
Efficient Wireless Channel Characterization for Context-Aware Scenarios

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1 Introduction

Nowadays, the population shift from rural to urban areas poses severe challenges to cities. In big urban areas, factors related to economies of scale help to reduce operational costs. However, managing such cities is challenging due to the large number of inhabitants and their needs. Thus, such management procedures have to be adapted to a growing and very demanding population. The citizens' quality of life is one of the most relevant aspects in this scenario. Therefore, healthcare services are also taken into account, due to their relevance and the potentially high cost inherent in service provision, which is constantly increasing due to the population growth and the increase in life expectancy. Smart health (s-health), which is understood as a natural evolution of e-health in the context of smart cities, was introduced by Solanas et al., and can be defined as follows:

“Smart health (s-health) is the provision of health services by using the context-aware network and sensing infrastructure of smart cities.”

Solanas et al. [13]

However, such new health paradigm has evolved to transcend the boundaries of smart cities and to be fully applicable to any context-aware environment with the aim to improve the quality of life of people. Noticeably, s-health is a subclass of e-health because it is founded in ICT like mobile health (m-health). However, it differs from m-health in that the underlying infrastructure is not necessary mobile and in most cases it is static. With the aim to provide a long-term sustainable healthcare system, optimized organization and management systems are combined in novel healthcare service implementations. In this way, new models based on e-health, m-health, s-health and Ambient Assisted Living, in which mobile communication systems, distributed sensor networks and optimized middleware have been proposed and are currently being deployed following different strategies (*i.e.* in conjunction with telecom

operators, hybrid mobile WLAN-WSN implementation, etc.). Therefore, one of the main enablers of context aware environments is the use of different wireless communication systems, which provide seamless connectivity to a potentially very large set of transceivers embedded in mobile and wearable terminals, WLAN hot spots or dense wireless sensor network deployments.

2 Wireless Channel Characterization

In the last decades, the use of wireless systems has increased substantially, given the popularity of mobile networks, wireless LAN and wireless sensor networks. The advent of context-aware environments, mainly driven by the trend in smart city/smart region development, is going to increase furthermore the deployment of 4G mobile networks, IoT and the overall evolution towards high capacity and capillarity of 5G systems. In this scenario, one of the main considerations is to control interference precisely, in order to increase coverage/capacity ratios. In this sense, given the wide variety of existent wireless systems and the inherent complexity of large, dense urban scenarios, radio-planning tasks are compulsory to fully account for useful server signals as well as intra-system and inter-system interference sources. In order to accomplish that, several techniques can be used, from semi-empirical regressive methods, which exhibit large errors and measurement dependent models, to deterministic based techniques like full wave electromagnetic simulation. As a midpoint between precision and computational cost, deterministic Ray Launching (RL) methods offer a good trade-off between precision and computational cost. However, performing real measurements is very time consuming and becomes impractical in complex, large scenarios [1]. With the aim to avoid this burden, simulation techniques based on Ray Tracing, combining Geometric Optics and Uniform Theory of Diffraction, are used to predict waves' behaviour within a given environment. Those simulations depend on a number of parameters, namely angular resolution, number of rebounds, cells size, etc. By tuning these parameters, high-definition (HD) and low-definition (LD) results can be obtained. Although more practical than manual measurements, the computational cost of simulations in HD prevents their use in complex environments and their LD counterparts are applied.

3 Recommender Systems and Collaborative Filtering

Recommender systems [11] play an active role in the Internet through the advances in data mining and artificial intelligence. Collaborative Filtering (CF) [8] is a kind of recommender system that comprises a large family of recommendation methods. The aim of CF is to make suggestions on a set of items I (*e.g.* restaurants, films or routes) based on the preferences of a

set of users U that have already acquired and/or rated some of those items. Recommendations provided by CF methods are based on the premise that similar users are interested in similar items (*i.e.* they share similar patterns). Therefore, items which pleased user u_a could be recommended to user u_b , if u_a and u_b are similar. In order to predict whether an item would interest a given user, CF methods rely on a matrix M of n users (rows) and m items (columns), where each matrix cell $M_{i,j}$ stores the rate of user i on item j . The interested reader could refer to [5,6,7,12] for a detailed CF's state-of-the-art.

4 Hybrid method for Wireless Channel Characterization

One of the issues to consider in the design of communication networks in the context of s-health scenarios is their performance in terms of coverage/capacity ratios [4,9], with particular consideration of the impact of interference due to simultaneous use of multiple users and systems [10]. It is in this case where careful radiofrequency signal analysis, in terms of useful signal transmission and existence of potential interference levels must be estimated, as a function of user density, transceiver type and location. As previously stated, wireless signal analysis in large complex scenarios is computationally costly and requires the use of optimized deterministic techniques. In the case of very large scenarios, such as cities, this approach can still be computationally too demanding and combination with other estimation approaches is compulsory [1]. In order to minimize computational cost for certain scenarios, we proposed the combination of in-house developed 3D Ray Launching code with CF techniques in [2]. The main idea of our hybrid proposal is to use the ability of CF methods of predicting rates to find the values of empty cells in LD simulations. Therefore, we implemented a hybrid method which follows a two step procedure (*i.e.* neighbourhood search and recommendation/prediction computation) in order to estimate the power level of empty/error cells so that they are as similar as possible to the values that would have been obtained in an HD simulation. Figure 1 shows an example of the outcomes obtained by the hybrid approach. Our proposal has been tested in different scenarios such as medical emergency rooms [3], in houses with concrete rooms distribution [10] and at universities with different kinds of laboratories and offices [2]. The outcomes of such experiments showed that our proposal was not only more accurate than other state-of-the-art methods, but also more efficient in terms of computational cost. Therefore, we may conclude that our proposal is accurate as well as efficient, and that could be used to enhance the accuracy of LD simulations in diverse scenarios.

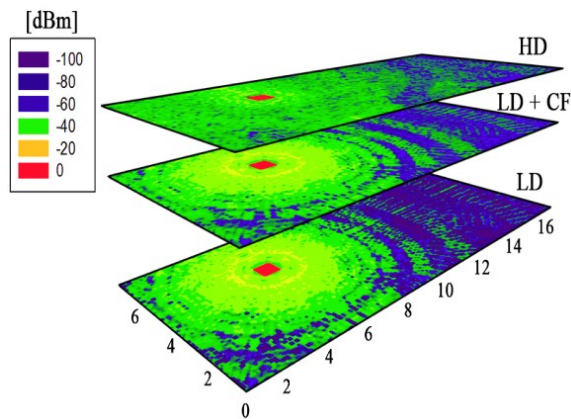


Fig. 1: Received power level estimation when using HD (top), LD+CF (middle) and LD (bottom).

5 Conclusions

In this paper, we have stated the importance of healthcare systems in the context of smart cities. Moreover, we have pointed out the relevance of the new health paradigm, smart-health, and the importance of increasing the coverage/capacity ratios of wireless systems in context-aware scenarios such as dense urban areas or hospitals. We have showed that CF methods can be successfully applied to improve the accuracy of LD simulations performed by a RL approach and that our proposal is fast and could help to reduce the HD simulation costs. Therefore, Collaborative Filtering could be integrated with the sensing infrastructure of smart cities to improve the sustainability by optimizing the resource usage in the communication networks field.

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