Indoor Localization System based on Commensal Radar Principle

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***Abstract*—This work describes a novel way to use commensal radar principle [1] for indoor localization. We use the existing LTE (Long Term Evolution) communication infrastructure for this purpose. The proposed system uses software defined radio (SDR) platforms for live demonstration and the performance evaluation of the same is presented for an indoor laboratory environment. The accuracy of the proposed system can be improved using 'timing advance' information.**
***keywords* - commensal radar, indoor localization, LTE, SDR.**

I. Introduction

Localization is a well attended topic because it has the potential of leveraging various commercial applications e.g. Internet of Things (IoT), advertisement and social networks. Localization at outdoor environments has been successfully implemented using global positioning system (GPS) technology. But, in indoor environments, there is a need for alternative specialized methods due to limited usability of GPS. Presently, indoor location-based systems use various techniques [2] like Time of Arrival (TOA), Time Difference of Arrival (TDOA), Angle of Arrival (AOA) and Received Signal Strength Indicator (RSSI). To cater for various indoor positioning applications [2], an indoor positioning system should have the following desirable properties; the most important parameter is the accuracy of localization. As the infrastructure will be mainly battery operated mobile devices, they should have less energy consumption, less footprint and less computational complexity and minimal dedicated infrastructure.

The proposed work uses a novel commensal radar system (inspired by biological inter-species coexistence where one system exploits other without detrimental effect) which uses communication radiation as the illuminator, called CommSense [3]. It uses LTE communication infrastructure [4] due to its wide availability in indoor environments. Therefore, we call this system LTE-CommSense [5]. We believe, utilization of orthogonal frequency division multiplexing (OFDM) and multiple input and multiple output (MIMO) may provide better resolution for our scenario. Indoor localization based on Wi-Fi RSSI is a well-studied area [6]. Therefore Wi-Fi based CommSense (WIFisense) can also be proposed. But LTE signal provides better range resolution due to its wide bandwidth ranging from 1.4 to 20 MHz. Also, large frequency bands ranging from 800-3500 MHz and support of both FDD and TDD enhances the opportunity of LTE deployment in many countries.

Following this principle, the proposed system uses passive receiver nodes only that uses existing LTE communication signal. Communication receiver modules extracts information which is affected by the channel condition. It uses the same spectrum of the communication system without any harmful effect on it. The commensal principle based indoor localization is done in three phases:

1) The communication signal strength between LTE receiver (UE) base station ($eNodeB$) gets affected by the span of the channel. Following the CommSense principle, we use three passive nodes (PN) for two dimensional (2D) indoor localization. These PNs determine respective distances of an LTE communication receiver equipment (UE) by measuring incident signal power at the PNs with which the UE communicates with the LTE base station ($eNodeB$). After the respective distances are calculated, we use the distances for trilateration to determine the co-ordinate of the UE. Depending on the PN placements, the trilateration algorithm is modified to have less calculation complexity. The calibration of the system to calculate the distance of the UE from a PN is performed. We calculated the accuracy of our proposed method in a indoor laboratory environment. Use of LTE for RSSI based indoor localization and demonstration on SDR platform is a novel effort. We will compare the performance of LTE-CommSense with WiFisense.
2) We extend the $Phase-1$ work for 3D localization in $Phase-2$. To the best of our knowledge, application of LTE-CommSense for RSSI based 3D localization in practical situation using SDR platforms is never attempted before.
3) In $Phase-3$, we perform the feasibility of using 'timing advance (TA)' information which is communicated between the UE and $eNodeB$. This involves synchronization of the PNs with LTE UE and $eNodeB$, decoding LTE control information to extract TA and evaluation of distance to be used for localization. LTE-CommSense application for localization has not been attempted before.

II. Experimental Setup and Requirements for Proposed Indoor Localization

The experimental setup for $Phase-1$ work is shown in Figure 1. Without any loss of generality, we place the PNs at right angle to each other to reduce the computational complexity for trilateration as will be detailed later. For calculating distances($d_i; i = 1(1)3$) of respective PNs (A, B, C) from the LTE UE we have adopted range based positioning algorithm with RSSI as the ranging metric. This computation depends on the channel model. An indoor channel model for indoor laboratory environment was selected [2], [7].

