Hihg-accuracy Indoor Positioning System with DecaWave Transievers and Auto-calibration

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***Abstract*—In this work we present the results of a year-long hardware, software and algorithms development for a high-accuracy indoor positioning system with the wireless infrastructure. DecaWave transceivers are used to measure the distances between stationary anchors as well as the distances from the anchors to a mobile tag. Main challenges being solved in this work, aiming to achieve higher accuracy and integrity of estimated position: given pretty accurate range measurements, provided by DecaWave, develop further assessment procedures, employing diverse signal quality markers available from the DecaWave chip; build an auto-calibration procedure, which will enable the on-site, simplified, but robust approach to correction of the user-provided anchor's coordinates, alongside with the estimation of the main properties of radio-signal propagation environment, pertinent to the area, where the system was deployed.**

I. System description

The indoor positioning system presented here has a commonly used architecture, in which stationary anchor nodes (fig. 1) define the coordinate frame used to track the mobile tag (fig. 2). All the communications, including time synchronization between the anchors are wireless, except for the gateway node, which requires wired Ethernet connection with the optional PoE interface. There are two operation modes in this system: Time Difference of Arrival (TDoA) and Time of Arrival (ToA). While first mode provides maximum allowable "capacity" of the system in terms of tags "density", it still lacks the maximum attainable accuracy of the second mode. In ToA mode tag periodically performs the sequence of two-way communications with all the anchors, present in it's communication range. In the end of the sequence, batch of measured distances between tag and each of the anchors is sent to the server, where this information is forwarded to the Location Engine (LE). LE code is based on a Baysian filtering approach, with flexible choice of particular algorithm, which is made in accordance with the current application scenario; it provides an estimate of tag's position - coordinates and their accuracy.

II. Getting more from the DecaWave chip

DW1000 chip, which our system is based on, is a mixed-signal UWB front-end capable of providing 20 ps-accurate time-stamps (theoretically yielding about 6 mm ranging accuracy). This chip operates by deriving channel impulse response

Fig. 1. UWB Anchor

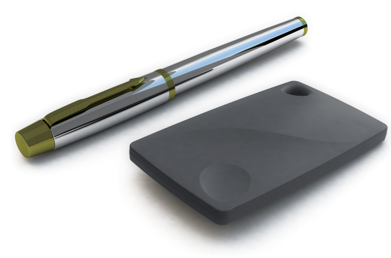

Fig. 2. UWB Tag

(CIR) for each communication event between the devices, which shows the magnitude of the energy received along the direct path and each of multi-paths that follows it. The particular advantage of this chip, is that, beside the range information, it yields the additional markers, that characterize the quality of communication. Our positioning system takes this information into account on two levels - coarse approach filters out "suspicious" ranges altogether whereas fine approach tries to assign the corresponding weights to the ranges, accounted for while calculating the probability of current tag's position. We are exploring the possibility to deal with weight assigning problem by "learning" the corresponding dependencies, using reference trajectory and real-life setup.

III. Auto-calibration of the positioning system

Taking into account pretty accurate range measurements, which one can get from the DecaWave-based indoor positioning system, the new question is raised: "How accurate

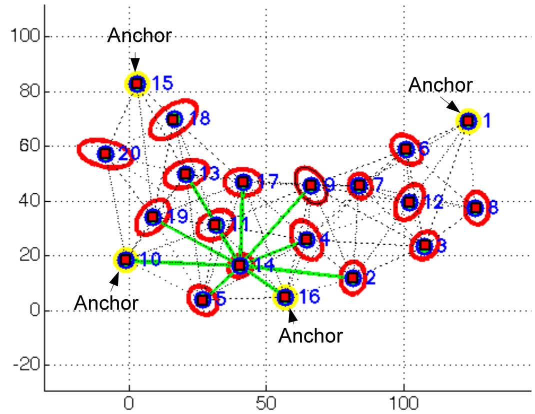

Fig. 3. Auto-calibration of anchors positions

my anchor's coordinates are?". Large inaccuracies in anchor's coordinates will inevitably deteriorate overall performance of the positioning system. In the other hand, precise external measurement of anchor's coordinates is time-consuming and costly option. Measurements of relative distances between the anchors could be used to correct user-provided positions [1]. This method doesn't require any user involvement, thus representing "true" auto-calibration procedure. Yet, successful application of that procedure depends on a connectivity graph structure, where edges are defined by the range measurements between the adjacent anchors (fig. 3). In this work we add one more step, that requires minimal user involvement. During this step, user is following some random trajectory over the area, covered by the positioning system, while range data are being collected by the server [2]. Off-line batch-processing of collected data by using procedures of constrained optimization allows the system to fine-tune, or correct the results, attained during auto-calibration step.

IV. Deployment Requirements

Our system consists of 5 wireless anchor nodes, with one of them performing a gateway functions, one mobile tag, and one laptop with server software. It requires minimum setup - anchors must be placed on the adjustable tripods. All the devices are battery-powered.

References

[1] Maximov V., Tabarovsky O., Filgus D., *Distributed localization algorithm for IoT network* Indoor Positioning and Indoor Navigation (IPIN), 2015, vol., no., pp.1-7.

[2] Hol J.D., Schon T.B., Gustafsson, F., *Ultra-wideband calibration for indoor positioning* International Conference on Ultra-Wideband (ICUWB) 2010 , vol.2, no., pp.1-4.