Wireless Networked Biological Applications

P. Mariño, F.P. Fontán, M.A. Domínguez, S. Otero

Abstract—**Biological research in agriculture needs a lot of specialized electronic sensors in order to fulfill different goals, like as: climate monitoring, soil and fruit assessment, control of insects and diseases, chemical pollutants, identification and control of weeds, crop tracking, and so on. That research must be supported by consistent biological models able to simulate diverse environmental conditions, in order to predict the right human actions before risky biological damage could be irreversible. In this paper an experimental distributed network based on climatic and biological wireless sensors is described , for providing real measurements in order to validate different biological models used for viticulture applications. First, the experimental network for field automatic data acquisition is introduced , as a system based in a distributed process. Following, the design of the wireless network is explained in detail, with a previous discussion about the state-of-the-art, and some measurements for viticulture research are pointed out. Finally future developments are stated.**
Keywords: sensor network, wireless network

1 Introduction

The experimental wireless network is deployed in a peninsula surrounded by two large sea arms called "rias" in Spanish language. In that peninsula, located in the northwest of Spain (near the northern border of Portugal), the vineyards have four main productive zones called: Meaño, Cambados, Ribadumia and Meis (Fig. 1).

Currently differences in productivity and quality of grapes are broadly related with relative heights and sea proximity from each of four zones but nevertheless more rigorous biological and climatic research [1, 2] must be done, in order to provide accurate biological models for ecological simulations applied to viticulture. For that reason multidisciplinary work must be done among electronic engineers, biologists and ecologists.

Each zone has an electronic zonal station (EZS), in order to bring differences (microclimates), in measurements like: temperature, relative humidity, leave humidity, soil temperature, solar radiation, rain gauge (tipping bucket), and other biological sensors. A data logger and a radio modem is included in each EZS in order to sense, process and transmit the data, enabling the development of an automatic wireless sensor network (WSN), which nodes

Figure 1: Peninsula photograph.

(the EZSs) are accessible from a wide area. These wireless communication capabilities allow that data could be remotely monitored. The implementation of a warehousing approach, allows the data to be stored in a centralized database that is responsible for query processing. The stored data will be used for biological and ecological models.

Firstly the paper describes the different elements employed in the experimental network. These include (a) the wireless nodes (b) the base station (c) the repeaters and (d) the data management. Finally some measurements from EZSs are depicted.

2 Data Acquisition System

The electronic zonal stations (EZSs) are connected with the base station (BS) by the UHF band (not licensed) between 869.4MHz to 869.65MHz, and the BS is also connected through Internet to the Data Base (DB), the biological and ecological models (BEMs), and to the Web access (Fig. 2). Each zonal station comprises an UHF radio modem that transmits the sensors information to the BS through a data call. A powering solar panel (PSP) is located near each EZS for feeding its circuits. In order to reduce costs, the BS makes a call to all the EZSs every 24 hours by means of a polling procedure [3]. During these calls the EZSs send all the information that has been stored on that period. Therefore the BS periodically executes the reading data process and later database storage

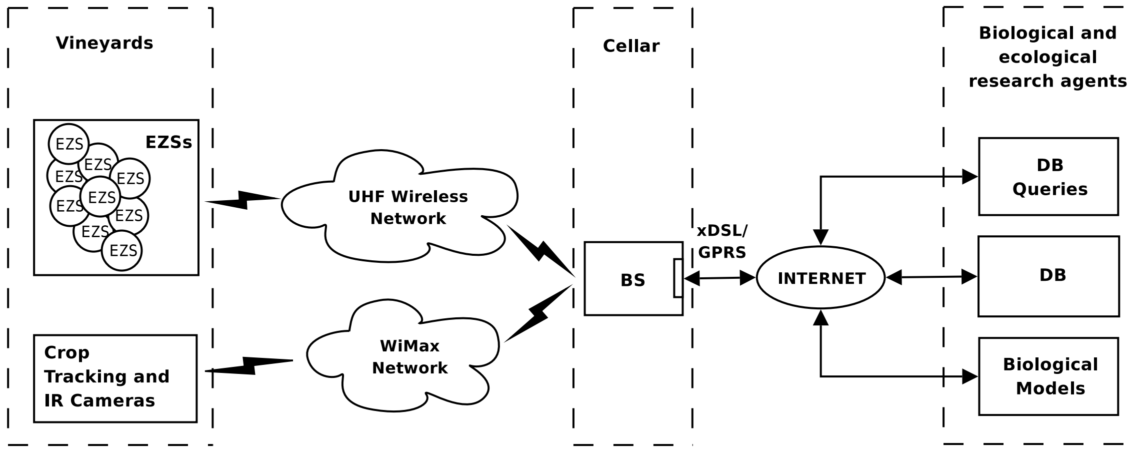

Figure 2: Network architecture and database interfaces.

of the received information, through an Ethernet local area network.

