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Enhancing Cooperative Localization by Exploiting Human-Induced Effects on RSS-based Ranging Measurements

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***Abstract*— In this paper we present quantitative experimental evaluations of human-induced perturbations on Received Signal Strength (RSS)-based ranging measurements applied to cooperative mobile positioning. We prove that the effect of cooperation based on ranging distances among neighbouring peer-to-peer devices is very limited if the impact of the human body is not taken into account when performing experimental activities.**

Keywords-component; Cooperative Positioning; Indoor Positioning; Human-body

I. INTRODUCTION

The smartphone market is foreseen to continue to grow in the near future mostly driving the competition to applications and services rather than to the technical specifications on the device itself. Services providing positioning information represent nowadays the applications that are forecast to maintain an increasing interest also in the near future. Moreover, the indoor environment has so far gifted researchers with huge challenges related to the implementation of location-based applications and positioning algorithms, because of its intrinsic complexity which severely affects the accuracy of measurements, due to unpredictable signal fluctuations [1]. As demonstrated in [1][2] overlapping channels, shadowing, multipath, objects, and sensitivity variations of heterogeneous wireless cards make it difficult to perform accurate applications providing positioning services [2][3]. This is the reason why, in literature, new positioning methods and techniques have been developed in order to provide valid alternatives to conventional approaches, known under the name of *Cooperative Mobile Positioning* [4] (Fig. 1). It is indeed understood how, differently from selfish traditional methods, the exploitation of the most likely reliable RSS measurements detected in the ad-hoc links offers a valid and complementary solution to non-cooperative ones. However, in the aforementioned scenario, the human body also represents another source of inaccuracies as it also causes unpredictable fluctuations in the RSS. In fact as it contains around 70% water, it absorbs part of the 2.4 GHz WLAN radio signal causing significant decays in the detected RSS. In particular,

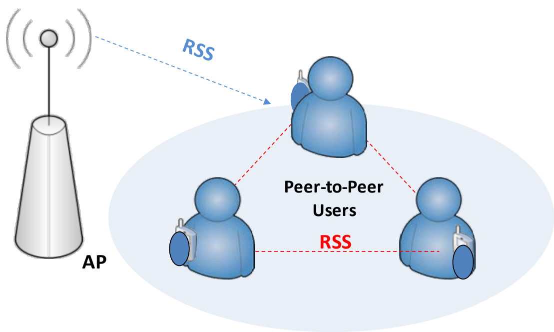

Figure 1. Cooperative positioning with human body effect

the effect of the user's body has already attracted interest in research being recognised as one of the most effective sources of errors in the final position estimation [4-6]. This is because the direct propagation path between the Access Point (AP) and the Mobile Station (MS) might be obstructed by the users when he is not facing the AP. Proposed results in [1][3] show that in specific locations the RSS can vary by up to 5 dBm and this depends on the direction that the user is facing, introducing constant biases in the estimated locations. On the other hand the latter, if correctly accounted, can offer a beneficial impact on the positioning accuracy. Additionally, since mobile devices are held by the users, the hand-grip represents an additional source of errors for the RSS measurements mainly due to the close proximity, showing an influence greater than the rest of the human body.

In this paper, we show that human influence cannot be ignored when performing experiments which involve RSS. We also experimentally demonstrate that although the effects of hand-grip (Fig. 2) and body-loss (Fig. 1) generate systematic errors, if correctly accounted and cognitively exploited, it is possible to enhance the beneficial effects of the cooperation among devices in terms of positioning accuracy.

The paper is organized as follows: Section II describes the conceptual flow from conventional to cooperative positioning laying the theoretical requirements for the subsequent human effect on the experimental activity shown in Section III. Conclusions are finally presented in Section IV.

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Figure 2. Hand-grip adopted in the experiments

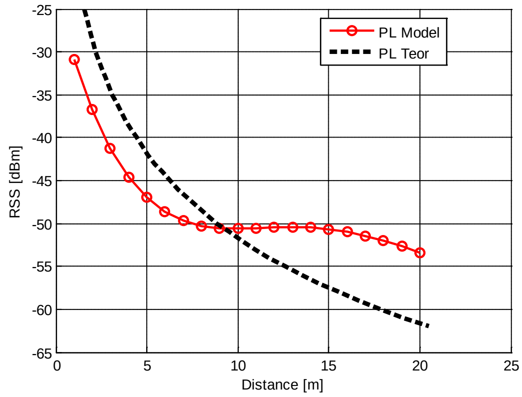

Figure 3. Comparison between theoretical and experimental pathloss

II. From Conventional to Cooperative Positioning

In wireless positioning, based on Signal of Opportunity (SoO) several methods, have been proposed [7]. In particular (Fig. 1), RSS-based methods calculate the location of the target by making use of theoretical, statistical or experimental models in order to relate RSS to the distance from the APs or directly to the MS location. RSS-based methods can be divided into three main categories: cell identifier-based, fingerprinting and pathloss-based. For location-based applications targeting at mass-market the RSS is easily available as it can be passively listened from the deployed WLAN APs. In fact, APs periodically broadcast beacon frames containing network identification information like SSID, BSSID, RSS, RSSI [7-9].

