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Proceeding

Integration of Autonomous Wireless Sensor Networks in Academic School Gardens†

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Abstract: In this work, the combination of capabilities provided by Wireless Sensor Networks (WSN) with parameter observation in a school garden is employed in order to provide an environment for school garden integration as a complementary educational activity in primary schools. Wireless transceivers with energy harvesting capabilities are employed in order to provide autonomous system operation, combined with an ad-hoc implemented application called MySchoolGardenApp. The system enables direct parameter observation, data analysis and processing capabilities, which can be employed by students in a cloud based platform. Providing remote data access allows the adaptation of content to specific classroom/homework needs. The proposed monitoring WSN has been deployed in an orchard located in the schoolyard of a primary school, which has been built with EnOcean's energy harvesting modules. For the assessment of the wireless link quality and the deployment of the modules, especially the central module which needs to receive directly the signals of all the sensor modules, simulation results obtained by an in-house developed 3D Ray Launching deterministic method have been used. Preliminary trials with MySchoolGardenApp have been performed, showing the feasibility of the proposed platform as an educational resource in schools.

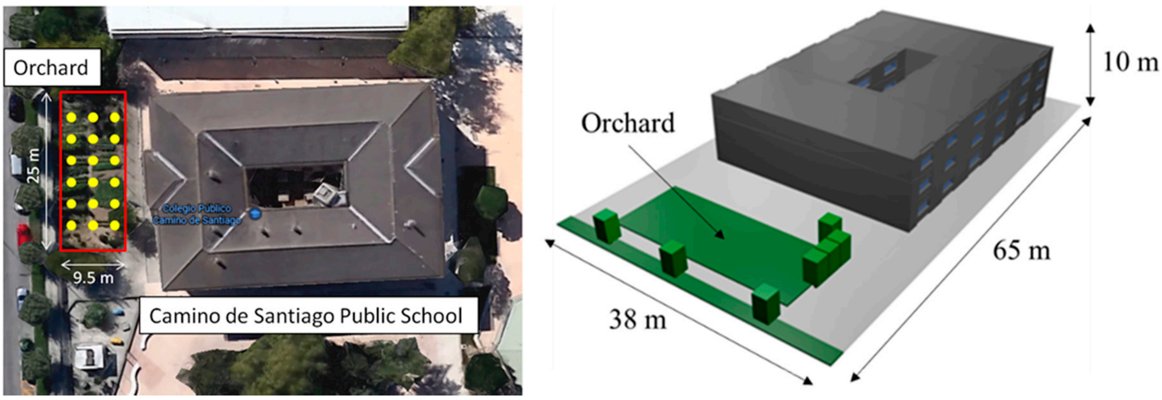
Keywords: Urban Garden; Wireless Sensor Networks; Energy Harvesting; MySchoolGardenApp

1. Introduction

Wireless Sensor Networks are being actively adopted as enablers for context aware communication capabilities within multiple scenarios, such as Smart Cities and Smart Regions. Moreover, within the educational community there are multiple initiatives in which development environments such as Arduino/Genuino or Raspberry Pi are being employed in order to enhance learning outcomes in multiple disciplines, with a clear focus on Science, Technology, Engineering and Mathematics (STEM). Information and communication technologies have also been adopted in order to improve multiple aspects of agriculture, such as precision agriculture or optimized crop watering or fertilizer use [1,2]. In this context, WSNs play a key role, given to the fact that they constitute inherent distributed systems, in which current platforms allow the inclusion of multiple analog/digital input/output ports. In this way, multiple parameters can be obtained and correlated, related with environmental parameters, location or chemical component detection, among others. In this work, the combination of capabilities provided by WSNs with parameter observation in a school garden is employed in order to enhance the outcomes within the learning process of students in primary school. Wireless EnOcean transceivers with energy harvesting capabilities are employed in order to provide autonomous system operation, combined with an ad-hoc implemented application called MySchoolGardenApp. Information is retrieved in a cloud enable environment, providing remote data access and off-line processing capabilities, in order to adapt content to specific classroom needs.