2.1 Data from Sensors

An electronic zonal station (EZS) is the basic acquisition equipment of the distributed system, that carries out the data registration (measurements and processing), and the communication with the base station (BS). In this way, each EZS comprises an automatic measurement unit with data transfer capability. The data acquisition process is made inside the EZS by the sensors and the data logger. Each EZS comprises the following sensors: temperature, relative humidity, leave humidity, soil temperature, solar radiation, rain gauge (tipping bucket), and other biological and ecological features depending on running models [4].

All that sensors are integrated in the data logger. The data logger is the EZS nucleus, it captures the data from each sensor, automates the measurements, synchronises the data and manages the communications. The data transmission is carried out by means of the data logger and the UHF radio modem connected to it. Next, the data captured by the EZS is sent to the database (DB), through the base station (BS), where they are saved. The communication process setting, through the UHF radio modem connected to the data logger, allows the control and programming of several tasks as well as the acquisition of stored data.

The data captured by the data logger are organised in registers. The registers comprise the sensor outputs as well as the time and date. These registers are then sent to the storage system where they are saved for a future access. The data logger is programmed for capturing and storing the sensors information each minute. Due to the limited capacity of the storage system integrated in the data logger, the data can only be stored during a day (24 hours). Figure 3 illustrates the data logger, the storage system,

Figure 3: EZS data acquisition and communications system assembled in the protection box.

the UHF radio modem and connections with the sensors and electrical supply. Al these elements are placed inside a box which protects them from the weather conditions. This box and all the sensors are fixed to a metallic base located at the site (Fig. 4).

3 Global Data Management

The information obtained from the EZSs are collected by the BS and stored in the DB for later process, analysis and query. The BS requests and compiles the data from the different EZSs to store them in the DB. Also the BS is provided with an UHF radio modem to make the polling query of each EZS in the wireless network. Therefore the BS is a PC connected to a wireless network and Internet that executes the developed program to perform its operations flowchart. The figure 5 shows this flowchart.

Since all the measured data must have the same time reference for its later process, the BS obtains the system

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Figure 4: Final assembly and EZS installation.

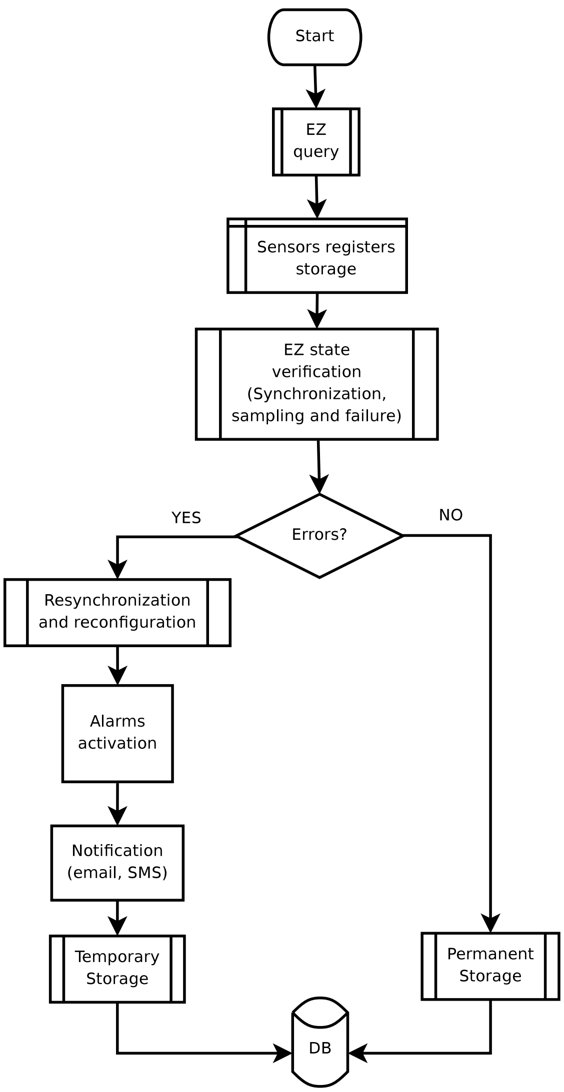

Figure 5: BS operations flowchart.

reference clock from a real time network server by the NTP synchronization protocol (Network Time Protocol). So after the date have been obtained, a time synchronization test is verified for the EZSs clocks, to determine if the collected data can be considered valid. If this is the case, the information is stored directly in the DB. Otherwise the problem is corrected (if it is possible), it is notified by e-mail and/or a message, and finally the data and the error information are stored. In this way is possible to know exactly when and what type of errors took place and, depending on this information data can be corrected.