Cell Identifier method makes use of MSs performing a continuous scanning of the radio channels in a passive way (e.g. WLAN) and the estimated position is usually related as the position of the relative AP having the strongest RSS, providing a coarse accuracy level together with an easy deployment and implementation.

Fingerprinting methods are based on time-consuming measurement campaigns necessary to build databases relating recorded RSS values directly to the measured position, which represent the main disadvantage of the technique. However, since fingerprinting algorithms make use of location-dependent error characteristics of RSS, represent the most robust technique against environmental impairments [1][8].

Pathloss models are used to relate RSS to the distances between the MSs-APs. When at least three fixed reference points are known, trilateration can be applied. Due to the low system set-up cost of pathloss-based positioning, we concentrate on this technique [1][8] (Fig. 3).

Cooperative Mobile Positioning (CMP) [4] makes use of data-fusion filters for combining short-range measurements (detected from peer-to-peer communications) and long–range ones measured from deployed infrastructure. The basic concept is that "*exploiting the most likely reliable short-range measurements coming from the neighboring mobile devices it is possible to enhance the location accuracy with respect to conventional techniques*" [4]. It has been demonstrated how exploiting the spatial proximity estimated within a group of devices connected in ad-hoc mode it is possible to enhance the accuracy of the location estimation by adopting Least Squares (LS) and Non-Linear-least-Squares (NLLS) (Fig. 4). In this paper, we show results with and without the effect of human body mitigation in the data-fusion algorithm achieved by exploiting the NLLS algorithm proposed in [1]. Further details concerning the positioning algorithm can be found in [1][4].

III. Human Effects on Cooperative Positioning

The human body has a huge impact on the RSS measurements [1]. This can be demonstrated by defining four study cases: 1) (front) Line-of-Sight (LOS) between AP and MS; 2) (back) No LOS between AP and MS, with the user's body occluding the path; 3) (right) AP on the right side of the user; 4) (left) AP on the left side of the user. We perform the experiment by placing the MS at 5m from the AP. As expected, Fig. 5 and Fig. 6 show the error introduced by the human body on the RSS and estimated distances when the LOS between MS-AP is obstructed by the human body. Specifically, the human body can introduce an error up to 13dBm. Being the RSS jeopardized by the human body, as a consequence also the estimated distance from the AP is corrupted as shown in Fig. 6. Additionally when the mobile device is hold by the user, even with a the simple hand-grip as shown in Fig. 2, the hand-grip itself can introduce a loss up to 18dBm if compared to the case without the hand effect. It is worth mentioning that such effect is visible even in cooperative positioning, highly reducing the benefic effect of the cooperation. At this purpose, the test scenario comprises four APs and three MSs placed in the center area with coordinates: AP1(0,0), AP2(0,14), AP3(-7,7), AP4(7,7), MS1(-1,7), MS2 (1,7), MS2(0,8). A set of 100 RSSs are logged from each AP in the three MSs. The experimental path-loss model of Fig. 3 has been applied to estimate the distances APs-MSs and MSs-MSs to be sent to the NLLS algorithm of Fig. 4. Fig. 7 shows an average of the estimated positions without cooperation, with cooperation affected by the human impairments, and with augmented cooperation exploiting the information provided by the human body. As expected, since short-range measurements are corrupted the data-fusion

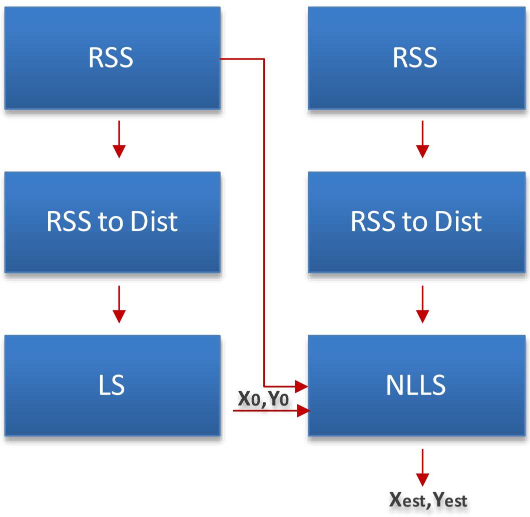

Figure 4. Data-fusion Algorithm

algorithm cannot provide the expected improvements in terms of positioning accuracy with respect to conventional non-cooperative cases. However, by knowing the most likely grip effect and orientation of the users among each other it is possible to apply a simple correction factor related to the human-induced impairments. By simply applying such correction-factor to the RSS recorded from the close ad-hoc links, the cooperation (augmented cooperation) among neighboring devices has the expected beneficial effect on the positioning of the overall group as shown in Fig. 7 and Fig. 8.

