Demo Abstract: UWB-based Single-anchor Low-cost Indoor Localization System

Bernhard Großwindhager, Michael Rath, Josef Kulmer, Stefan Hinteregger, Mustafa Bakr, Carlo Alberto Boano, Klaus Witrisal, and Kay Römer
Faculty of Electrical and Information Engineering, Graz University of Technology, Austria

ABSTRACT

In this demo, we present a low-cost indoor localization system based on the off-the-shelf ultra-wideband transceiver Decawave DW1000. To obtain an accurate position information, the system makes use of a *single anchor* and of multipath reflections from walls, hence removing the need of installing a network of anchors or any other additional infrastructure. The procedure of determining the position of a tag can be divided in four consecutive stages. First, the location of *virtual anchors* is computed by mirroring the anchor position at reflective surfaces. Using two-way ranging, the distance and channel impulse response (CIR) between anchor and tag is obtained. This actual CIR is compared with expected CIRs from possible tag locations using a maximum likelihood approach to estimate the tag's position. Finally, a *switchable directional antenna* can be exploited to improve the robustness of the system by suppressing undesired, interfering multipath components. By following this procedure, the proposed system can achieve a decimeter accuracy and react to position updates in real-time.

CCS CONCEPTS

• **Computer systems organization** → **Embedded systems**; • **Networks** → *Location based services*;

KEYWORDS

Single-anchor indoor localization, Ultra-wideband technology.

ACM Reference Format:
Bernhard Großwindhager, Michael Rath, Josef Kulmer, Stefan Hinteregger, Mustafa Bakr, Carlo Alberto Boano, Klaus Witrisal, and Kay Römer. 2017. Demo Abstract: UWB-based Single-anchor Low-cost Indoor Localization System. In *Proceedings of SenSys '17*. ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3131672.3136961

1 INTRODUCTION

The superior time-domain resolution of ultra-wideband (UWB) technology allows for accurate localization and tracking, which makes it well-suited for future localization systems, especially in settings with limited global navigation satellite system (GNSS) reception. The off-the-shelf IEEE 802.15.4-compliant UWB transceiver Decawave DW1000 enables UWB-based localization also for low-cost and mobile applications, such as assisted living [7]. However, setting up an indoor localization system is often a costly and time-consuming effort because of the number of anchors that need to be deployed. Existing systems such as SurePoint [2] and ATLAS [6], for example, make use of nine and eight anchors each, respectively.

In this demo, we propose a novel *single-anchor* and low-cost localization system that can achieve a decimeter accuracy and react to changes in the position of a tag in real-time. Instead of making use of multiple physical anchors, the system exploits multipath propagation. The latter consists of scattering from small objects, but also from specular reflections originating from static objects such as walls or windows. By knowing the locations of those objects, the theoretical multipath propagation can be compared with a measured channel impulse response (CIR; see Fig. 1) to tear down the position estimate to a unique solution even in the case of a single anchor. Beside reducing the number of anchors and the required infrastructure, another key benefit of the proposed system is its low channel usage and traffic load. In existing multi-anchor solutions, indeed, ranging is typically conducted with *each* individual anchor.

We present next the principle of the proposed localization system in Sect. 2 and a detailed description about our demo in Sect. 3.

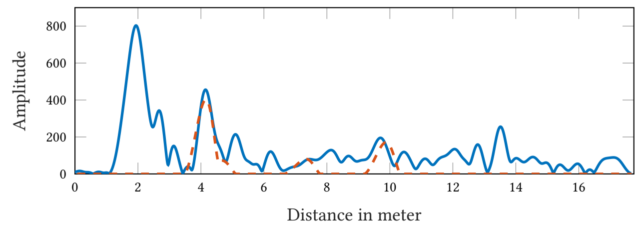

Figure 1: Measured CIR (blue, solid) and theoretical multipath propagation (red, dashed) at estimated tag position $\hat{\mathbf{p}}$.

2 PRINCIPLE

We consider two UWB transceivers, denoted as *anchor* and *tag*. The tag is located at an unknown position $\mathbf{p} \in \mathbb{R}^2$ and estimates its position by communicating with an anchor located at a known position $\mathbf{a} \in \mathbb{R}^2$ and by following the four-stage procedure described next.

Deriving virtual anchor position. Starting from the known location of the anchor and the floor plan, we model the multipath propagation by employing the concept of virtual anchors (VA), also known as image-source model [4]. Rather than calculating the length and angle of individual reflection paths, we assume that the reflections originate from VAs and the geometric distance between VAs and tag determines the path length. The locations of the VAs are obtained by mirroring the anchor position at the reflective surfaces (see red crosses in Fig. 2). These calculations can

SenSys '17, November 6–8, 2017, Delft, Netherlands

ACM ISBN 978-1-4503-5459-2/17/11...$15.00
https://doi.org/10.1145/3131672.3136961

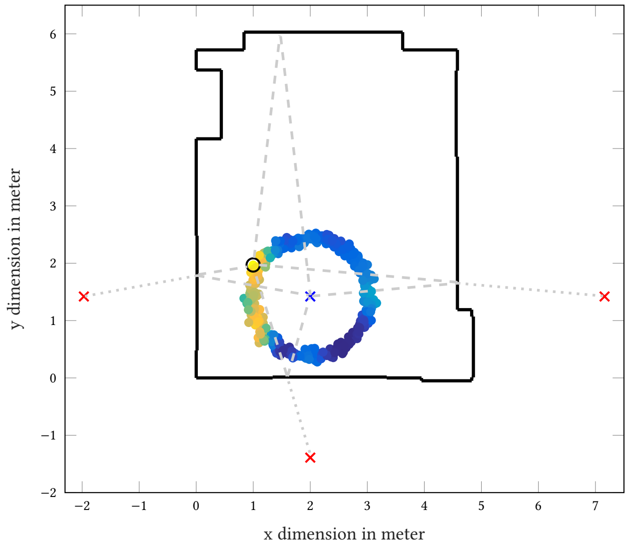

Figure 2: GUI shows floor plan (black, solid), involved multipath reflections (grey, dashed) with extension to the VAs (dotted), anchor (blue, x), VAs (red, x; northern VA not shown), and estimated tag position (black, o). The candidates are colored according to the likelihood.

be done beforehand, which makes the concept of VA attractive for resource-constrained devices.

