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Radio Characterization for ISM 2.4 GHz Wireless Sensor Networks for Judo Applications

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Abstract: In this work, the characterization of the radio channel for ISM 2.4GHz Wireless Sensor Networks (WSN) for Judo applications is presented. The environments where Judo activity is held are usually complex indoor scenarios in terms of radiopropagation due to its morphology, the presence of humans and the electromagnetic interference generated by personal portable devices, wireless microphones and other wireless systems used by the media. For the assessment of the impact that the topology and the morphology of these environments have on electromagnetic propagation, an in-house developed 3D ray-launching software has been used in this study. Time domain results as well as estimations of received power level have been obtained for the complete volume of the presented scenario, which have been compared with measurements. The measurement campaign has been carried out deploying ZigBee-compliant XBee Pro modules at a local Judo club's facilities, emulating a competition/training venue with a contest area with the dimensions specified by the IJF for international competitions, and using approved Judogis (jacket, trousers and belt). The analysis is completed with the inclusion of an in-house human body computational model.

Keywords: Judo; Wireless Sensor Networks; Ray-launching; ISM 2.4 GHz band; ZigBee

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1. Introduction

Judo is an Olympic sport, in which the International Judo Federation (IJF) gives assistance and guidelines for the organizers of international competitions. Following IJF rules, the environments where Judo competitions are held are complex indoor scenarios in terms of radioplanning, as some competition venues have large spectator capacity, multiple competition areas, furniture, and other facilities. Training venues are usually less complex than competition venues in terms of interferences, but they also have the inherent complexity of indoor scenarios in terms of radiopropagation.

In the literature, some related works for large sport venues can be found, as the development of wireless video services [1] or the design of wireless environmental monitoring system based on ZigBee for stadiums [2]. But there is a neediness of radioplanning studies for both large (competition venue) and smaller (training venue) sport environments. Furthermore, taking into account that wearable sensors for monitoring sport performance and training, including martial arts, have been developed [3,4]. Specifically for Judo environments, there is no reported work about radioplanning analysis.

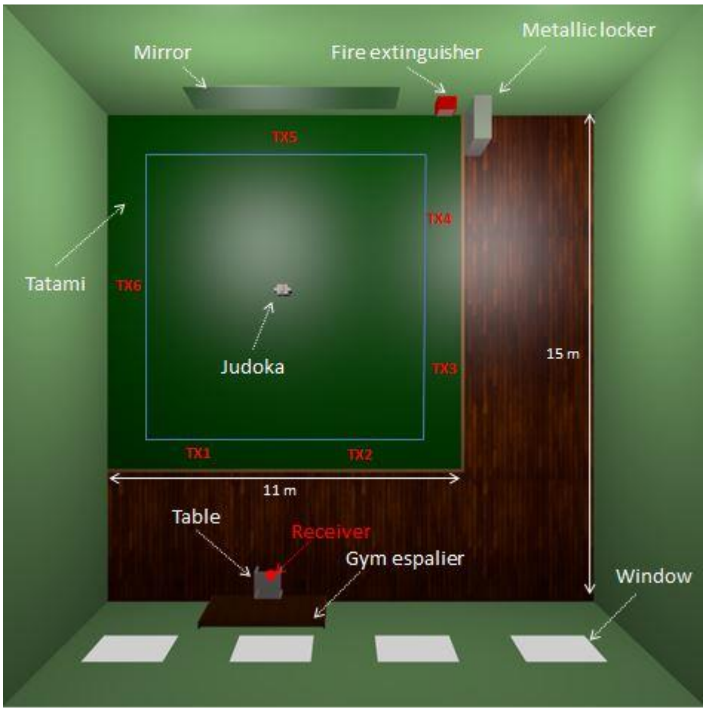
For the purpose of analyzing this kind of environments, in section 2, the analyzed real Judo scenario is described, as well as the process of taking radiopropagation measurements. In section 3, the measurement results have been used in order to validate the estimations obtained by the aid of an in-house developed 3D ray launching tool. The presented analysis can aid in the optimal network deployment, making the use of WSNs attractive for multiple applications in this kind of environments, as helping referees, monitoring vital signs, coaching support, anti-doping control or Judoka identification.

