Analysis and Implementation of Wireless Communications Systems and IoT with Human Body Interference in Inhomogeneous Environments

Imanol Picallo Guembe
Electric, Electronic and Communication Engineering Dept.
Public University of Navarre
Pamplona, Spain
imanol.picallo@unavarra.es

Hicham Klaina
Electric, Electronic and Communication Engineering Dept.
Public University of Navarre
Pamplona, Spain
hicham.klaina@unavarra.es

Leyre Azpilicueta
School of Engineering and Sciences
Tecnologico de Monterrey
Monterrey, Mexico
leyre.azpilicueta@tec.mx

Ana Vazquez Alejos
Signal Theory and Communications Dept.
University of Vigo
Vigo, Spain
analejos@uvigo.es

Peio Lopez-Iturri
Electric, Electronic and Communication Engineering Dept.
Public University of Navarre
Pamplona, Spain
peio.lopez@unavarra.es

Francisco Falcone
Electric, Electronic and Communication Engineering Dept.
Public University of Navarre
Pamplona, Spain
francisco.falcone@unavarra.es

***Abstract*—The Integration of wireless communication systems is one of the main drivers of the development of the future connected society. However, this will cause challenges due to the non-static channel effect and interference impact. For this reason, a research work is proposed that enables to obtain optimal node location in relation to radio planning tasks (coverage/capacity analysis, number of lost packets, devices' consumption...), as well as to characterize the environments considering obstacles and human body being, in terms of the received power level in the complete simulation volume and at the time domain level. This will help derive wireless channel models taking into account real channel variations to deploy a Wireless Sensor Network (WSN) and reduce the impact on wireless systems performance.**

Keywords*—*Internet of Things, wireless characterization, Wireless Sensor Network, 3D Ray Launching, body interference

I. Introduction

Due to the high demand for connectivity and low latency anywhere, wireless devices will grow exponentially in the coming years. Thanks to the deployment of 5G networks, the paradigm of the Internet of Things (IoT) will be promoted, which will allow meet these demands and transform society at an economic and social level. Moreover, industry digitalization will be based on Industry 4.0, enabling companies to combine advanced techniques in the fabrication and operation process together with smart technologies, thanks mainly to the Industrial Internet of Things (IIoT). Another key term that will become a reality with emerging 5G networks is the Intelligent Transport System (ITS), which allows for evolution towards full connectivity to enable services such as optimized route planning or autonomous driving within a Smart City. As a result of the high number of devices, potential interfering systems during the communication will strongly increase significantly, requiring an in-depth analysis of their behavior in complex and non-static environments due to the fact that cause the weakening of the wireless channel response.

For this reason, the research work is defined from the point of view of analyzing the behavior of the electromagnetic waves in inhomogeneous environments, that is, radio electrically complex environments that must be characterized in order to perform radio-planning tasks. In this way, the performance of the wireless communication systems will be evaluated at both the experimental and simulation level. Most of the environments, both the indoors (such as homes, auditoriums, sports venues...) and the outdoors (such as forests, cities...), depend strongly on the morphology of the scenario and the chosen location for the nodes deployment. Another critical factor to consider in this kind of environment is the presence of human beings that make dynamic scenarios and, depending on the density of people, could be a limiting factor for the devices' communication.

The most relevant propagation phenomenon in this kind of environment is the multipath effect, which is produced due to a set of phenomena such as reflection, diffraction and dispersion that affect electromagnetic waves during their propagation. For example, in vegetation surroundings, according to the vegetation density, the environment can be more diffractive (low density) or more dispersive (high density) [1]. Indoor environments, especially morphologically complex scenarios, cause an inherent difficulty on the waves propagation due to the high number of obstacles within it. In addition, the presence of humans within these environments play a key role due to the fact that the human body absorbs a significant amount of electromagnetic waves, causing the shadowing effect, which has more influence when the number of people increases, for example, in a congress center [2].

II. Methods

In order to characterize the above-mentioned environments analytically, the literature shows that techniques based on Ray Tracing are appropriate approaches for the wireless channel characterization due to the accuracy of the obtained results and the computational time required. Therefore, an in-house implemented deterministic 3D Ray Launching (3D-RL) algorithm [3] optimized with hybrid simulation has been used to analyze, characterize, and model real environments for optimal radio planning. From the point of view of the experimental analysis, a set of wireless systems from PAN (Personal Area Network) to WAN (Wide Area Network), such as ZigBee, UWB (Ultra-Wideband) and LoRaWAN, among others, have been deployed individually or in combination according to the environment and the need to cover. All of this, to convert these types of environments into context-aware scenarios (Smart Home, Smart Health, Smart Nature...), considering accuracy and optimization on the deployments of the WSN.

