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Wireless System Integration to Enable Smart Cities and Smart Regions †

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Abstract: The advent of Smart Cities and its extension to Smart Regions requires seamless interaction of systems as well as with users, in a context where a great deal of devices exhibit potential network connectivity. Wireless systems are key elements in order to enable high interactivity, with multiple different systems operating simultaneously within a given region. Multiple network coordination and analysis is compulsory in order to enhance coverage/capcity relations, whilst achieving required bit rates and Quality of Service demands. In this work, the analysis of multiple wireless systems, based on the combination of WLAN/WBAN/NFC will be analyzed in the context of Smart Cities, examining inter-operation performance and overall deployment considerations.

Keywords: Smart Cities; Smart Regions; HetNet; coverage/capacity; IoT

1. Introduction

The evolution towards more sustainable, efficient and interactive environments is leading towards the paradigm of context aware Smart Cities and Smart Regions. In order to achieve high levels of user/system interaction, a large number of sensors, actuators and different types of information generators and sources require communication capabilities. In this context, wireless communication systems can provide low cost solutions for massive transceiver deployments, in line with Internet of Things (IoT) scenarios. In the majority of cases, these transceivers must be compatible with reduced form factors, as well as limited energy resources. Moreover, the increase in required transmission bit rate and the use of wireless systems mainly based on radio broadcast communications, such as Wireless Sensor Networks (WSN), Wireless Personal or Body Area Networks and Public Land Mobile Networks (PLMN), implies further restrictions in terms of coverage/capcity relations. In this sense, one of the fundamental issues to consider is the potential increase of overall interference levels, which can effectively limit wireless system operation. This effect holds for all operational scenarios, but can be particularly remarkable in the case of indoor scenarios, in which wireless transceiver density can increase by 2 orders of magnitude as compared with current values. Therefore, device location and configuration can play a decisive role in overall system performance, reducing interference impact [1–2].

In this work, the analysis of wireless transceivers located within indoor scenarios, as a relevant sub-set of context-aware environments is presented. Different WLAN/WPAN systems have been considered, operating in different frequency bands and Modulation and Coding Schemes (MCS). Wireless channel analysis results are obtained, as well as performance analysis as a function of receiver sensitivity levels, in order to obtain insight in wireless transceiver operation and potential device location.

2. Scenario Description and Wireless System Analysis

As previously stated, indoor scenarios are envisaged to host a great deal of devices requiring wireless communication capabilities, particularly in the 2.4 GHz and 5.8 GHz bands, such as WLAN/WPAN/WBAN transceivers. In order to analyze wireless system performance, a conventional indoor scenario has been implemented, depicted in Figure 1. In order to perform the wireless analysis, an in-house implemented 3D Ray Launching code has been employed, based on Geometric Optics and Uniform Theory of Diffraction and enhanced with acceleration functions based on Neural Network interpolators, Collaborative Filtering database extraction and Electromagnetic Diffusion Equation hybrid simulation, among other [3–4]. The employed simulation parameters are defined in Table 1. Different sources have been located within the scenario, in which all of the electromagnetic material parameters (i.e., conductivity and dielectric permittivity) have been included for all of the elements, such as furnisnings and constructive materials (walls, ceilings, doors, windows, etc.). Moreover, in order to provide realistic system operation, a specifically adapted human body model has also been considered, providing insight in the operation of wearable devices within the scenario.