Obtaining distance and CIR. The Decawave DW1000 transceiver provides several sources of position-related information, e.g., their distance to other nodes or the channel impulse response. The tag determines the distance to the anchor $d_{\mathrm{TWR}} = \|\mathbf{p} - \mathbf{a}\|$ in a double-sided two-way ranging (TWR) scheme to avoid the necessity of a tight clock synchronization. The distance estimation is corrected with a distance- and setting-dependent calibration factor. In the last ranging frame of the TWR scheme (from tag to anchor), the anchor is gathering the CIR.

Position estimation. The distance measurement limits the set of potential position candidates to those located on a circle with the anchor's location as center and radius d_{TWR}, as illustrated in Fig. 2. For each candidate, we calculate the *theoretical* multipath propagation using the geometric distance to the VAs and estimated amplitudes (see red dotted line in Fig. 1) and compare this derived CIR with the measured one (blue solid line) using the likelihood function proposed by Kulmer et al. [3]. This procedure is performed for all position candidates on the circle and the candidate whose theoretical multipath propagation fits best the measured CIR is selected as estimated tag position $\hat{\mathbf{p}}$, marked with a black circle in Fig. 2. A brighter color in the GUI indicates a better multipath propagation fit.

Increasing robustness by means of directional antennas. The principle described so far is already sufficient to estimate the position of the tag. By exploiting a directional antenna at the anchor, also the angular domain can be explored, and one can increase the robustness of the system by suppressing undesired, interfering multipath components. Using directional antennas, indeed, reduces the required bandwidth as shown in [5].

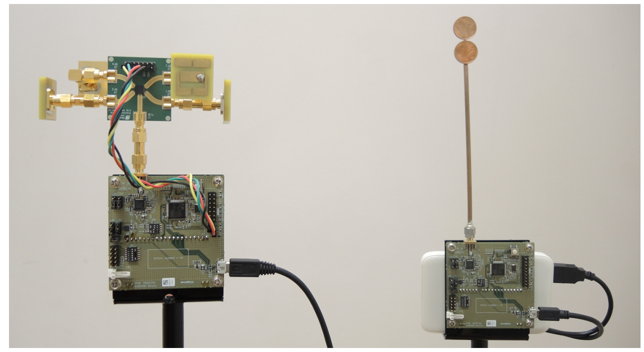

Figure 3: Left: Anchor with switchable antenna system. Right: Tag with omnidirectional antenna and battery pack.

3 SETUP AND DEMO

We demonstrate the functionality of the proposed indoor localization system using two Decawave EVB1000 evaluation boards mounted on tripods to act as anchor and tag, respectively (see Fig. 3). The anchor is powered via USB and connected to a PC for further processing, whereas the tag is powered by a battery pack and can be moved freely by the audience to show the real-time capability of the system. The position of the anchor is known beforehand: the exact coordinates and the floor plan (required to compute the multipath propagation) are obtained during the set-up phase using a laser distance meter. To achieve accurate localization while maintaining a high responsiveness, we limit the algorithm described in Sect. 2 to single reflections, resulting in four VAs inside a rectangular room. This allows for an update rate of several Hz, which is comparable to classical GNSS receivers. Both anchor and tag make use of self-made, omnidirectional UWB antennas. To show how directional antennas can improve the robustness of the system, we also employ a switchable antenna system [1] at the anchor-side (see Fig. 3). The PC connected to the anchor node via USB processes the data in real-time and computes the algorithm described in Sect. 2 using Matlab. Fig. 2 depicts the GUI that is displayed to the audience, which shows the floor plan, the anchor's location, the estimated tag position, as well as the direction of the multipath components.

ACKNOWLEDGMENTS

This work was supported by the TU Graz LEAD project "Dependable Internet of Things in Adverse Environments".

REFERENCES

[1] B. Großwindhager et al. 2017. Switchable Directional Antenna System for UWB-based Internet of Things Applications. In *Proc. of the 14th EWSN Conference*.
[2] B. Kempke et al. 2016. SurePoint: Exploiting Ultra Wideband Flooding and Diversity to Provide Robust, Scalable, High-Fidelity Indoor Localization. In *Proc. of the 14th SenSys Conference*.
[3] J. Kulmer et al. 2017. Using DecaWave UWB transceivers for high-accuracy multipath-assisted indoor positioning. In *Prof. of the ICC Workshops*.
[4] P. Meissner et al. 2010. UWB positioning with virtual anchors and floor plan information. In *7th Workshop on Positioning, Navigation and Communication*.
[5] M. Rath et al. 2017. Multipath-assisted Indoor Positioning Enabled by Directional UWB Sector Antennas. In *Proc. of the 18th IEEE SPAWC Workshop*.
[6] J. Tiemann et al. 2016. ATLAS - an open-source TDOA-based Ultra-wideband localization system. In *Intern. Conf. on Indoor Positioning and Indoor Navigation*.
[7] K. Witrisal et al. 2016. High-accuracy localization for assisted living: 5G systems will turn multipath channels from foe to friend. *IEEE Signal Processing Magazine* 33, 2 (2016), 59–70.