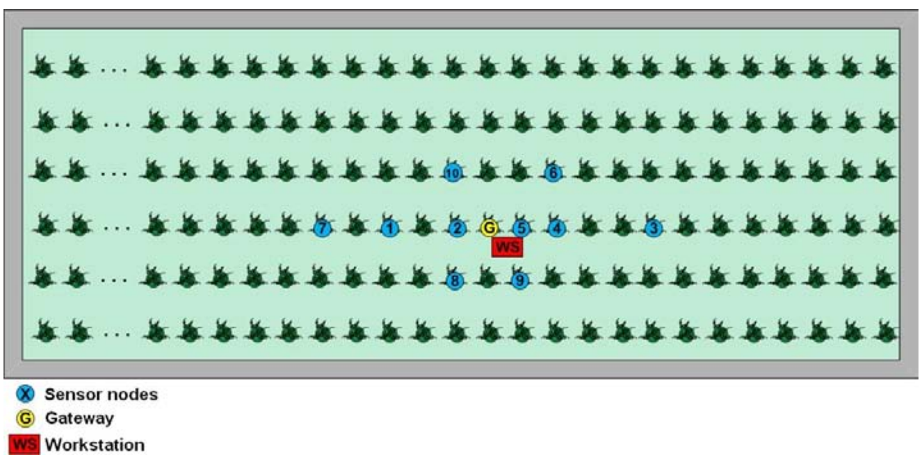

Fig. 3. Topology 1 – data sampling every 5 min.

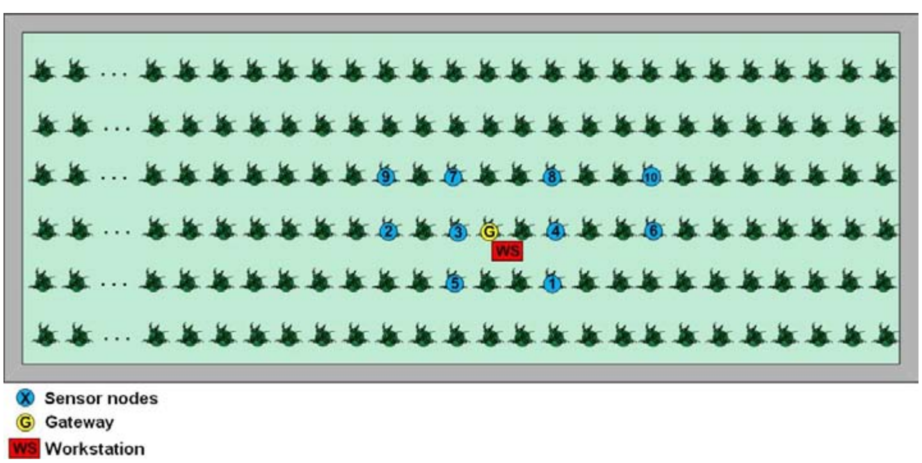

Fig. 4. Topology 2 – data sampling every 10 min.

Proposed architecture

Figure 5 shows the proposed architecture for this work; sensor nodes, deployed in the vineyard installed a firmware to collect ambient temperature and relative humidity data. The values of these variables are acquired from the environment at a given sampling rate (stored in the variable TIMER_REPEAT); for this example, when temperature values are between two thresholds previously defined (10 and 30 ºC), the sampling rate is 10 min, once the temperature value exceeds this threshold, the sampling rate is changed automatically (5 min). These rules are implemented in the firmware installed on the motes. To be able to dynamically change these variables (sampling rates, higher and lower thresholds), a solution is designed to implement commands such as XCommand (a feature of MoteWorks), which can be executed through a virtual terminal (XServeTerm).