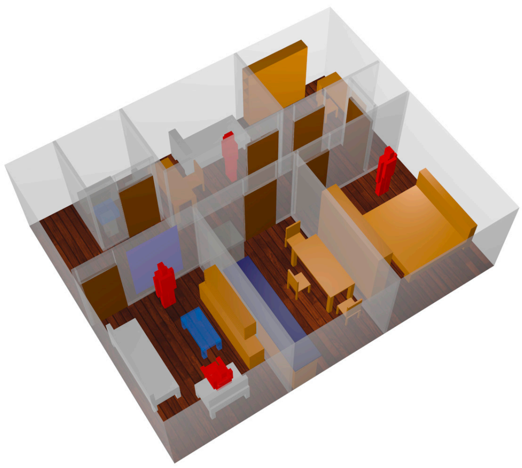
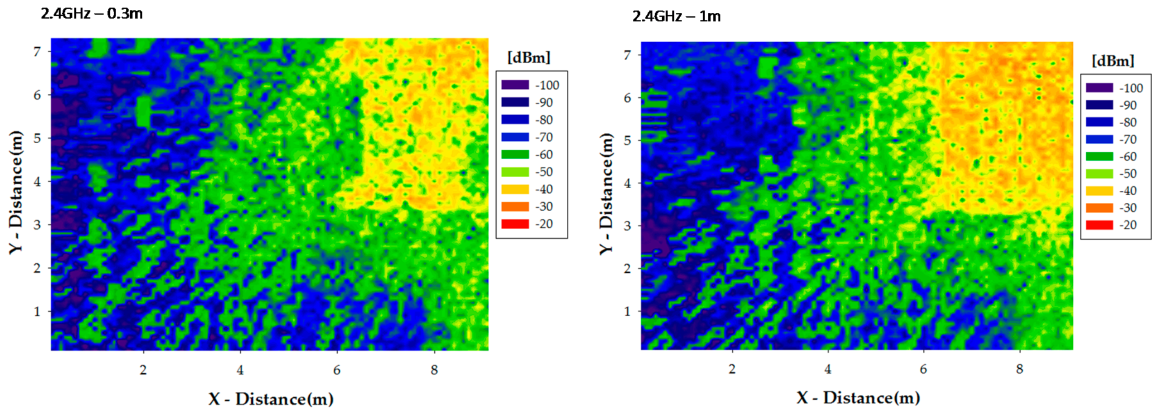


Figure 1. Simulation scenario implemented for analysis with 3D Ray Launching technique, including indoor furnishings and the presence of human bodies within the scenario.

Table 1. 3D Ray Launching & System Parameters.

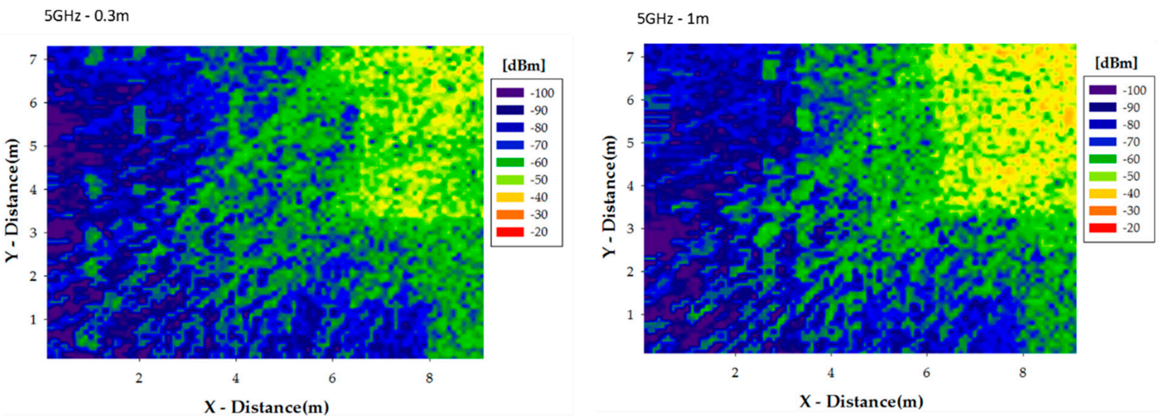
Parameter	Value
Operation frequency	2.45 GHz/5.8 GHz
Output power level	0–10 dBm
Permitted reflections	6
Cuboid resolution	0.1 m–0.3 m
Launched Rays resolution	1°
Modulation and Coding Schemes	802.11n MCS-0, 802.11n MCS-4, Bluetooth LE1M, Bluetooth LE (S = 2), Bluetooth LE (S = 8)

Estimation of received power levels have been obtained for the complete 3D volume of the scenario. Different bi-dimensional cut-planes have been represented for different frequencies of operation in Figures 2 and 3. As it can be seen, wireless signal distribution is strongly dependent on node location as well as on the topology of the scenario. It is worth noting that even if the presence of elements such as walls attenuates the signal, there is still a relevant power distribution within the rest of the scenario. Therefore, simulataneous multi-transceiver operation can lead to increased interference and hence, system degradation in terms of transmission rate reduction and increase in bit error rate/packet error rate values. The presence of users in the scenario also impacts system performance, in terms of increased shadowing as well as on modification of multipath propagation componenets. The impact in wireless channel can be observed in Figure 4, in which values when users are not included and when they are included are shown. Local variation in received power levels can be in excess of 5 dB when including users, reducing therefore effective coverage area of the wireless systems.