2. Experimental Section

2.1. Radiopropagation Measurements

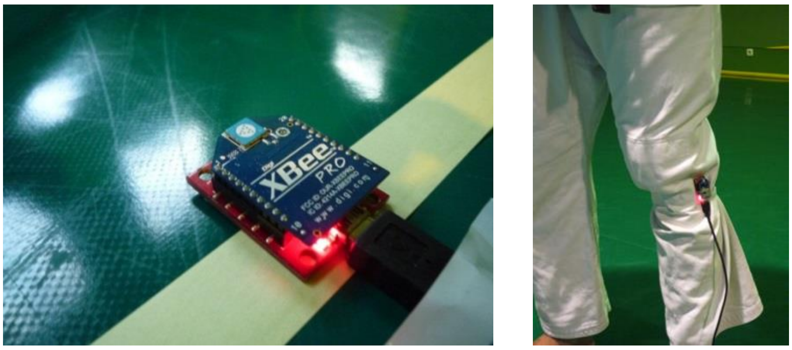
The scenario where the analysis of the radiopropagation has been carried out is located in the facilities of Judo Klub Erice, a local Judo club. This scenario has the typical morphology of a training venue and additionally, the tatami complies with the dimensions specified by the IJF for contest areas for international competitions (11m x 11m).The dimensions of the studied scenario are 15m (long) x 15m (wide) x 8m (height), and there are concrete walls, parquet flooring and some furniture elements as wooden gym espalier and table, metallic locker and a fire extinguisher inside a metallic box with methacrylate cover. Although most of the scenario is air, the existing furniture and the presence of people make it a complex indoor scenario in terms of radiopropagation. The schematic scenario created for the 3D ray-launching algorithm, which represents the real Judo training venue where measurements have been taken, can be seen in Figure 1. The red point represents the receiver, which has been placed on a 0.75m height table, emulating the referees' table or a wireless node receiving the information from the Judoka on the tatami (e.g. vital signs during training sessions). The positions of the transmitter are represented by red text (TX) and a number. In the middle of the tatami, a Judoka is placed, facing the receiver point.

Figure 1. Scenario under analysis, created for the 3D ray-launching simulations.



Due to the performance in terms of power consumption and spectrum availability, IEEE 802.15.4 based XBee Pro modules with chip antenna (gain of -1.2 dBi) have been used for the experimental setup (see Figure 2). The transmission power level has been set to 18 dBm and the frequency of operation has been set to 2.41 GHz, which corresponds to ZigBee channel number 12. As a receiver, an omnidirectional antenna with 5 dBi gain, connected to a portable spectrum analyzer (Agilent N9912 Field Fox) has been used. Two different measurement campaigns have been carried out. First, the XBee module acting as transmitter has been placed in 6 different positions along the perimeter of the emulated competition venue (marked as red text 'TX' with a position number in Figure 1). Thus, the radiopropagation from different distances can be analyzed. Besides, this transmitter placement emulates a possible application. For example, by placing pressure sensors throughout the perimeter of the competition area, a wireless message could be sent to the referee's table to know if a Judoka is inside or outside the competition area.

Figure 2. XBee Pro module deployed on the tatami (left), and on the Judoka's knee (right).



The second measurement campaign consists on placing a Judoka in the center of the tatami with the transmitter on different parts of its body (chest, back, knee and arm), as seen in Figure 2. It is worth noting that all the measurements have been made using Judogis (jacket, trousers and belt) approved by IJF, in order to make them as close as possible to a realistic high level Judo environment.

2.2. Simulation Technique

For the assessment of the impact that the topology and the morphology of these environments have on electromagnetic propagation, an in-house developed 3D ray-launching software has been used. This simulation method offers a good trade-off between precision and required computational time for radioplanning calculations, as it is based on geometrical optics approximation [5], and it has been validated previously for different complex indoor environments [6].

Time domain results as well as estimations of received power have been obtained for the complete volume of the presented scenario, which have been compared with measurements in the next section. The analysis is completed with the inclusion of an in-house human body computational model, in order to understand the behavior of the propagation when a wireless mote is placed on a Judoka.

3. Results and Discussion

Received power level results have been obtained for the whole volume of the scenario by means of the 3D ray launching simulation algorithm. The parameters defined for the simulations are shown in Table 1, which are equivalent to those of the used ZigBee system.

Table 1. 3D Ray launching simulation parameters.

Parameter	Value
Transmitted power level	18 dBm
Frequency	2.41 GHz
Launched rays resolution	1º
Resolution (cuboids size)	10cm x 10cm x 10cm
Maximum reflections permitted	5
Transmitter/Receiver antenna gain	-1.2 dBi / 5 dBi

Figure 3 shows the obtained received power level for the plane at height 0.75m (the height of the receiver on the table), when the transmitter is placed on the tatami at position TX1 without the presence of the Judoka, and when the transmitter is placed on the back of the Judoka. As can be seen, 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 phenomenon in indoor environments. The influence of the human body is clearly seen. In order to see the impact of the multipath propagation in the scenario, in Figure 4 power delay profiles at the center of the table are presented. The transmitter positions correspond to TX1 and the back of the Judoka. The sensitivity of the XBee Pro modules (-100 dBm) has been delimited by a red line. As expected, more components with higher power level reached the table from position TX1 than position on the back of the Judoka, as the distance is shorter and no human body is affecting the propagation.

Figure 3. Estimated received power planes at 0.75m for the transmitter placed on the tatami at position TX1 and on the back of the Judoka.

