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Radio Propagation Analysis for ZigBee Based Indoor Dog Monitoring System

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Abstract: The flexibility of new age wireless networks and the variety of sensors to measure a high number of variables, lead to new scenarios where anything can be monitored by little electronic devices, thereby building Wireless Sensor Networks (WSN). Thanks to ZigBee, RFID or Wi-Fi networks the precise position of humans or animals as well as some biological parameters can be known in real-time. However, since wireless sensors must be attached to biological tissues and they are highly dispersive, propagation of the electromagnetic waves must be studied to build an efficient and well-working network. In this work, the radio wave propagation produced by ZigBee devices working over ISM 2.4GHz based network is studied through a home-made 3D Ray Launching simulation tool. Furthermore, a simplified dog model is developed for the chosen simulation code, considering not only its morphology but also its dielectric properties. Power distribution, Power delay profile and delay spread graphs are extracted from simulation results concluding in an extensive and accurate wireless radio propagation studio. Finally, a dog monitoring system is presented, it works over the ZigBee network and sends information to Android based devices.

Keywords: Dog monitoring; WSN; 3D Ray Launching; ZigBee

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1. Introduction

Nowadays, the monitoring of inanimate objects as well as of living beings can be easily carried out thanks to the high variety of sensors working together with increasingly smaller technology and the different wireless communication standards. In relation to animal tracking, numerous identification systems have been developed over the years, specially for wildlife, attaching radio transmitters to animals to monitoring their position, behavior or migratory habits. For farm beasts or pets some identification systems have also been extended, however these systems are not based on wireless networks and therefore owners must extract the information on approach.

Nevertheless, the healthcare and monitoring of animals is essential for society today and hence, some works related with this topic can be found in the bibliography. In [1,2] a farm is monitored thanks to wireless networks and in [3] the vital signs of a dog are wirelessly read, extracting information from photophethysmogram (PPG) and electrocardiogram (ECG). Notwithstanding, these kind of systems must be deployed after an extensive radio-planning study to construct a robust and efficient Wireless Sensor Network(WSN), especially when the number of animals is high, they are in wide areas or they are inside complex places from the electromagnetic point of view.

In this work a 3D Ray Launching method developed by the Public University of Navarre is used to study the electromagnetic propagation inside a home when a WSN device is attached to a dog. A simplified dog model has been developed for this simulation tool considering its morphology and dielectric properties, since the wireless transceiver is inevitably attached to biological tissues and they are highly absorptive and dispersive. Measurements have also been carried out inside the home attaching a Xbee device to a real dog to calibrate the simulation tool and compare obtained data with theoretical results. Finally an android based application for the studied scenario is presented.

2. Simulation Scenario and Dog Simplified Model

As previously mentioned, the 3D Ray Launching simulation code used in this work has been integrally developed by researchers from the Public University of Navarre. This tool has already shown its accuracy and it is well documented in previous works, where numerous scenarios with different characteristics and levels of complexities have been considered [4].Besides, biological tissues has also been taken under consideration with the development of a simplified human body model [5,6].

Table 1. Simulation parameters used in the 3D Ray Launching code.

Frequency	2.41GHz
Transmitter power	0dBm
Antenna gain	5dBi
Horizontal plane angle resolution (ΔΦ)	1º
Vertical plane angle resolution (Δθ)	1º
Reflections	5
Cuboids resolution	0.3m x 0.3m x 0.3m

In this case an entire one floor home (Figure 1) has been simulated with all the furniture (chairs, tables, mirrors, beds, etc.), taking under consideration not only the morphology of the scenario but also

the dielectric properties of all the objects inside it. The size of the scenario is of 65m^2 and it is divided in eight rooms.