To evaluate the parameters of the channel model in an indoor environment, we have collected the RSSI values at multiple known distances. By using Python Script, we have calculated the constant values of the parameters.

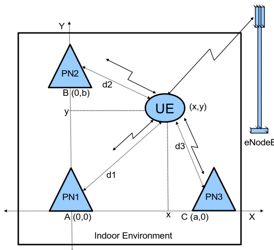


Fig. 1. Experimental Setup for Indoor Localization using LTE-CommSense

After we have evaluated the distances($d_i; i = 1(1)3$) of respective PNs (A, B, C) from the LTE UE, we apply our proposed less computation intensive trilateration algorithm to find out the location of the UE. For the PN coordinates and their evaluated distances from the UE (Figure 1), the co-ordinate of the UE can be derived as: $(x, y) = \left(\frac{a^2+d_1^2-d_3^2}{2a}, \frac{b^2+d_1^2-d_2^2}{2b}\right)$

We have used four SDR Platforms. Three of them are used as PN and the fourth is modeled as LTE UE [8]. Laptop is used to interface with the SDR platforms.

III. Evaluation and Results

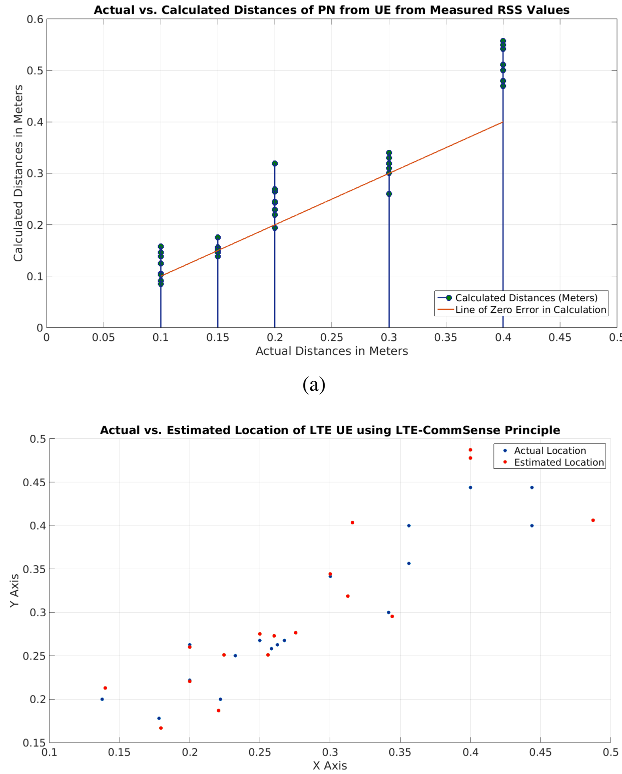
First we evaluate the accuracy of distance calculation of individual PNs. The evaluated distance values using our proposed approach along with the actual distance values are shown in Figure 2(a). For the complete localization system, the localization performance of eighteen different indoor location coordinates are shown in Figure 2(b).

IV. Deployment Requirements

We deploy SDR platforms as passive nodes for the localization purpose and model the LTE UE in SDR as well. For 2D localization in $Phase - 1$ of our work, we deploy three SDR platforms as defined locations and one SDR as LTE UE. One more SDR platform needs to be deployed in $Phase - 2$ i.e. for 3D localization. To position the passive nodes at defined locations and provide absolute position measurements, a ground truth measurement is required for the SDR based passive nodes.

V. Conclusion and Future Work

In this work we have proposed commensal radar principle based approach for indoor localization application and divided the activity into three $Phases$. As part of $Phase - 1$ activity, 2D localization system comprising of passive nodes along with the LTE UE is modeled using SDR platforms and the performance evaluated. By incorporating more nodes at defined locations and by enhancing the trilateration algorithm, the proposed 2D localization method is planned to be extended for 3D localization ($Phase - 2$ activity). Additionally, considering the RSSI as the ranging metric, utilizing the timing advance (TA) of LTE communication system may further improve the recognition accuracy. In $Phase - 3$ of our planned work, feasibility of this will be investigated.



(a)

(b)

Fig. 2. (a) Evaluated distance of UE from PN along with actual distance value and their differences, (b) Localization performance of CommSense based System.

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