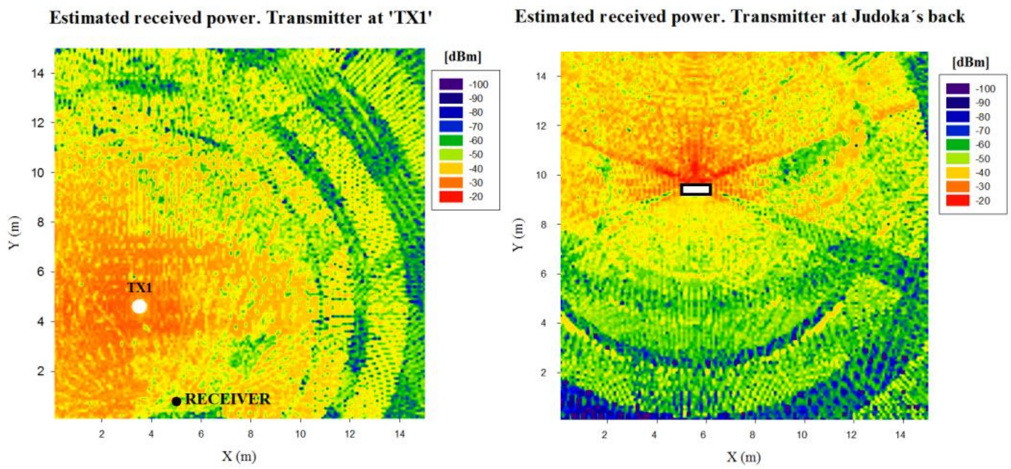
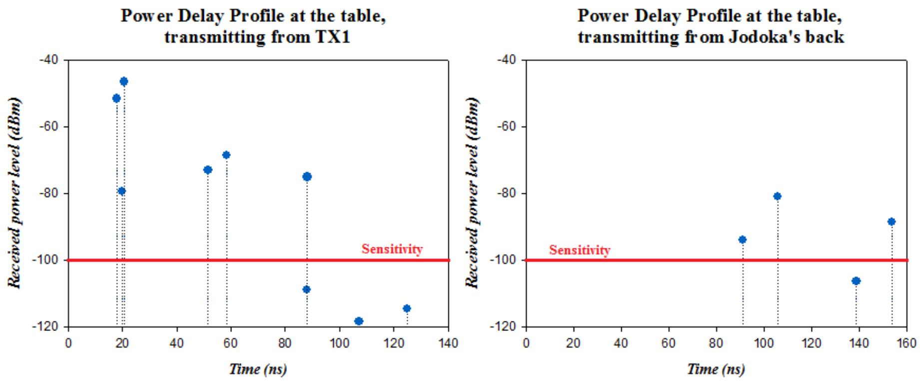
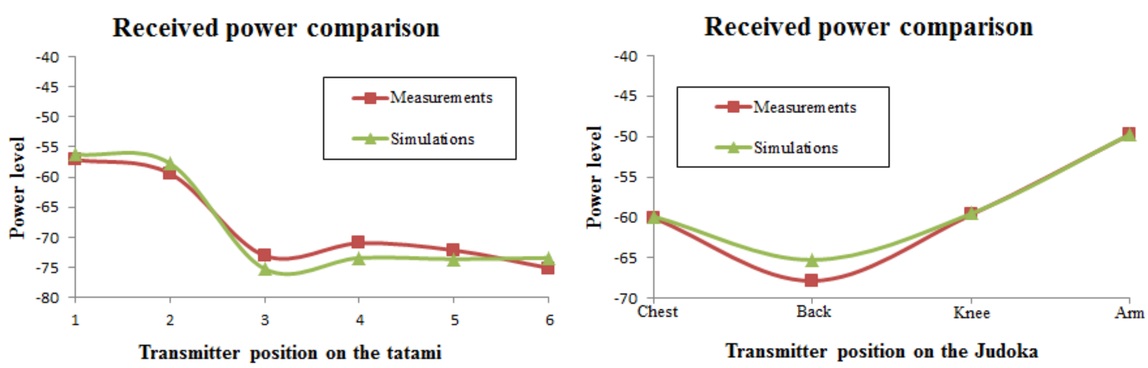


Figure 4. Power delay profiles at the receiver location for the transmitter placed on the tatami at position TX1 and on the back of the Judoka.



In order to validate the obtained simulation results, in Figure 5 a comparison between the simulation results and the measurements of the received power level are shown. As can be seen, the received power estimations obtained by means of this method are accurate.

Figure 5. Received power comparison between simulation results and measurements for different transmitter positions.



4. Conclusions

In this paper, the topological influence in the operation of a WSN at 2.4 GHz band in a Judo training/competition venue is analyzed by means of an in-house deterministic 3D ray launching algorithm as well as by measurements. The accuracy of the presented in-house simulation method is high, and the feasibility of a deployment of a WSN at 2.4 GHz band for Judo applications is demonstrated. The use of precise radioplanning techniques to aid in wireless transceiver deployment can be a determining factor for the adoption of these emerging technologies for Judo and other sports applications.

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Conflicts of Interest

The authors declare no conflict of interest.

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