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Room-level Indoor Positioning with Wi-Fi and RFID Fingerprints

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ABSTRACT

This paper shows the advantages and limitations of combining RFID and Wi-Fi technology for estimating the location of a user in an indoor environment. The paper relies on a simulated environment, with one or several RFID readers being deployed inside a room and several Wi-Fi devices spread, exclusively, around the surrounding area. The parameters of the simulated environment were drawn from a real measurements.

Categories and Subject Descriptors

D.2.m [**Software Engineering**]: Miscellaneous—*reusable software*

General Terms

Design, Performance, Theory

Keywords

Wi-Fi, RFID, fingerprinting

1. INTRODUCTION

This study considers RFID due to its popularity in various indoor scenarios, such as commuting hallways, office buildings, schools, hospitals, among others [2]. It is an attractive signal for indoor positioning and tracking, since it offers, contactless communication, non line-of-sight readability, compactness and low cost [3]. Passive elements are particularly attractive as they can be used to mark a wide range of objects, *e.g.*, clothes, but raise more privacy concerns. However, the coverage of this technology is, by definition, smaller than traditional Wi-Fi networks [4, 3, 2] as the information is carried in the back-scattered power.

The aim of this study is to understand how RFID emitters, deployed inside a room, improve the performance of a Wi-Fi based indoor positioning method taking into account low and high density Wi-Fi scenarios. In addition to this, the study offers advice for possible deployment of such system, regarding the best location for the RFID emitters and the environment where they should be deployed. Furthermore, the software developed for this study is available at [1].

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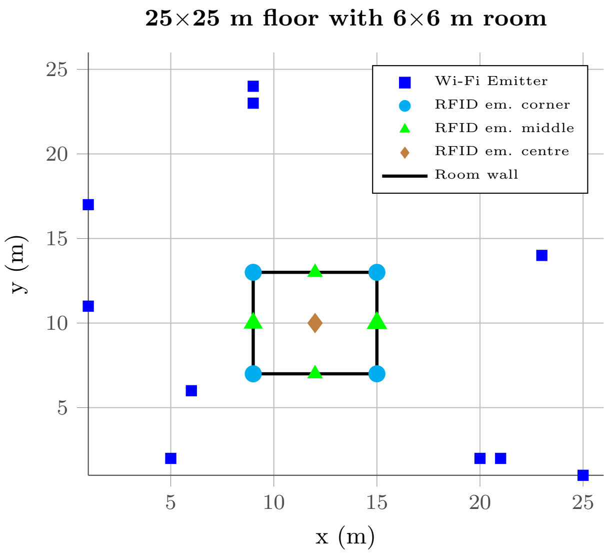

Figure 1: Simulated area and room.

2. SIMULATION DESCRIPTION

The simulation is done over a $M_1 \times N_1$ m area with a room of $M_2 \times N_2$ m randomly placed inside this area. In this simulation M_1 and N_1 were set to 25 m and M_2 and N_2 to 6 m. The simulation defines several user paths inside the room, where RFID emitters are deployed in different configurations, as shown in Fig. 1. The Wi-Fi emitters are exclusively deployed on the outside of the room, with a density according to the studies carried out in university buildings in Finland [7, 6]. For high density scenarios the number of Wi-Fi emitters was set to 24 and 8 for low density scenarios. The user movement follows a random walk [5] model with 1 meter fixed steps. For each scenario, the simulation defines 1000 paths of 100 steps in inside the room.