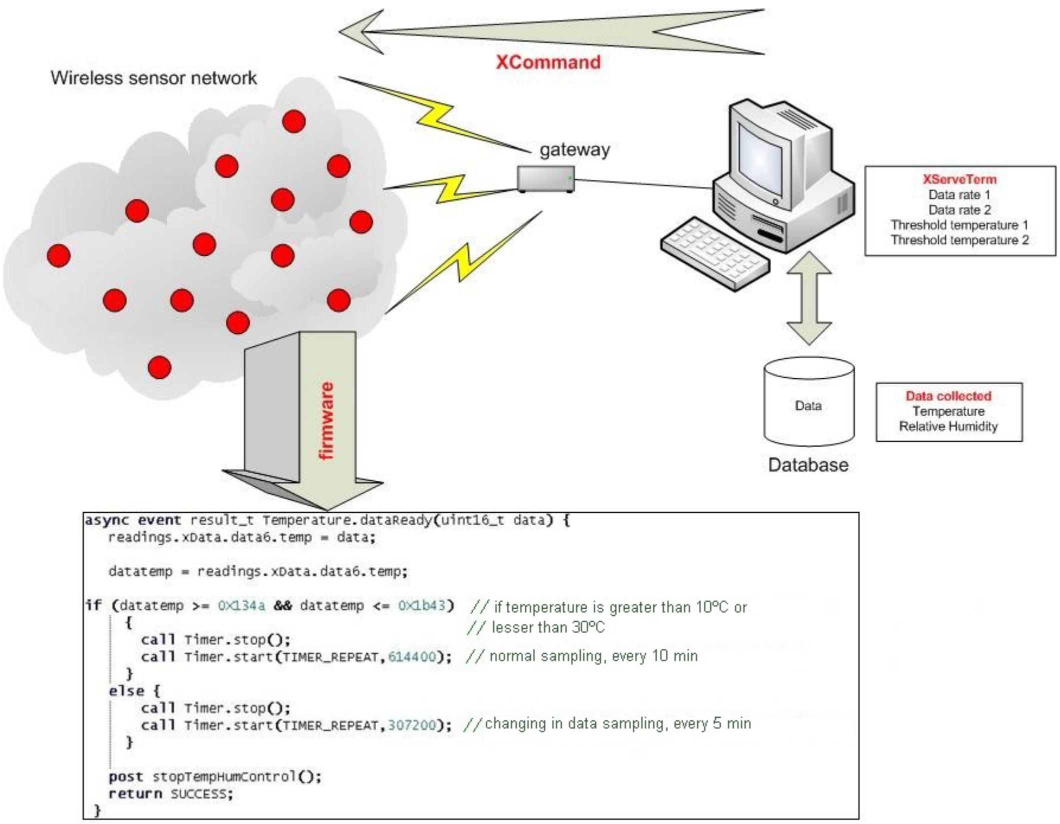

Fig. 5. Proposed architecture for collecting data through a different sampling.

RESULTS AND DISCUSSIONS

Changes were made in firmware XMTS400 in order to collect only data of ambient temperature and relative humidity, three other sensors (barometric pressure, light and acceleration) were disabled (Figure 6). This reduced the size of the firmware to be installed on motes (6% smaller than the program size).