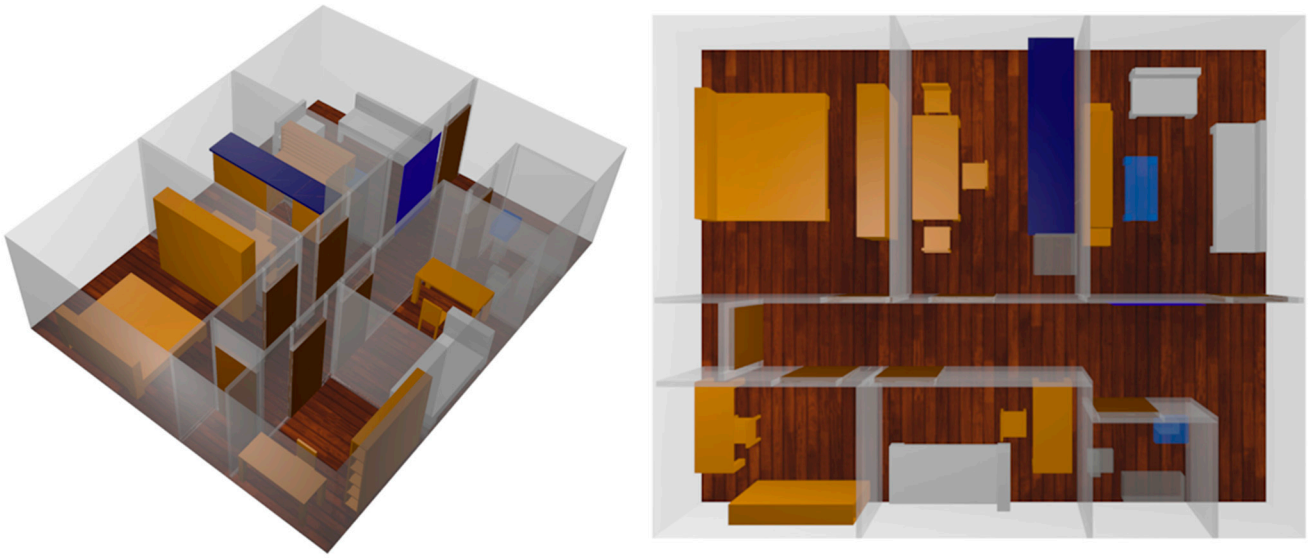

Figure 1. 3D view of the simulated and measured scenario.

In Figure 2 the developed simplified dog model is depicted. This model is entirely compatible with the simulation technique and it has been provided with the dielectric characteristics and the proportions of a real dog. Furthermore, the developed model allows to generate dogs of different proportions, from mini-dogs as Chihuahuas to giant-dogs as St. Bernard and they can be placed inside the scenario in different positions.

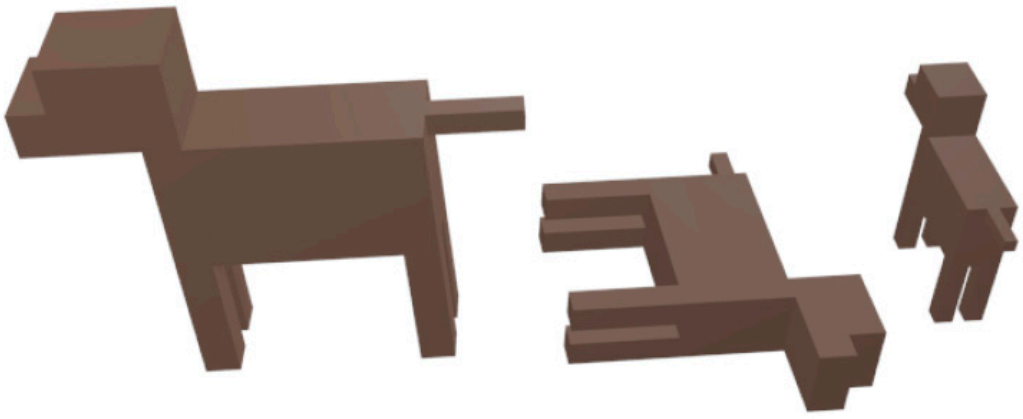

Figure 2. Example of the developed simplified dog model in different position and with different sizes.

Since the chosen communication system is a ZigBee Wireless Personal Area Network (WPAN), simulation parameters of the antenna match with a real device characteristics, particularly they are the same as Xbee devices which have been used for measurements. In Table 1 these parameters as well as resolution values used in simulation can be shown.

