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Assessment of ISM 2.4 GHz Wireless Sensor Networks Performance in Judo Training Venues

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Abstract: In this work, the performance of ISM 2.4GHz Wireless Sensor Networks (WSN) deployed in Judo training venues is analyzed. Judo is a very popular martial art worldwide, which is practiced by thousands of people not only at competition level, but also as part of physical education programs at different school levels. There is a great variety of Judo training venues, as each one has specific morphological aspects, making them unique complex indoor scenarios in terms of radiopropagation due to the presence of furniture, columns and equipment, and the presence of human beings, which is a major issue as the person density within this kind of scenarios could be high. Another key aspect is the electromagnetic interference created by other wireless devices, such as personal portable devices and other wireless systems such as WiFi or other WSNs, which make the radioplaning a complex task in terms of coexistence. In order to analyze the impact that these features has on the radiopropagation and the performance of WSNs deployed within a real Judo training environment, an in-house developed 3D Ray Launching algorithm has been used.

Keywords: Judo; Wireless Sensor Networks; Ray-launching; Interference; ZigBee

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1. Introduction

Nowadays Judo is a sport practiced by thousands of people around the world. The venues where Judo is practiced usually have some common aspects (such as having a Tatami), but in general, each training venue has specific morphological aspects, making them unique complex indoor scenarios in terms of radiopropagation due to the size of the venue itself, the presence of furniture (e.g. cupboards, benches, chairs), columns, pads and other elements and equipment that can be found within training gyms. In order to deploy a WSN in such environments, the electromagnetic interference created by other wireless devices, such as personal portable devices and other wireless systems such as WiFi or other WSNs must also be taken into account, as the coexistence could be a complex task. Finally, the presence of human beings is a major issue in terms of radiopropagation, since the person density in this kind of scenarios can be high.

In the literature, few related works can be found, and they show WSN deployments within sport venues much larger than Judo training venues: the development of wireless video services [1] or the design of wireless environmental monitoring system based on ZigBee for stadiums [2]. Specifically for Judo, some action recognition works have been published [3,4], and only one about radiopropagation analysis [5]. But there is still a neediness of in depth radioplanning studies for Judo environments, especially in order to assess the influence of human body in radiopropagation, even more, taking into account that wearable sensors for monitoring sport performance in martial arts have been already developed [6].

In this work, an in-house developed 3D Ray Launching algorithm has been used in order to assess the impact that the presence of human beings has in the radiopropagation in Judo training environments. For that purpose, in section 2, the used simulation technique and the description of the scenario under analysis are presented. In section 3, the obtained simulation results are shown and discussed.

2. Simulation Technique

2.1. The 3D Ray Launching Method

In complex indoor environments like the scenario presented in this work, it is greatly important to conduct a radiopropagation analysis before the deploying of a WSN. Traditionally, empirical methods such as Okumura Hata or COST-231, among others, have been used for that purpose. They provide rapid results, but not as accurate as the results obtained by deterministic methods (e.g. Method of Moments and Finite Difference Time Domain). These last methods are based on the resolution of Maxwell's equations, giving very accurate results with a high computational cost, i.e. highly time-consuming.

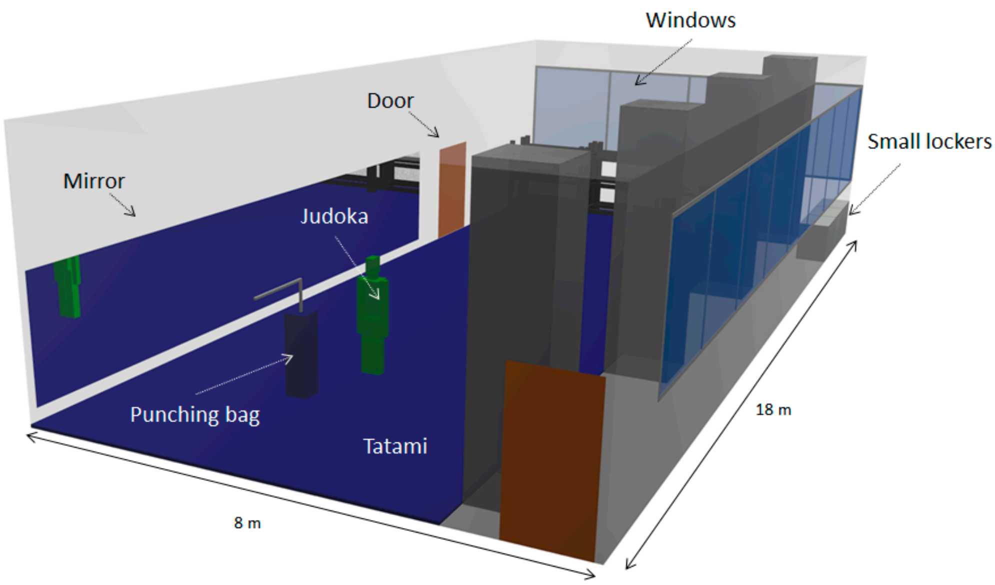
The 3D Ray Launching algorithm used in this work is a deterministic method based on geometrical optics, making it offer a reasonable trade-off between accuracy and required calculation time [7]. It has been developed in-house, based on Matlab, and its validity has been proved in previous works [9]. The algorithm takes into account the electromagnetic phenomena of reflection, refraction and diffraction. Besides, the properties of all the materials present within the scenario are considered (dielectric constant and loss tangent). Parameters such as frequency of operation, radiation patterns of the antennas, number of multipath reflections, separation angle between launched rays, and cuboid dimension are also taken into account.