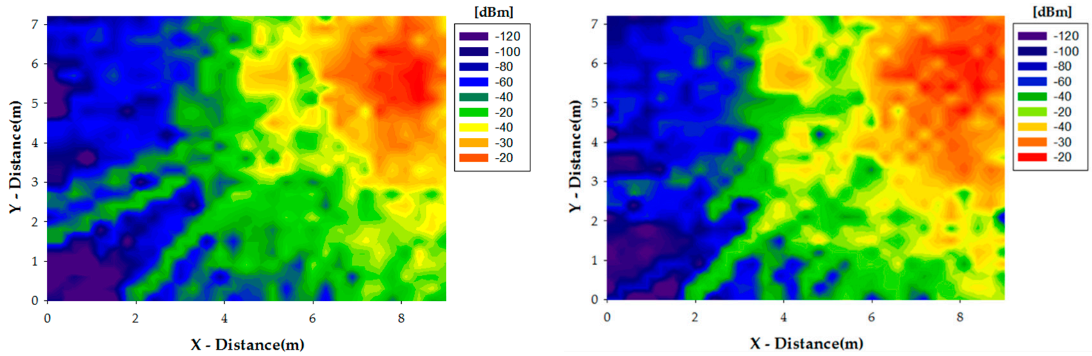
(**a**) (**b**)

Figure 2. Bi-dimensional received power level distributions at an operating frequency of 2.4 GHz, for h = 0.3 m (**a**) and h = 1 m (**b**).



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

Figure 3. Bi-dimensional received power level distributions at an operating frequency of 5.8 GHz, for h = 0.3 m (**a**) and h = 1 m (**b**).



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

Figure 4. Bi-dimensional received power level distributions at an operating frequency of 2.4 GHz, for h = 0.6 m including persons (**a**) and h = 0.6 m without considering the presence of persons (**b**).

Coverage/capacity estimations have also been obtained, as a function of receiver sensitivity. Examples of such estimations are shown in Figure 5 for the case of WLAN 802.11n system operation and in Figure 6 for Bluetooth LE operation, for different MCS in each case. As it can be seen, large signal variations occur in small local variations, owing to strong multipath propagation. As a function of the employed system, coverage values can be compromised. On the other hand, high values of received power levels can also be observed, which in the case of multiple transceiver operation can lead to interference excess. It is therefore compulsory to adequately estimate average coverage values for the specifi zones and reduce transmission levels in order to avoid undesired interference, as well as reducing energy consumption.

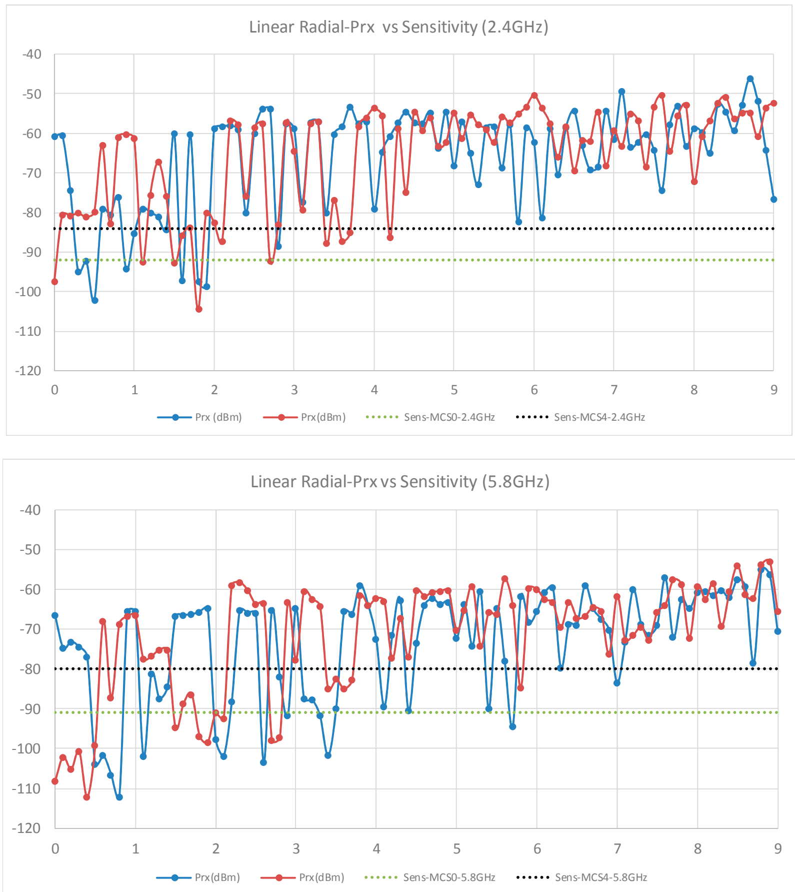


Figure 5. Linear Radial Received Power level distribution vs WLAN 802.11n sensitivity values (MCS-0 and MCS-4). **Top** figure represents values for 2.4 GHz band; and **bottom** figure for 5.8 GHz band.