III. Main Results and Discussion

In this section, the main results of the research work that have been published in JCR/SJR indexed journals are presented. Fig. 1 shows the design and validation of an Augmented Reality system for impaired people in Baluarte Auditorium [2]. Fig. 2 shows a basketball player on-body biophysical parameter monitoring based on WSN integration [4]. Finally, in Fig. 3 and Table 1, a wireless characterization of an UWB-based system in an industrial environment is assessed [5].

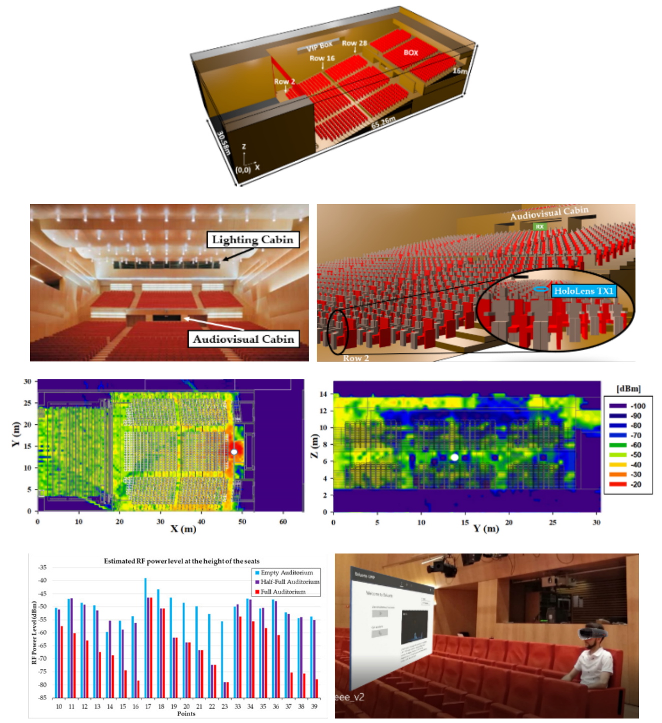

Figure 1. (a) Baluarte Palace of Congresses and Auditorium of Navarre scenario created with the 3D-RL tool; (b) Main auditorium real view; (c) Full auditorium with 1,568 people seated for simulation analysis; (d) and (e) Estimated RF power distribution 2D horizontal and vertical planes (XY and YZ); (f) Comparison of estimated RF power level for three different audience distributions (empty, half-full and full auditorium); (g) AR application for Microsoft HoloLens able to help hearing-impaired people during shows in Baluarte Auditorium has been developed and tested.

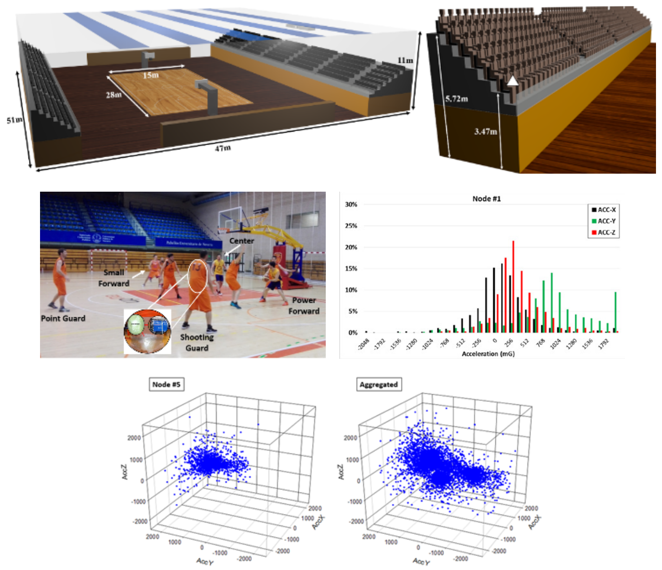

Figure 2. (a) Sport pavilion located at the Public University of Navarre created with the 3D-RL tool; (b) Detailed of a full stand including human user body models for simulation analysis; (c) Offensive tactic during the basketball training (with ZigBee node's packaging on the player's back); (d) Accelerometer data collected distribution from the Point Guard player; (e) and (f) Movement distribution from the Power Forward player and aggregated data for all the players.