2.2. Scenario Under Analysis

The Judo training venue under analysis in this work is located in the facilities of the Public University of Navarre. The dimensions of the scenario are 18m (long) × 8m (wide) × 4.8m (height) and it contains a tatami of 17.5m × 6m. Besides, within the scenario there are typical elements easily found in indoor training environments, such as a punching bag, doors, columns and some furniture elements such as small lockers. The existing elements and mainly the presence of people within the scenario make it a very complex indoor environment in terms of radiopropagation. Figure 1 shows the real scenario and the schematic view of the created scenario for the 3D Ray Launching simulations.

Figure 1. (**a**) Real scenario under analysis. (**b**) Schematic view of the created scenario for 3D Ray Launching simulations.

(**a**)

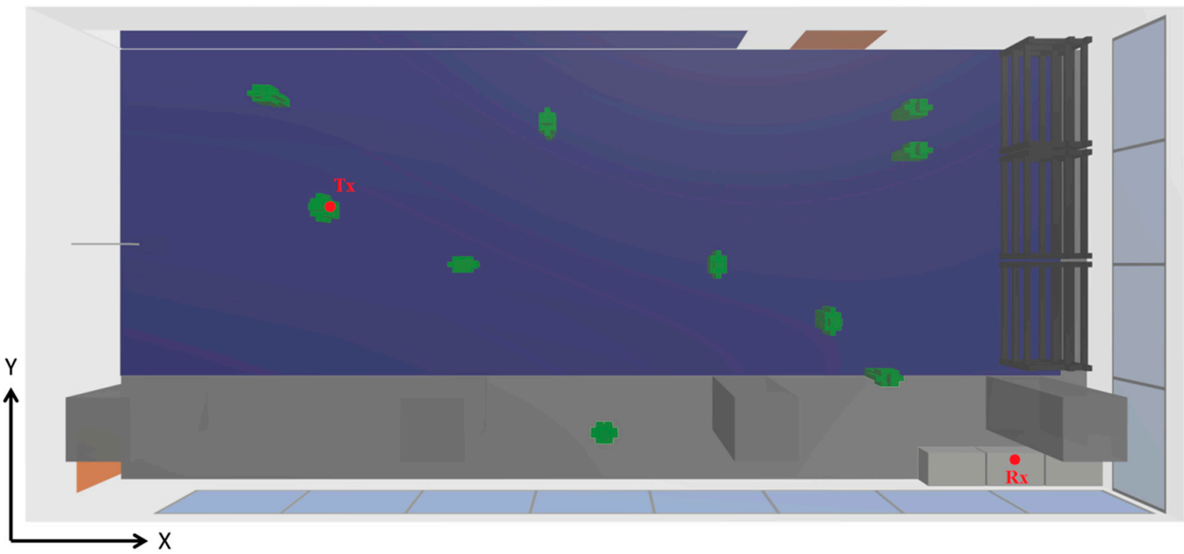


(**b**)

3. Results and Discussion

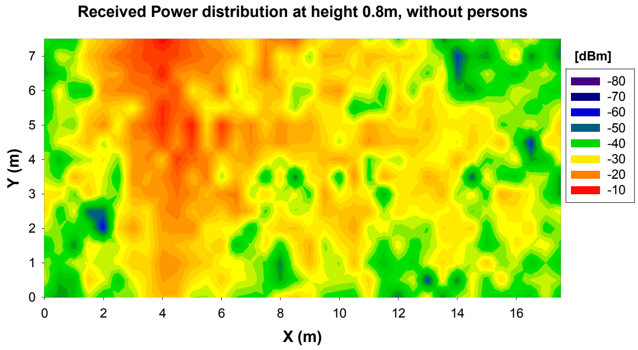
In this section, the influence that the presence of human beings has on the radiopropagation in Judo training environments is shown. For that purpose, a transmitter has been placed on the chest of a Judoka, at 1.35m height, and a receiver has been placed on the small lockers at height of 0.8m, emulating a wireless link between a wearable wireless sensor and a laptop acting as sink, receiving the information of the deployed WSN. Two cases have been simulated, the first one with no other person within the scenario apart from the Judoka with the sensor, and the second one with 9 more persons distributed randomly throughout the scenario. The human body model included in the simulator has been developed in-house and has been previously used and validated [9]. The configuration of the first case can be seen in Figure 1, and the second case in Figure 2, where the positions of the transmitter (Tx) and the receiver (Rx) are marked by red dots.

