

Towards Self-Learning Radio-Based Localization Systems

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Abstract—Location-awareness indoors will be an inseparable feature of mobile services/applications in future wireless networks. Its current ubiquitous availability is still obstructed by technological challenges and privacy issues. We propose an innovative approach towards the concept of indoor positioning with main goal to develop a system that is self-learning and able to adapt to various radio propagation environments. The approach combines estimation of propagation conditions, subsequent appropriate channel modelling and optimisation feedback to the used positioning algorithm. Main advantages of the proposal are decreased system set-up effort, automatic re-calibration and increased precision.

Index Terms—propagation models; localization techniques; indoor applications;

I. INTRODUCTION

The large-scale adoption of wireless technologies, and the rapidly growing number of mobile services and applications, offers an excellent opportunity to explore the potential of localisation to improve service provisioning (e.g., Location Based Services). This holds equally strong for both outdoor and indoor environments (museums, shopping malls, hospitals). The global positioning system (GPS) technology has solved the problem of outdoor localisation, but an effective and affordable localisation solution for indoor environments is still challenging to find [1]. A localisation solution combines input parameters from a specific technology with a positioning algorithm that processes these parameters to derive location. Various technologies and localisation techniques have been proposed and yet not a single one provides cost-efficient and easy to deploy system that can meet strict requirements towards accuracy.

Technologies Several competing technologies are discussed for localization purposes. We mention few commonly used ones. *Bluetooth and WiFi* are attractive due to their wide spread adoption and low deployment cost. However, location is derived from signal strength and therefore radio interference introduces position inaccuracies. The *Radio-Frequency Identification (RFID)* technology is easy to deploy with cheap devices but it also requires high installation density and target's cooperation [3]. *Ultra-wide band (UWB)* can provide centimeter-based accuracy and robustness to interference at the cost of expensive hardware needed for accurate time synchronisation [6]. Cellular networks are also well studied

for the purpose of support localisation due to their ubiquitous coverage

Positioning techniques The number of proposed localisation techniques is large as well. The most often cited techniques are angulation, lateration and fingerprinting, e.g., [1], [6]. The choice of techniques is determined by the application environment, cost, and complexity. In an *angulation/lateration* technique the target coordinates are derivative of different angle/distance measurements to known reference points [6]. Distances can be obtained by various methods such as time of arrival (ToA), time difference of arrival (TDoA), or received signal strength (RSS). Lateration accuracy depends on the input parameters and their vulnerability to the indoor multipath phenomenon. A *fingerprinting* technique compares real-time measurements to an off-line constructed database [2]. Since the database is constructed for a specific indoor environment, fingerprinting is time and effort consuming and unfit for dynamic environments [7], [5]. An improvement to the technique explored by [7] is to alternate between several pre-generated databases depending on sensed changes in the radio channel.

Adaptive localisation system (ALS) We take an alternative approach towards indoor positioning, namely a flexible system that can dynamically detect changes in the radio environment and adapt to them. ALS focuses on the use of radio frequency technologies such as WiFi and Bluetooth with the intention to extend towards cellular technologies such as UMTS and LTE. The goal of ALS is easy deployment, minimum re-calibration and high localisation accuracy.

II. ADAPTIVE LOCALISATION SYSTEM

The proposed technique consists of two components. The first component - an adaptive propagation model - is responsible for monitoring the indoor propagation conditions and adapting the parameters of the propagation model when necessary. The second component - a self-learning localisation algorithm - uses feedback from the (adapting) propagation model to re-calibrate the localisation mechanism.

A. Adaptive Propagation Model

Radio-based systems for indoor localisation that rely on RSS are strongly dependent on the appropriate modelling of the propagation channel. An indoor radio channel is highly

affected by multipath components and shadowing due to complex indoor layout, e.g., multitude of obstacles on the signal path. Therefore, the accuracy of the whole system depends on how well the different signal components (reflected, scattered and refracted) are modelled.

Indoor channels have been popularly modelled by a log-normal shadowing model [4]. Most previous works on indoor propagation models apply fixed propagation parameters such as shadowing variance σ_{dB}^2 and path loss exponent α . A disadvantage of such approach is its inability to scale to different environments or to changes in the same environment. Each environment has its own specific characteristics. Moreover, changes in the indoor layout (e.g., moving persons) causes changes in the propagation parameters.

Our target is to develop a smart algorithm to derive propagation parameters without any pre-knowledge on the channel. We rely on periodically listening to the channel between reference points with known location to gain knowledge on the propagation conditions and changes therein. Similar approach but only applied to fingerprinting is proposed in [5]. The WiFi radio channel is periodically sensed to detect changes in the propagation conditions and to correct the fingerprinting database. The authors show promising results that can solve the problem of re-calibration. Our goal is to explore even further the potential of a ALS for other radio technologies and applied to lateration and artificial neural networks (ANN) such that the cumbersome generation of database in fingerprinting is avoided.

B. Self-learning Localisation Algorithm

We plan to investigate the benefits of the adaptive model to two positioning techniques. On the one hand, we foresee significant contributions in terms of accuracy and effort to a RSS-based lateration system. Our target is to use the proposed adaptive propagation model to minimise distance errors by updating the model parameters either periodically or before a positioning decision is made. As a result of the update a more up-to-date RSS estimation can be made.

As an additional improvement we envision to combine the adaptive propagation model with opportunistic techniques for signal derivation. One such technique is the careful selection of which reference signals to use in the localisation decision (or to acquire the new propagation parameters for that matter) and the weighting of each contribution when deriving an object's coordinates. Another technique is to make use of channel diversity by collecting readings on several channels and taking the combined feedback in the RSS evaluation. The latter approach is inspired by [8].

Additionally, advantages are also foreseen for localisation methods using ANN. Training the network to identify a correct position can be very time consuming. We believe that our proposed model can be improved by providing more accurate data as input and thus decrease learning times.

III. RESEARCH APPROACH

In order to achieve our goal we identify the following steps. First, we study in detail which aspects of the indoor radio

environment and involved devices affect signal propagation and RSS in particular. Later, we decide on relevant aspects and how to take them into account in the ALS. Currently, we focus on the following aspects:

- RSS sensitivity to device's technical characteristics due to different manufacture specifications;
- differences among devices of the same model due to manufacturing discrepancies;
- propagation characteristics of the radio environment in different directions;
- changes in propagation conditions caused by environmental factors such as temperature or moisture content;
- signal deformation by various types of obstacles.

Based on extensive experiments, we draw several conclusions: performance differences between devices of the same model are smaller than differences between models; indoor channels rarely show the same characteristics in different directions; and depending on the type of obstacle radio signals can vary significantly. We believe that the ALS can offer a way to cope with this differences.

Second, we will design the adaptive propagation model and compare its performance to the log-normal propagation model and to real-time measurements. The success of the model depends on the availability of pre-set reference points that periodically transmit beacons. By overhearing a beacon and knowing the identity and location of the sender current propagation conditions can be derived for the direction of the sender. We currently investigate the minimum set of reference points sufficient for channel estimation. In terms of propagation conditions we are interested in path loss exponents and shadowing variances.

As last step we will select several promising solutions in the area of multilateration, fingerprinting and ANN and extend them with the adaptive propagation model. In order to evaluate the potential gains of the model we intend to design evaluation scenarios spanning various indoor settings in simulation environments and real-world deployments.

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