The data from the EZSs are centralized in a relational database. This DB presents one interface with the BS through which all the system information is introduced, and three interfaces to access this information: general data access, access to interesting data to analyse viticulture features, and query of data for providing models (Fig. 5). The interface between BS-DB and queries-DB are executed directly by means of ODBC (Open Database Connectivity).

The general data access will directly take place through an Internet accessible Web page. Whereas for queries related to the analysis of viticulture features and models, the access is made through specific views for each type of study [3]. Figure 6 shows an example of the EZS data management. This picture illustrates the structure of communications among equipments, interfaces and layers.

4 The State-of-the-Art and the Implemented Network

Past decade has been very fruitful in the development and application of several standards for mobile, nomadic and fixed wireless networks related with sensors [5, 6, 7]. Some specific problems about this kind of networks have been well studied, like: energy efficiency due to collisions, overemitting-receiving, control of packets and idle listening; scalability and changes adaptation in network size, node density and topology; communication paradigms like node-centric, data-centric and position-centric; and many others.

Nevertheless this great researching effort over wireless networks for sensors, there is no any accepted MAC for them, because this kind of sensor networks has a very big dependence of the application. Recent surveys about the most advanced wireless networks like MANETs [8, 9] show poor real results in front of expected ones, because the great complexity involved in simulated MAC protocols, on big programming tools, was not after validated with implementation, integration and experimentation over real equipment (chips, microcircuits, modems, antennas, and others). In this way, a particular field of application, called "wireless sensor networks" (WSN) is pro-

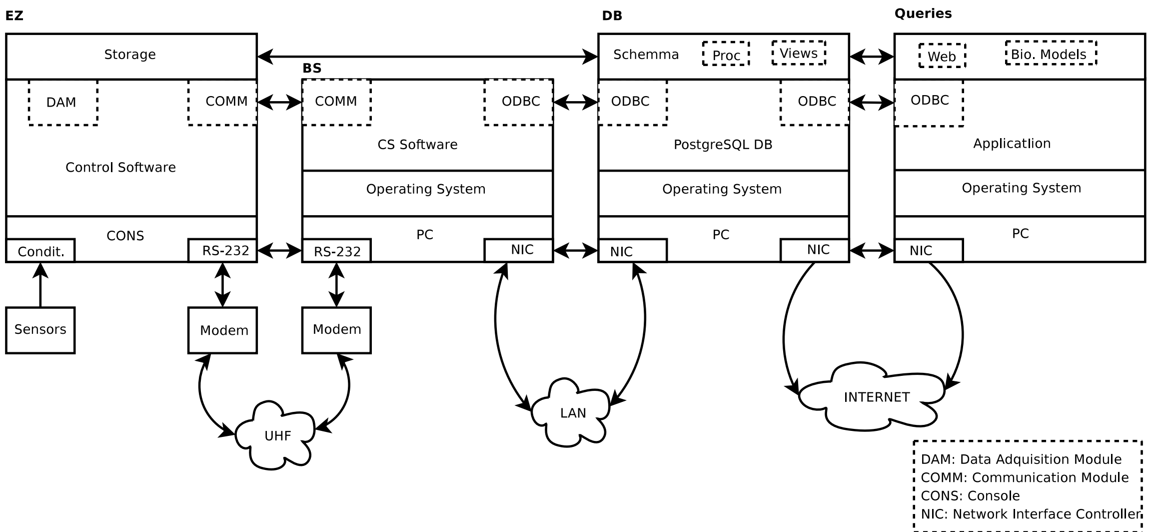

Figure 6: Communication example between elements, interfaces and layers.

posed for environmental monitoring, industry and precision agriculture, among other sectors of activity. The WSNs are featured by a stronger interdisciplinary collaboration for creative projects, and a change in the communication paradigm from node-centric to data-centric one, because the main point is the transfer of data from the application field, and not the communication between all the network nodes.

4.1 The Wireless Sensor Network (WSN)

Several comparatives among general wireless standards like ZigBee [10, 11], Ultra Wide Band (UWB) [12], Bluetooth [13] and WiFi [14] have been made in order to evaluate some examples of application included industrial wireless sensors. Also, more specific WSN applications could be found about environmental research like: hydrology [15], fire monitoring [16], deep ice [17], and others [18].