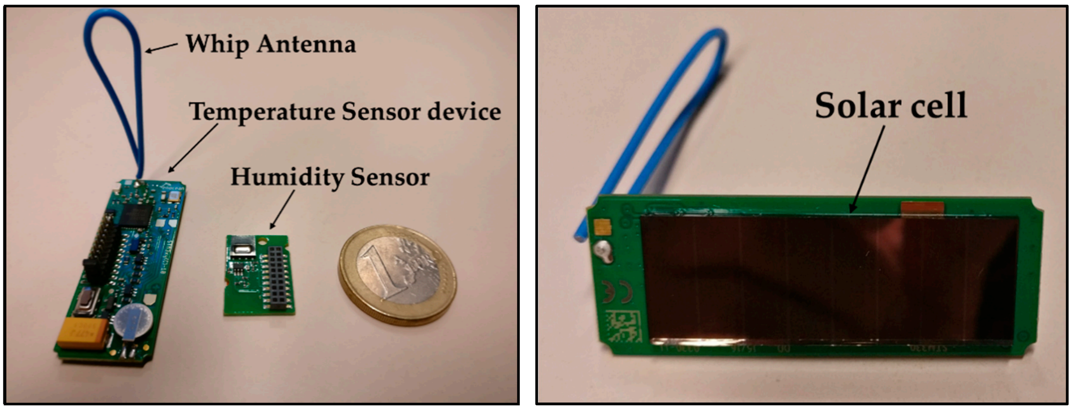
2. Experiments and Results

The experiments have been carried out in the orchard of the 'Camino de Santiago' primary school, located near the city of Pamplona. The orchard has an educational role, as the students learn how to grow different kind of vegetables such as cucumbers, pumpkins, onions, garlic, tomatos, beans, zucchini, corn, etc. The orchard is 25 m long and 9.5 m width and it is located within the school yard, near the school building, as can be seen in Figure 1a delimited by a red rectangle. The 18 yellow dots within the red rectangle that can be seen in the figure represent the positions where the sensors belonging the WSN have been placed. This proposed WSN for monitoring the orchard has been built based on EnOcean's energy harvesting modules. Specifically, the STM 330 modules have been employed. These wireless modules have incorporated a temperature sensor (range 0 to 40°C) and there is the possibility of equipping them with a humidity sensor, which has been used in this study as it provides interesting informations for the purpose of the presented application. Figure 2a shows a picture of a STM 330 module alongside the optional humidity sensor. In the same way, Figure 2b shows a picture of the opposite side of the same module, where the solar cell used for the energy harvesting can be seen. Besides the reduced size of the modules, which provides an easy-to-deploy feature, it is very important to note that the energy harvesting technology of the devices (they are self-powered by the small solar cell) avoids the maintenance task of replacing batteries that common WSNs usually need. Regarding the radio characteristics of the STM 330 modules, they operate at 868.3 MHz, which provides longer distances than common devices operating at 2.4 GHz due to lower radio propagation losses. They provide a low data rate of 125 kbps (in comparison, ZigBee at 2.4 GHz transmits 256 kbps), which is enough in order to transmit the required information and by the way they save energy. The transmitted power level is between 5 and 8 dBm. The network topology is restricted to a star topology, which means that each of the deployed STM 330 modules communicates only with a central module usually connected to a PC or laptop via USB.



(**a**) (**b**)

Figure 1. (**a**) 'Camino de Santiago' public school's upper view; (**b**) View of the created scenario for the 3D Ray Launching simulations.



(**a**) (**b**)

Figure 2. (**a**) EnOcean's STM 330 module and the includable humidity sensor; (**b**) Detail of the STM 330 module's solar cell.