Figure 2. Upper view of the scenario under analysis with the presence of 10 persons and the position of the transmitter (Tx) and the receiver (Rx) depicted.

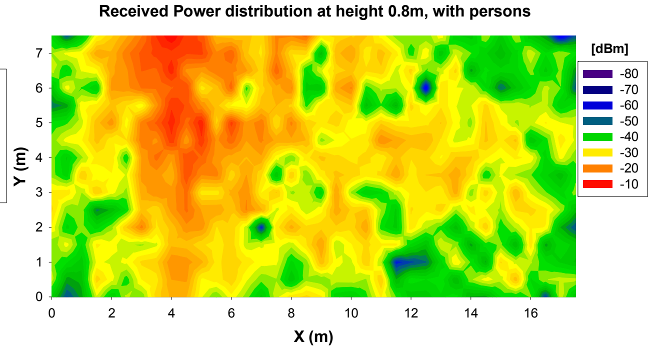


The parameters used for the simulations have been chosen to match the characteristics of ZigBee-compliant devices operating at ISM 2.4GHz band. Figure 3 shows the received power level for a plane at 0.8m (the height where the receiver has been placed), for both simulated cases. The received power level is dependent on the position of the potential transmitter and receiver elements. The short term variations of the received power level are mainly due to the multipath propagation, which is usually the strongest propagation phenomenon in this kind of indoor environments. As expected, the power distribution is similar for both cases, but not the same. This difference can be significant in terms of wireless channel quality.

Figure 3. Estimated received power level distribution for the transmitter on the Judoka's chest, (a) without more persons in the scenario and (b) with persons.



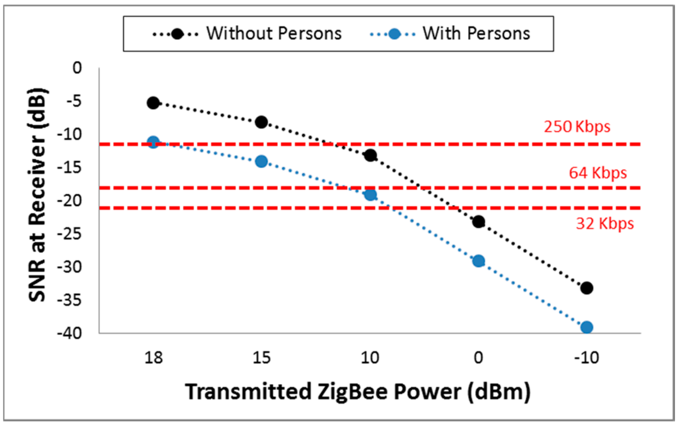
(a)



(b)

In order to gain insight in how this difference affects the quality of the transmission, in Figure 4 a Signal to Noise Ratio (SNR) graph is presented. It shows the SNR value calculated in the receiver position, assuming an interference level of -40dBm, which could be generated by other wireless systems such as WiFi or other WSN. The x-axis indicates different transmission power levels for the ZigBee sensor of the Judoka's chest. The red dashed lines represent the minimum SNR value needed to transmit successfully at indicated bit rates. As can be seen, for the chosen position of the receiver, the received power difference leads to a different SNR value between the case without persons and with persons. Depending of the application of the WSN, a minimum bit rate will be needed, and as it can be seen in Figure 4, the presence of persons can be a determinant factor between a good performance of the WSN and a failed communication.

Figure 4. Estimated SNR values for different configurations of the Tx-Rx wireless link.



4. Conclusions

In this paper, the influence of the presence of human beings in the performance of WSNs at ISM 2.4GHz band in Judo training venues is analyzed by means of an in-house deterministic 3D Ray Launching algorithm and an in-house developed human body model. The presented analysis can aid in obtaining the optimal wireless network deployment, configuration and performance, making the use of WSNs attractive for the development and adoption of multiple applications for Judo training activities. This method can be easily transferred and adopted for similar assessments in other sports.

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Conflicts of Interest

The authors declare no conflict of interest.

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