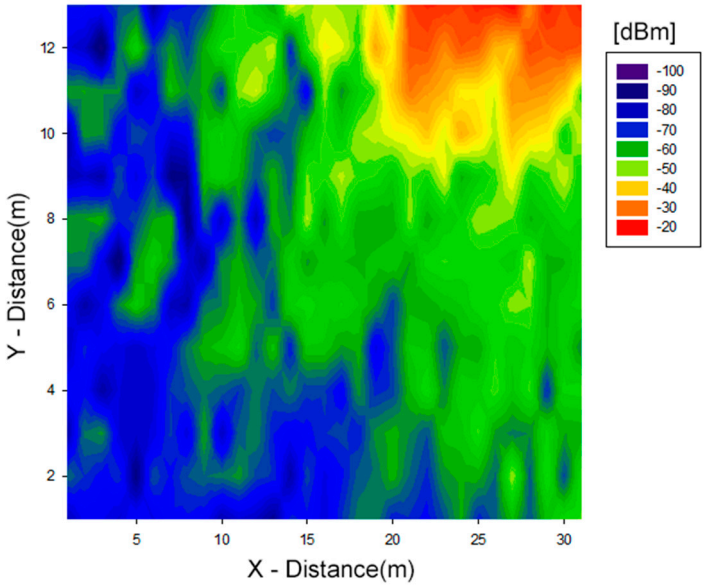

Figure 3. Power distribution in the scenario when transmitter is placed in the living room.

In Figure 3 power distribution results for the entire home floor are presented. Since the transmitter is placed in the living room most of the energy is confined in this area, however, the power levels obtained in the rest of the scenario are compatible with usual sensitivity of -100dBm of Xbee devices.

3. Experimental Results and Application Example

Experimental results are obtained attaching to a dog a Xbee device working over an Arduino (Figure 4(b)). In this case the dog has been placed in the living room and simulation and measurement results have been obtained all over the home. Therefore, once the device is working, five measure points are defined in different rooms of the home (Figure 4(a)).

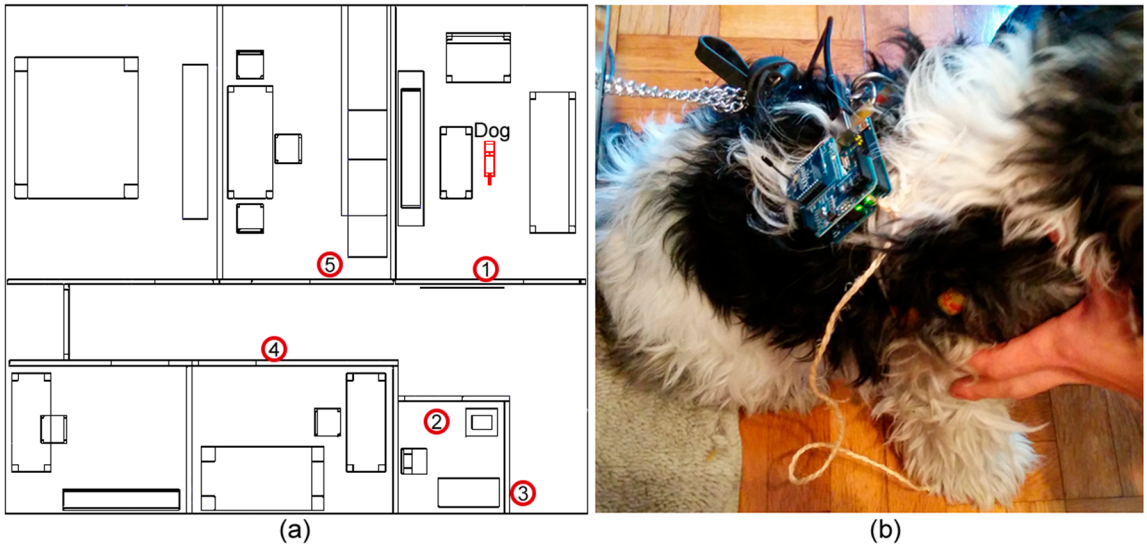

Figure 4. (**a**) Measurement points distributed around the home and the location of the dog(a); (**b**) Xbee device attached to the dog for measurements.

In Figure 5 both, measurement and simulation results are compared concluding that the simulation tool gives accurate results with a maximum error of 5dB. In any case, it can be shown the power value far away from the sensitivity and therefore, a good performance of a ZigBee system can be expected.