The scenario under analysis have been simulated by a 3D Ray Launching simulation tool in order to analyze and optimize the deployment of the wireless sensors and the central node of the network. This simulation tool has been broadly used and validated in previous works [3,4]. The simulated scenario is composed by the 'Camino de Santiago' public school building and the orchard which is part of its facilities (see Figure 1b). They are distributed in a 2470 m^2 area scenario, where the orchard occupies 237.5 m^2. The building has dimensions of 40 m long, 28 m width and 9 m height. The material properties (dielectric constant and conductivity) of all the elements within the scenario, including organic materials for trees and orchard have been considered. For this study, Radio Frequency (RF) power distribution results for the whole volume of the scenario have been obtained by means of the 3D Ray Launching tool for each of the deployed wireless sensors. As an example, Figure 3 shows the obtained values for a bi-dimensional plane at 5 m height (equivalent to the second floor of the building) for the simulation of one of the wireless sensors deployed on the orchard. These results give a valuable information for a correct deployment of the proposed WSN, as the central node (GW) will be deployed within the building as it has to be connected to a PC or laptop via USB. Since the sensitivity of the central node is −96 dBm, sensitivity fulfilment planes can be obtained from RF power distribution planes (see Figure 4), where the zones that do not comply with the sensitivity requirements are highlighted in red, whereas the blue zone indicates that the GW could be deployed as the received power level is higher than the sensitivity threshold. Obtaining the sensitivity fulfilment planes for each of the deployed wireless sensor, an adequate location for the GW can be estimated. The used simulation parameters are summarized in Table 1.

Table 1. 3D Ray Launching Parameters.

Parameter	Value
Operation frequency	868.3 MHz
Output power level	8 dBm
Permitted reflections	6
Cuboid resolution	2 m × 2 m × 2 m
Launched Rays resolution	1°
Data rate	125 kbps

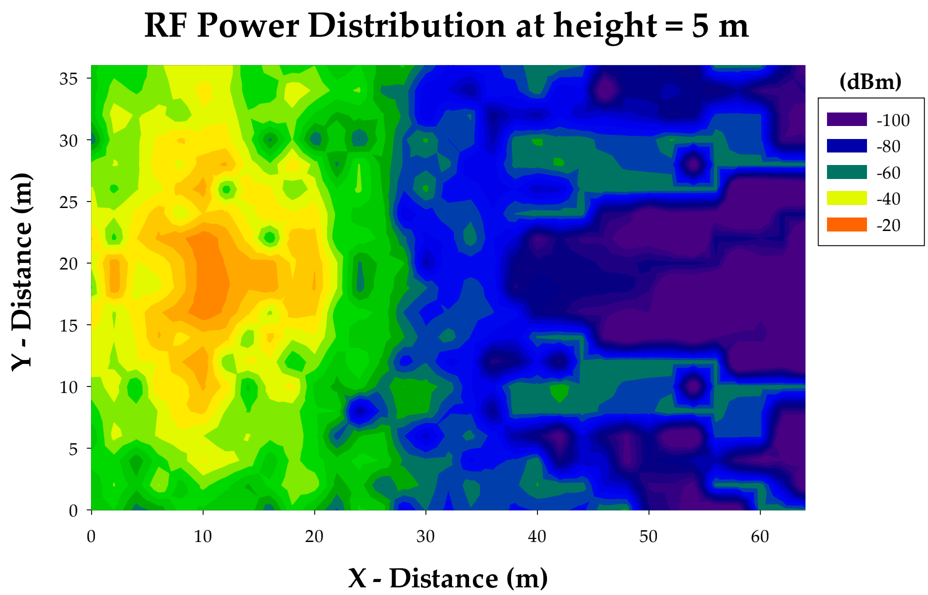


Figure 3. Estimated RF power distributions at height = 5 m for a wireless sensor on the orchard.

