Demo: InPhase – 3D Localization in Wireless Sensor Networks

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***Abstract*—The location of nodes in Wireless Sensor Networks can be valuable information, e.g. for routing sensor data to a sink node. We demonstrate the InPhase localization system. It allows to locate wireless sensor nodes in 3D space. By measuring the phase response of the radio communication channel the distance between two sensor nodes can be computed. With multiple distance measurements the location of a wireless sensor node can be determined. The measurement is done via a standard IEEE 802.15.4 radio transceiver. No extra hardware besides the radio is required.**

***Index Terms*—localization, ranging, distance estimation, WSN, phase-based**

I. Introduction

Wireless sensor nodes can measure a large variety of different data, e.g. temperature, humidity or acceleration. However, obtaining the location of sensor nodes is problematic. While inexpensive sensors with low power consumption can be found for the above mentioned environmental data, location sensors are only available as Global Navigation Satellite System (GNSS) receivers. These devices have some caveats: They are rather expensive, need an extra antenna and have a high power consumption. Further, GNSS receivers only work outdoors, as signals from the satellites need to be received.

We demonstrate the InPhase localization system. It allows to localize nodes in a Wireless Sensor Network (WSN) by only employing an already available IEEE 802.15.4 radio transceiver. The system measures the phase response of the 2.4 GHz radio channel between two sensor nodes and computes the physical distance. From multiple distance measurements to sensor nodes in known locations, the position of a sensor node with unknown location is determined.

II. Distance Estimation

The distance estimation is implemented according to our previously published work [1], [2]. A distance is always measured between two nodes of the WSN. The phase response of the radio channel between the two nodes is measured via the Active-Reflector-Principle (AR-Principle) [3]. The AR-Principle requires radio transceivers that can measure the phase of an incoming radio signal. We employ off-the-shelf AT86RF233 radio transceivers with integrated Phase Measurement Units (PMUs) [4]. Figure 1 shows an example phase response of such a measurement. The result resembles a sawtooth signal. The steepness of the slope is proportional to the distance between sensor nodes. The Complex-valued Distance Estimation (CDE) algorithm is used to determine the distance from this raw measurement data [2].

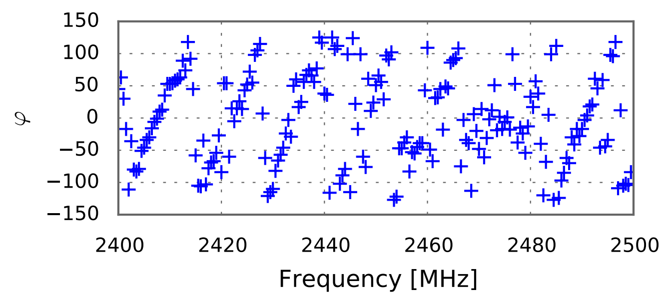

Fig. 1. Raw phase response measurement (reproduced from [1])

III. Localization

For localization, multiple distances are measured (see Section II). Multiple sensor nodes with known locations – so called anchors – are deployed in an area. A sensor node with unknown location measures distances to the anchors in a round-robin fashion. The measured data is relayed to a server that computes the distance and localizes the sensor node.

The localization problem is solved by a particle filter in multiple localization rounds. Each particle represents a potential location of the sensor node. Initially, when the location is unknown, all particles are randomly distributed in the whole 3D volume of the allowed area.

Then, for each measured distance to an anchor node, the probability of every particle is determined. If the particle's distance to the anchor fits the measurement, it is marked with a high probability. If its distance to the anchor node does not match the measured distance, it is marked with a low probability. Afterwards, a final location for this localization round is derived from the weighted particle cloud.

The particle positions are then refined based on the assigned probabilities. Particles with low probability will be removed, particles with high probability will be cloned and considered as possible locations for the round. Before the localization loop is restarted with the next distance measurement, all particles are moved randomly in a small radius to allow the cloned particles to spread out.