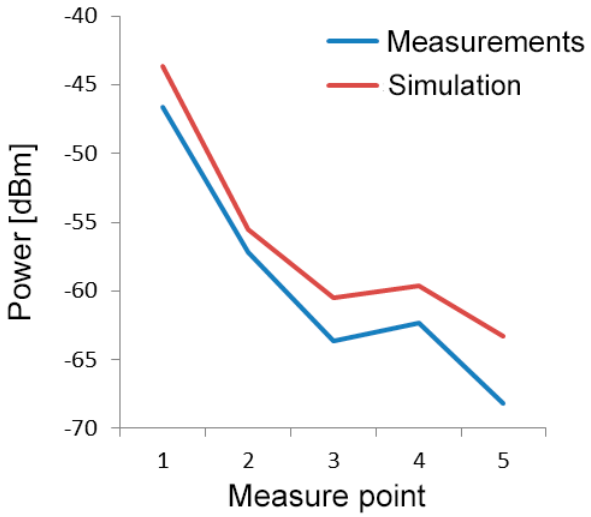

Figure 5. Measurement vs simulation results when Xbee device is attached to the dog.

Finally an in-house dog monitoring system is developed for android devices based on a ZigBee network. With the application shown in Figure 6 the distance walked by the dog can be easily known and the place where it is as well as the time that it has been in banned places can be monitored.

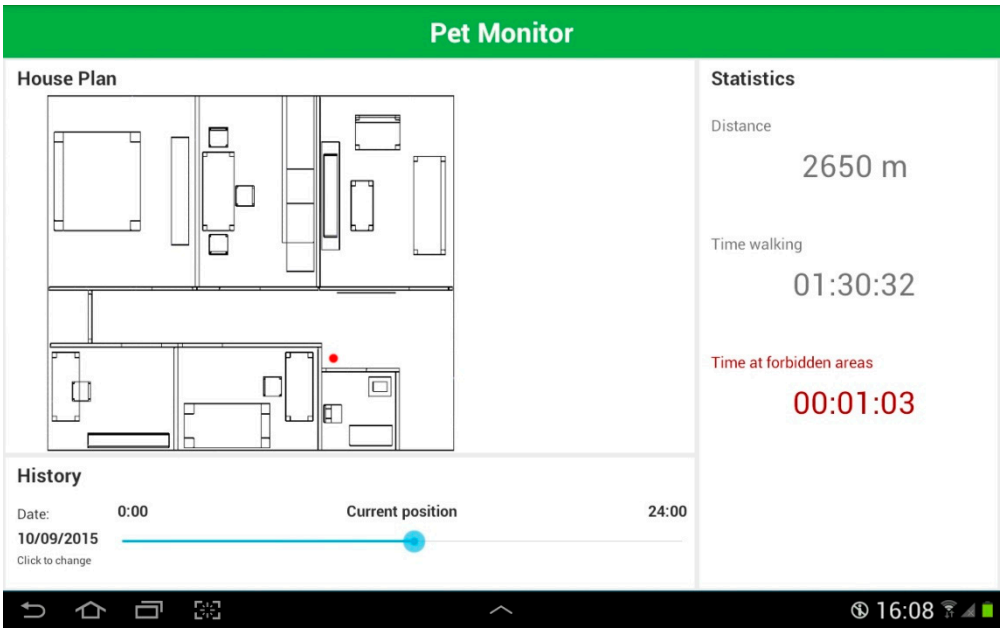

Figure 6. Example of android based application for dog monitoring inside a home.

4. Conclusions

In this work the viability of using a WSN network for dog monitoring is studied through a 3D Ray Launching simulation tool. For this method a simplified dog model is developed considering different dog size proportions and the dielectric properties of its biological tissues. A entire one floor home has been chosen as studied scenario considering all its topology and characteristics.

Firstly, the potential of the tool to determine the power distribution in this scenario is demonstrated and therefore, it can be concluded that a proper radio-planning study can be carried out by the use of this technique. Secondly, the simplified dog model is introduced inside the living room to compare simulation results and measurements. Five measure points are chosen and compared obtaining a maximum error of 5dB and demonstrating the high accuracy of the 3D RL simulation method. Finally and once the viability of the network has been demonstrated, an Android based indoor dog monitoring application is presented for the same scenario.

Conflicts of Interest

The authors declare no conflict of interest.

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