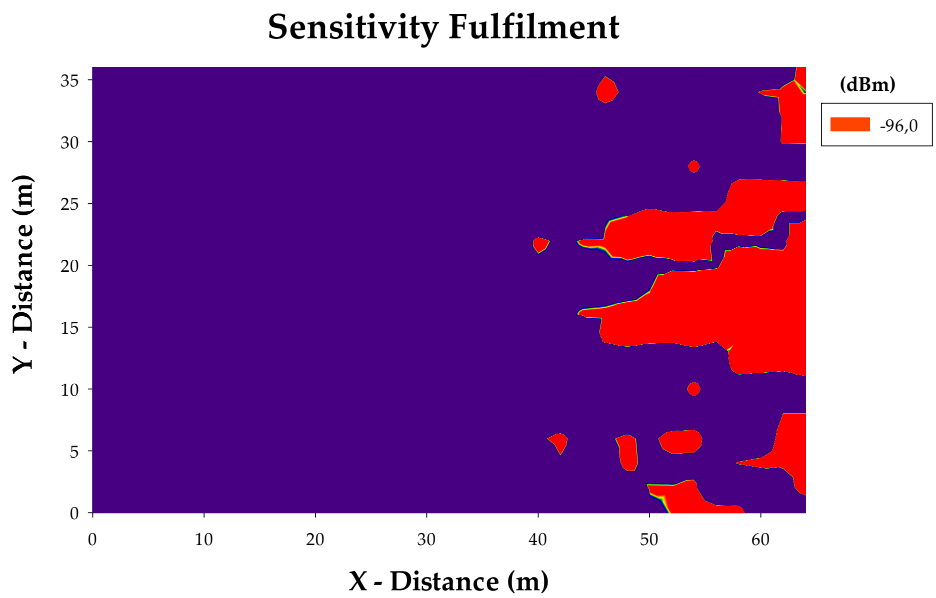


Figure 4. Fulfilment of the sensitivity for the central node (GW), which sensitivity threshold is −96 dBm.

4. Application Design and System Validation

Once the deployment of the WSN has been assessed, this section presents an educational application for its use in schools, as the creation of school gardens is having a great boom nowadays. School gardens are a very useful educational resource for urban schools. They boost students' interest in learning botanical concepts while they engange in agricultural practices on a small scale. In the same way, the students become responsible caretakers, learning about the responsibilities and impacts of land cultivation. The application presented in this work, called MySchoolGardenApp, allows to increase the interest of students regarding topics such as the value of the natural environment and its importance in human life, the history of the different crops, mathematics for the calculus of surfaces, weights collected, number of fruits and, in higher courses, the use and interpretation of graphs on the time, and the Internet search on different methods of cultivation.

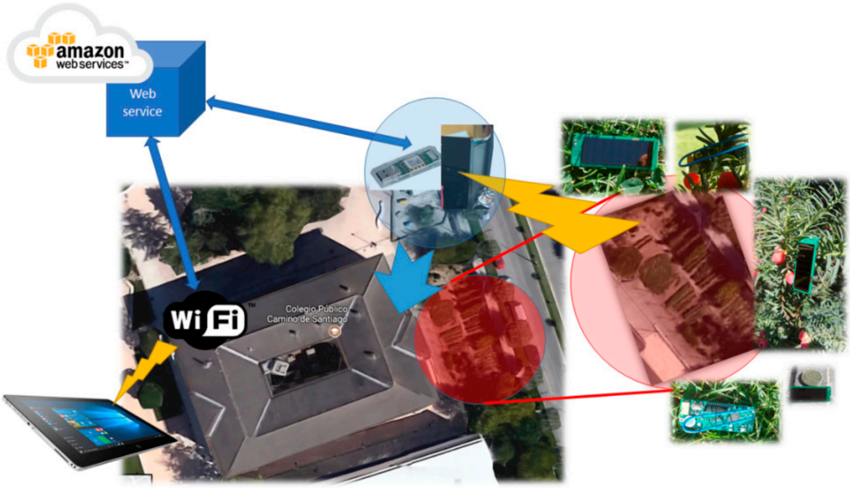


Figure 5. Shema of the system architecture.