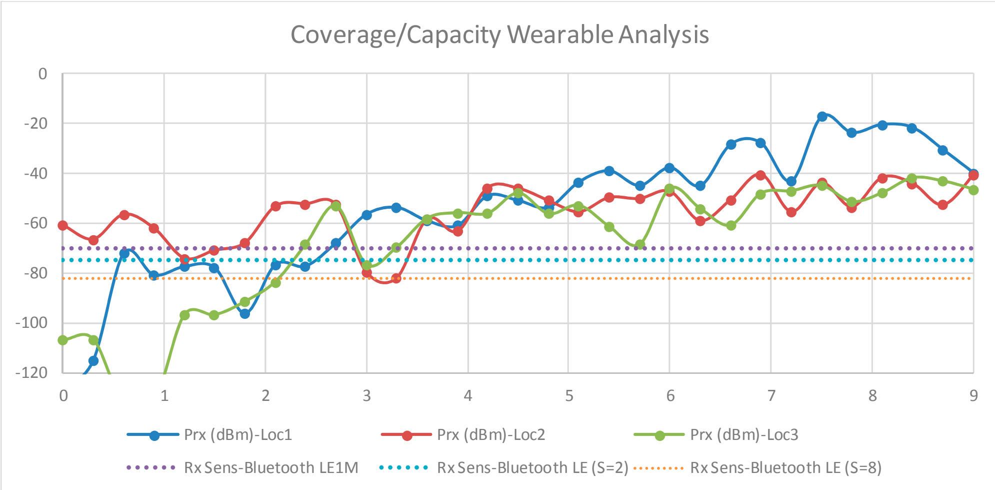


Figure 6. Linear Radial Received Power level distribution in the case of wearable devices operating in different Bluetooth modes (LE1M, LE with 2 symbol/bit header coding and LE with 8 symbol/bit header coding)

3. Conclusions

In this work, we have analyzed the wireless channel performance in a conventional indoor environment, as a function of spatial signal distribution as well as in terms of coverage/capacity analysis for different frequency bands and employed MCS values. The characteristics of indoor scenarios, which include complex topological details given by constructive elements, furnishings as well as the presence of human users determines received power levels distribution, which in turn impact receiver sensitivity as well as overall interference levels. The obtained spatial signal distributions can aid in the network planning phases prior to the deployment of massive transceiver sets, which are bound to operate in collaborative Heterogeneous Network modes.

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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 system analysis; 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.

Abbreviations

The following abbreviations are used in this manuscript:

WSN	Wireless Sensor Network
WLAN	Wireless Local Area Network
WBAN	Wireless Body Area Network
WPAN	Wireless Personal Area Network
PLMN	Public Land Mobile Networks
IoT	Internet of Things
MCS	Modulation and Coding Scheme

References

1. López-Iturri, P.; Aguirre, E.; Azpilicueta, L.; Astrain, J.J.; Villandangos, J.; Falcone, F. Challenges in Wireless System Integration as Enablers for Indoor Context Aware Environments. *Sensors* **2017**, *17*, 1616, doi:10.3390/s17071616.
2. 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 Ubiquitous Comput.* **2014**, *15*, 171–184.
3. Azpilicueta, L.; Rawat, M.; Rawat, K.; Ghannouchi, F.; Falcone, F. A Ray Launching-Neural Network Approach for Radio Wave Propagation Analysis in Complex Indoor Environments. *IEEE Trans. Antennas Propag.* **2014**, *62*, 2777–2786.
4. Azpilicueta, L.; Rawat, M.; Rawat, K.; Ghannouchi, F.; Falcone, F. Convergence analysis in deterministic 3D ray launching radio channel estimation in complex environments. *Appl. Comput. Electromagn. Soc. J.* **2014**, *29*, 256–271.