Regarding the RFID, the simulator assumes the user is wearing a passive tag, being tracked by the network. For this paper, up to four readers are deployed inside the room at specific locations. These readers are responsible for capturing the back-scattered power sent by the antenna or tag placed at the user. The tag can be placed, for example, directly in the garments of the user [2]. Afterwards, the

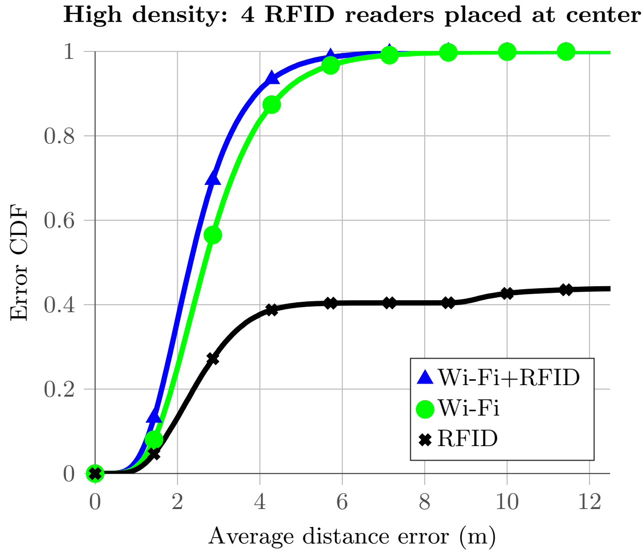

Figure 2: Average error probability using four RFID emitter configurations.

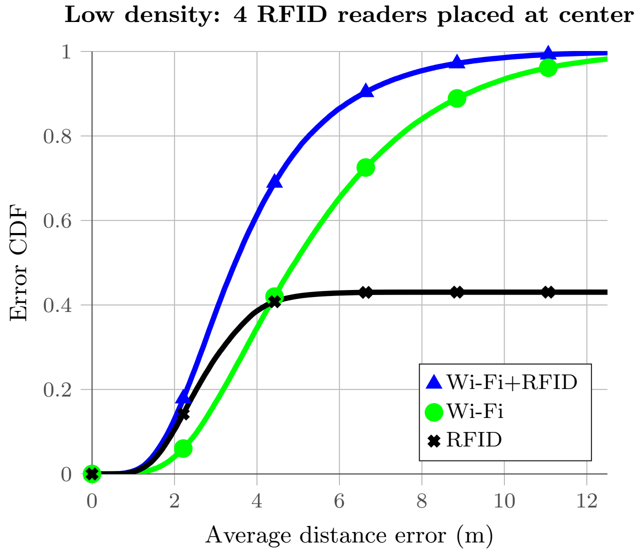

Figure 3: Average error probability using one RFID emitter configurations.

read values are communicated over a network with possible synchronization issues left out of this study. The backscatteredpower of RFID has been modeled according to the real-field measurement analysis in [2, 4, 3].

3. RESULTS AND CONCLUSIONS

In high density Wi-Fi environments (Fig. 2), the combination of Wi-Fi and RFID fingerprints leads to an estimation error below 4 m for 95% of the times when using Wi-Fi and RFID, compared to 85% of the times when only Wi-Fi is used. For low density Wi-Fi environments (Fig. 3), the presence of in-room emitters leads to a significant accuracy improvement. An estimation error below 4 m is reported 70% of the times when Wi-Fi and RFID are used, in comparison to 30% of the times when only Wi-Fi is used.

Hence, the deployment of RFID emitters for hybrid Wi-Fi-RFID localization is highly recommended in low density Wi-Fi environments (e.g., density below 1 emitter per 50 m^2), because, in such scenarios, the accuracy is expected to improve by 40%. Table 1 summarises the root mean square error for the several configurations considered over a larger number of environments. Also, while in the table the configuration with RFID only is showing better performance than Wi-FI for some scenarios, one should take into mind that the coverage area of the technology is smaller.

Table 1: Root mean square error per location for 50 low density scenarios

Location and number of RFID readers	Root mean square error (m)		
	Proposed Wi-Fi+RFID	**Wi-Fi only**	**RFID only**
Corner, 1	4.90	5.12	2.94
Middle, 1	4.59	5.09	7.70
Center, 1	4.61	5.16	6.21
Corner, 4	4.59	5.10	3.48
Middle, 4	3.39	5.09	4.19
Center, 4	3.45	5.14	3.57

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