In summary, as a key point of cooperative mobile positioning is in the accuracy of the distance estimation among neighbors connected in ad-hoc mode, when the aforementioned distances are not properly calculated, the expected beneficial effects of cooperation are highly compromised. In fact, the effect of both hand-grip [10-13] and body-loss [13-16] does not only corrupts APs-MSs measurements but also MSs-MSs ones, causing a degradation in the potential of cooperative approaches. Hence, the close-proximity range estimation needs to be very accurate, which in real-case scenarios does not happen due to the effect of body-loss and hand-grip in the RSS.

Conclusions

In this paper, we have demonstrated that the influence of the human body on mass market devices has huge impact when performing experiments on RSS-based positioning. Specifically, the proposed results have shown the beneficial effect of the knowledge of the user's body influence by finding that the cooperation among neighboring mobiles does not significatively improve the accuracy of the estimated positions with respect to non-cooperative scenarios if the presence of the user is not correctly accounted in the data-fusion algorithm.

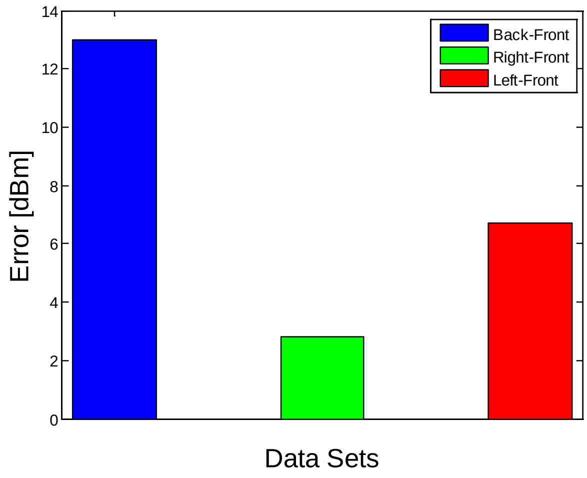

Figure 5. Error in RSS detection with respect to Front view

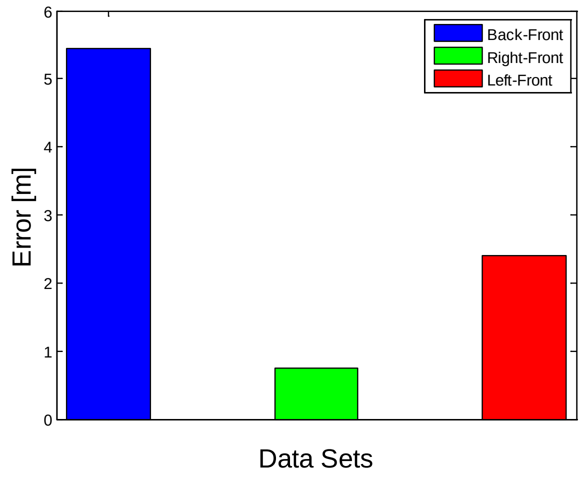

Figure 6. Error in distance estimation with respect to Front view

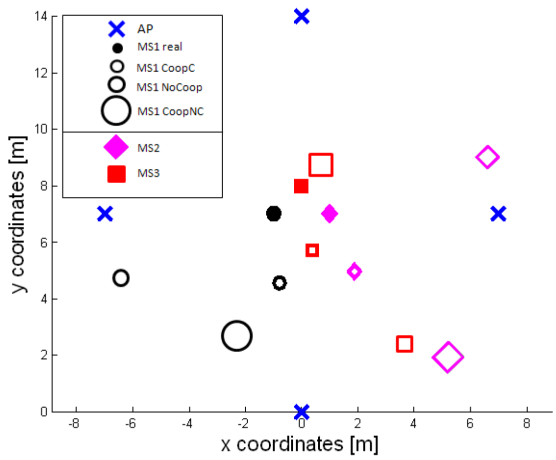

Figure 7. Estimated positions with and without augmented cooperation

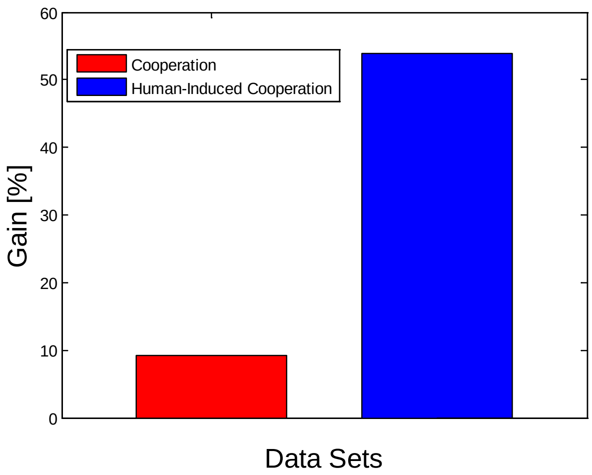

Figure 8. Peercentage Gain introduced by considering the effect of the human body

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