Given the hilly nature of the vineyard zones (Section 1), the coverage challenges for linking the EZSs with the BS (Section 3) were founded in power, data speed and acceptable error ratio. For example, in the Meis zone the coverage area was over 5km, with difference in heights about 200m, very prone to interpose obstacles in the line-of-sight (LOS) among EZS-BS. In order to achieve a wireless network with very low cost and reduced power consumption, because static nodes are transmitting infrequently (low duty cycle) only two-way small data packets, the European ISM band (868-870MHz) was selected, where one channel with a data rate of 20kbps is available [13]. In this ISM band the used radio modems for linking EZS-BS, have the following features: 10-500mW of transmitting power, 25kHz of channel spacing, half-duplex communication, 10% duty cycle and 36 seconds of maximum emission time (must be controlled by the data logger, Section 2.1). To avoid an obstacle in the LOS between the BS and the EZS, a repeater station (RS) is inserted with other ISM radio modem and a directive antenna, linking the EZS (2,1km) with the BS (5,17km). Figure 7 shows an illustrative example of measured rain series carried out between EZS-RS-BS in the Meis zone.

5 Future Developments

Experimental work over the implemented WSN is being made in the following lines:

- Addition of new climatic and biological sensors to the EZSs.
- Deployment of new EZS over the four different vineyard zones for providing more spatial resolution to biological and ecological models.
- Design of a wireless broadband (20Mbps) network in order to provide crop tracking by real time images, and infrared cameras (zonal isotherm maps), by WiMax (IEEE 802.16) equipment [19, 20] over the 5GHz ISM band (Fig. 2).
- Integrate those images in the global data management system (Section 3), for giving to the biological and ecological researchers new knowledge for future enhancement of models.

6 Conclusions

The authors have developed an experimental distributed network based on the WSN paradigm for wireless sensors. This WSN is based on the European ISM band for providing a low cost and low power consumption network, bringing real measurements to validate different biological and

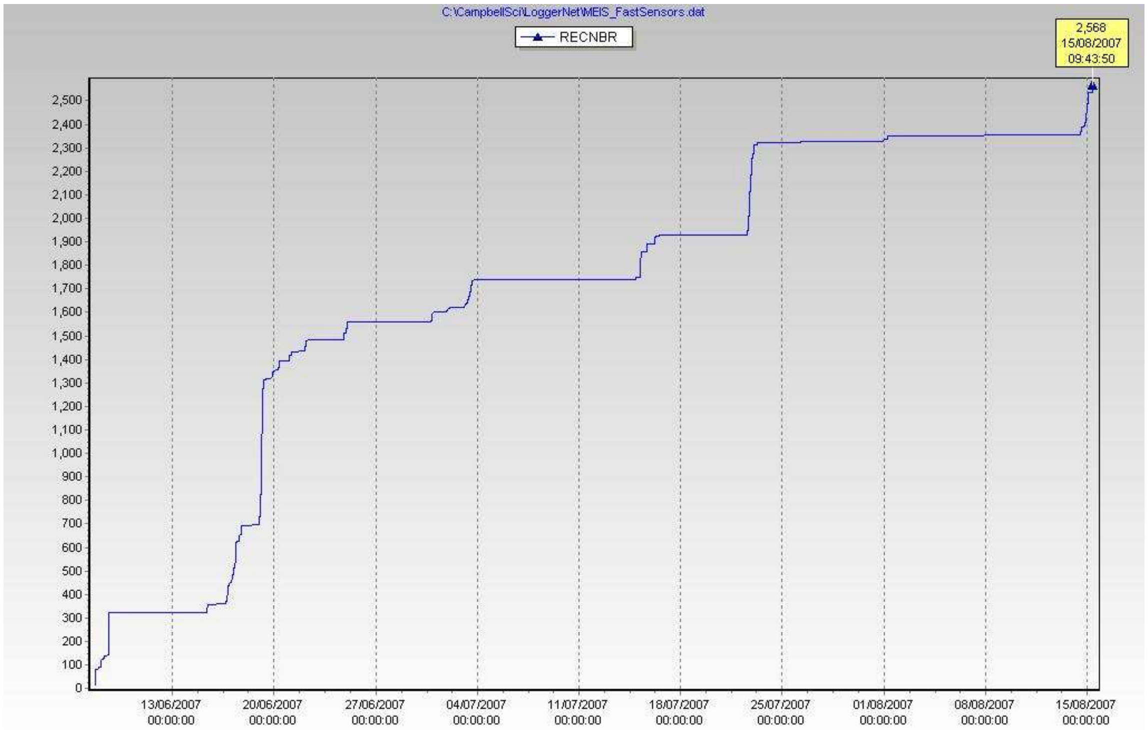

Figure 7: Measured rain plot.

ecological models used for viticulture applications. Also a global data management system is designed to integrate consistently the measured data in the models. New developments in the experimental wireless network are being tested to add real time images and infrared cameras information, by means of broadband network standards.

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