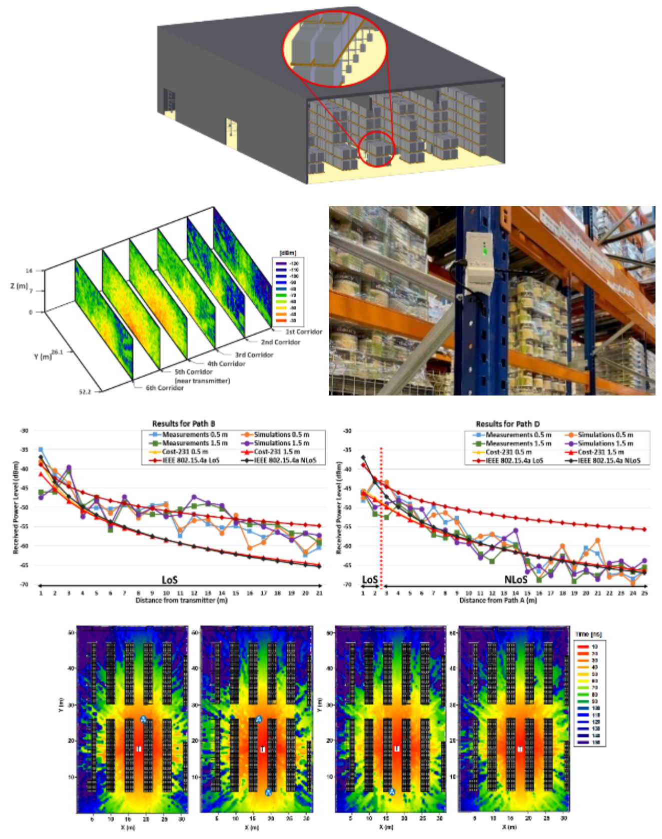

Figure 3. (a) Truck & Wheel Logistics plant created with the 3D-RL tool; (b) Estimated RF power distribution 2D vertical planes (YZ) corresponding to each corridor; (c) UWB anchor's position on the rack; (d) and (e) Comparison of the measurements, simulations with the 3D-RL tool and some empirical models for path B and D; (f) and (g) Estimated 2D ToF at the height of Anchor A20, A15, A30, A29 and Tag (T).

TABLE I. Time of Fligt (ToF) and Distance Comparison Between Tag and Anchors for Decawave (DW) Devices and 3D-RL

Anchor	*DW ToF (ns)*	*3D-RL ToF (ns)*	*DW dist. (m)*	*3D-RL dist. (m)*	*Abs. Error (cm)*
A20	27.95	24.04	8.38	7.21	**117**
A15	28.09	27.08	8.42	8.12	**30**
A29	38.98	40.13	11.69	12.04	**35**
A30	38.96	39.0	11.69	11.70	**1**

IV. Future Work

As future work, we are working on analyzing sub-and millimeter-wave through-human body and vegetation scattering effect evaluated at both the experimental and simulation levels.

References

[1] I. Picallo et al., "A Radio Channel Model for D2D Communications Blocked by Single Trees in Forest Environments," *Sensors*, vol. 19, pp. 4606, 2019.

[2] I. Picallo et al., "Design and Experimental Validation of an Augmented Reality System With Wireless Integration for Context Aware Enhanced Show Experience in Auditoriums," *IEEE Access*, vol. 9, pp. 5466-5484, 2020.

[3] L. Azpilicueta et al., "Convergence analysis in deterministic 3D ray launching radio channel estimation in complex environments," *Appl. Comput. Electromagn. Soc. J.*, vol. 29, pp. 256-271, 2014.

[4] I. Picallo et al., "Basketball Player On-Body Biophysical and Environmental Parameter Monitoring Based on Wireless Sensor Network Integration," *IEEE Access*, vol. 9, pp. 27051-27066, 2021.

[5] I. Picallo et al., "Wireless Characterization and Assessment of an UWB-Based System in Industrial Environments," *IEEE Access*, vol. 9, pp. 107824-107841, 2021.