The system architecture is quite simple (see Figure 5). EnOcean's STM 330 nodes gather the information and transfer it wirelessly (868.3 MHz) to a gateway node (GW) located into the building, where a USB-based device connected to a PC is in charge of data collection and its transmition to the cloud. This channel is also used to provide control commands to the sensor nodes when needed. The PC is an Ubuntu 16.4 Linux computer that uses an API REST to transfer data to the cloud (Amazon) by means of a web service. The GW node collects periodically the information and transfers it to the cloud. In addition, meteorological information is also obtained periodically from another web service of the Government of Navarre (http://meteo.navarra.es). All the harvested information is stistically processed using Amazon RDS (Relational Database Service) and RStudio server. The access to the generated reports (by teachers as well as students) can be made by means of mobile devices (smartphones and tablets), electronic boards and computers through the WiFi network of the building. Students can query the information using their own devices, and, according to their age and knowledge, the system provides information at different levels of granularity. For example, the system provides easy to understand pictograms adecuated to the younger students, while it provides comparative tables of the evolution of multiple variables measured by sensors, advanced graphs, and even regressions and trends for the most expert students. That is, the prosposed system is a customizable tool, in which teachers can decide the level of presentation more suitable for the educational needs of their students. Figure 6 shows the graphic user interface of the application. In this example, the graphs presented are aimed at students who are already able to understand graphs of a certain complexity with their knowledge of statistics and regressions.

Figure 6. MyShoolGardenApp user interface.

5. Conclusions

In this work, an environment to enhance School Garden observation for educational purposes in primary school has been presented. The system is formed by a set of autonomous wireless sensor nodes, which transmit information to a cloud capable platform. An ad-hoc application called MySchoolGardenApp has been implemented, in order to monitor and process the obtained observation data from the sensors located on a garden located within the school yard of a primary school. Initial testbed results have been obtained, showing the feasibility of the proposed system, which can provide multiple and adaptive results, tailored to the specific classroom needs.

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Author Contributions: Peio Lopez-Iturri, Erik Aguirre and Francisco Falcone conceived and designed the experiments; Jose J. Astrain and Jesús Villadangos developed and validated the MySchoolGardenApp application; Peio Lopez-Iturri, Erik Aguirre and Leyre Azpilicueta conducted the simulations and the analysis of wireless propagation phenomena. Peio Lopez-Iturri, Jose J. Astrain and Francisco Falcone wrote the paper.

Conflicts of Interest: The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

References

1. Angelopoulos, C.M. A Smart System for Garden Watering using Wireless Sensor Network. In Proceedings of the 9th ACM International Symppsium on Mobility Management and Wireless Access, New York, NY, USA, 31 October– 4 November 2011; pp. 167–170.
2. Abbas, A.H.; Mohammed, M.M.; Ahmed, G.M.; Ahmed, E.A.; Seoud, R.A.A.A.A. Smart Watering System for Gardens using Wireless Sensor Networks. In Proceedings of the International Conference on Engineering and Technology (ICET), Cairo, Egypt, 19–20 April 2014; pp. 1–5.
3. Sesma, I.; Azpilicueta, L.; Astrain, J.J.; Villadangos, J.; Falcone, F. Analysis of challenges in the application of deterministic wireless channel modelling in the implementation of WLAN-based indoor location system in large complex scenarios. *Int. J. Ad Hoc Ubi. Comput.* **2014**, *15*, 171–184.
4. Granda, F.; Azpilicueta, L.; Vargas-Rosales, C.; Lopez-Iturri, P.; Aguirre, E.; Astrain, J.J.; Villadangos, J.; Falcone, F. Spatial Characterization of Radio Propagation Channel in Urban Vehicle-to-Infrastructure Environments to Support WSNs Deployment. *Sensors* **2017**, *17*, 1313.