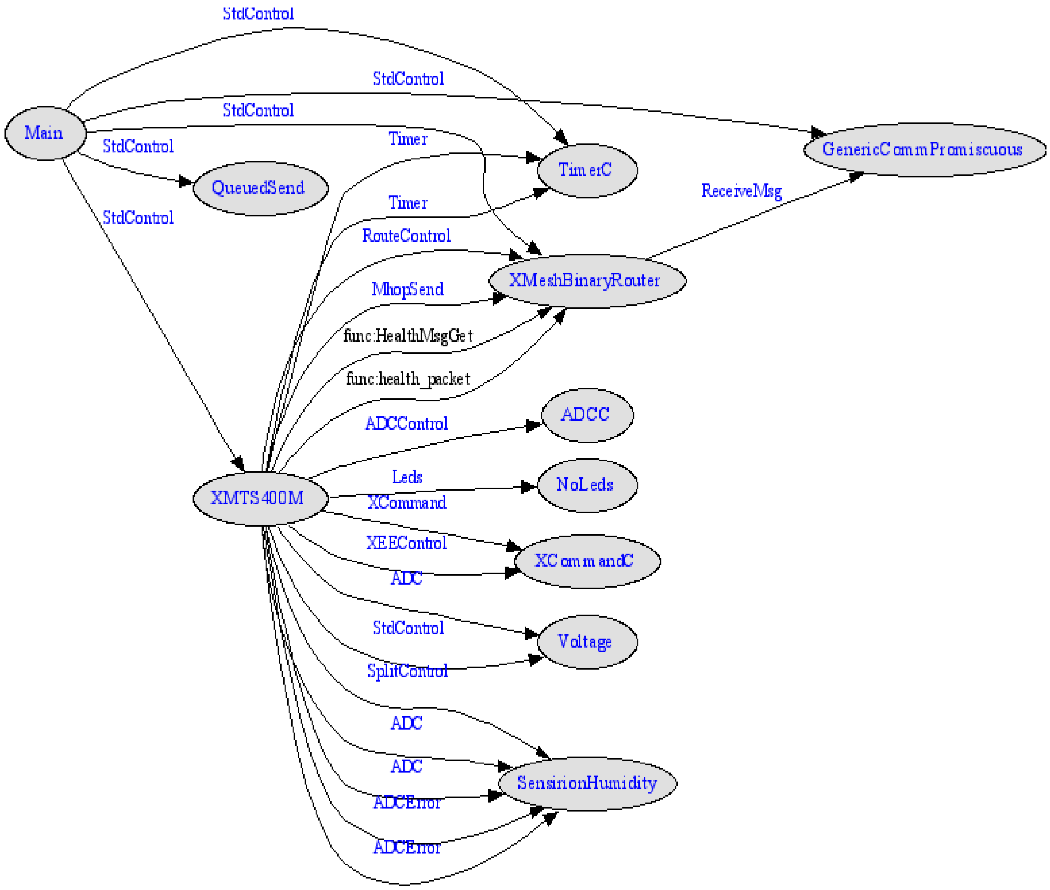

Fig. 6. XMTS400 components diagram to collect ambient temperature and relative humidity.

Another advantage seen from this change was the decrease in data storage size, generating savings of approximately 40% on the central computer, compared with the original firmware that allows the collection of all values of the MTS400 sensor board.

Energy consumption calculated for the two sampling rates (5 and 10 min) of experiments performed with 10 sensor nodes within the vineyard results in about 40% less of consumption for the sampling rate of 10 minutes compared to that of 5 minutes. This was noticed in the three battery types evaluated (DURACELL alkaline, rechargeable typ. 2100 and 2500 mAh). Figure 7 shows the energy consumption in the three types of batteries (AA) evaluated for pairs of sensor nodes placed in same conditions (distance to the gateway, type of battery used, positioning within the network), for a period of 135 hours of data collection. The protocol used was XMesh in LP mode, and from this Figure, a higher sampling rate can be seen to allow a saving in energy consumption, but it was also noted that, for a greater sampling rate within the network, there is a greater loss of data packets.

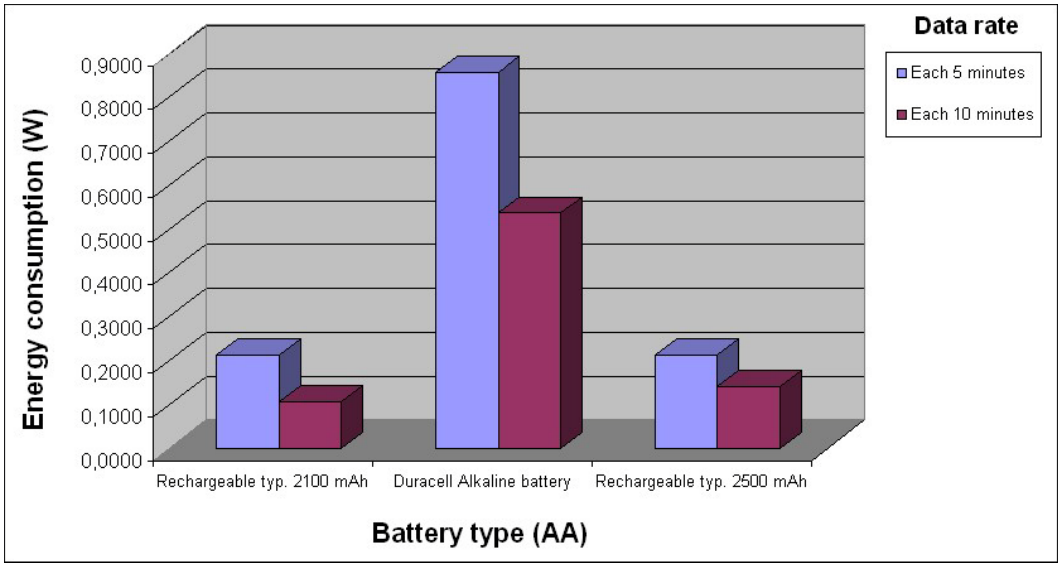

Fig. 7. Energy consumption for two sampling rates evaluated (5 and 10 min) in tree types of batteries.

In view of this, it is proposed in this work a data collect through a different data sampling, with the implementation of rules in the code of the firmware which allow an automatic reconfiguration of the sampling rate, allowing to extend the lifetime of sensor nodes and collecting data with an appropriate temporal resolution depending on the application.

CONCLUSIONS

Two data sampling rates (5 and 10 min) were evaluated, using XMesh protocol in Low Power mode. For a greater sampling rate, lower power consumption was perceived; however, there was a greater packet loss within the network. The proposed work is a collection of data through a data sampling differentiated by implementing rules in the firmware code, which allows an automatic reconfiguration of the sampling rate. For the defined variables to change dynamically, the implementation of commands to be executed from the central computer is evaluated.

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