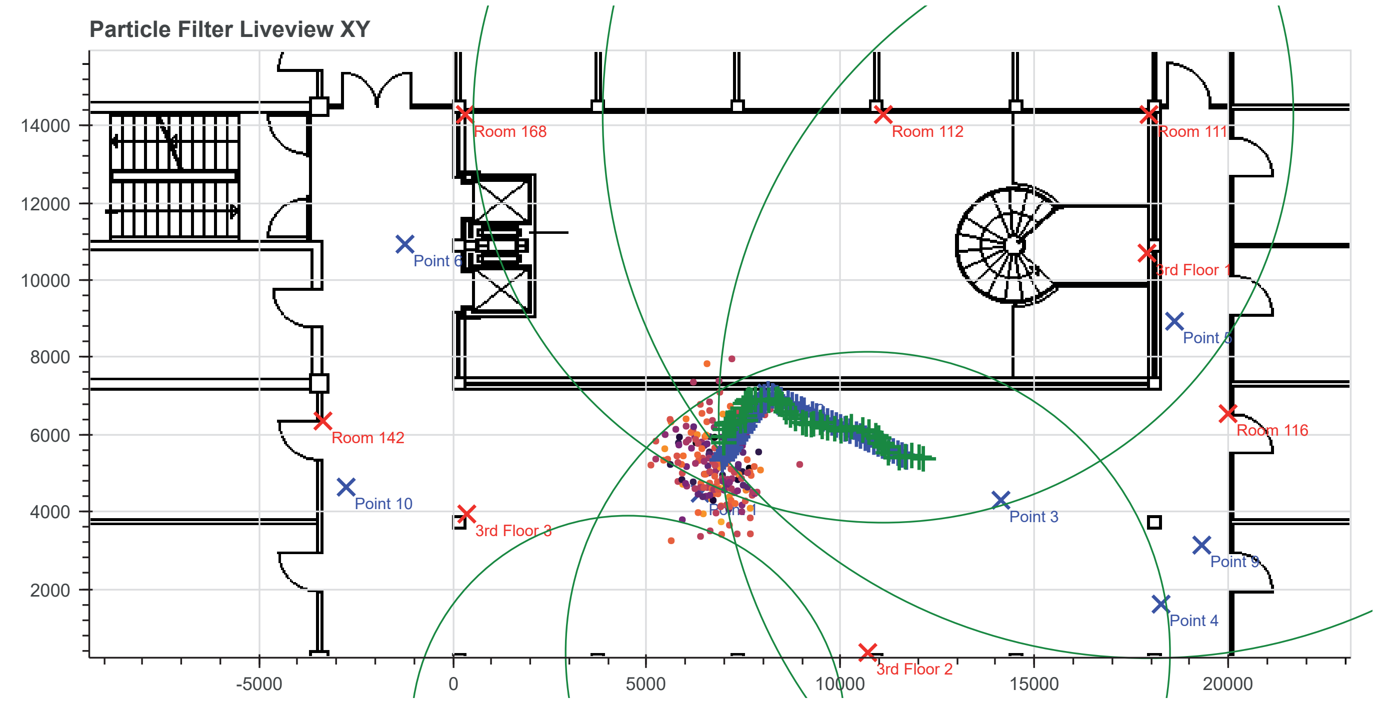

Fig. 2. Visualization of the localization algorithm. Red x's: Anchor nodes. Blue x's: Known reference points. Green Circles: Measured distances. Blue +-symbols: Ground truth path. Green +-symbols: Localization output. Orange point cloud: Particles. Both axes are marked in millimeters. Reproduced from [5].

Fig. 3. Battery-powered InPhase sensor node (reproduced from [5]).

IV. Demo Setup

The live demonstration shows a full localization setup that localizes a wireless sensor node with unknown location (tag) inside the demo area. Our InPhase sensor nodes are used as anchors and tag, see Figure 3.

The anchor nodes are mounted to walls or beams in the deployment area. To allow 3D localization, the anchors are spread over multiple different heights across multiple floors. Generally, the anchor nodes need a Line-of-Sight (LOS) to the tag node for the measurement to succeed. However, as this cannot always be guaranteed in real deployments, the demo area features some obstacles that introduce Non-Line-of-Sight (NLOS) conditions. This allows experimentation with adverse channel conditions during the live demonstration.

The tag node is mounted on a tripod and can be freely moved in the demo area. An attached single-board computer relays the measurement data to a server. The server runs the localization algorithm and displays the resulting location in real-time, see Figure 2.

References

[1] G. von Zengen, Y. Schröder, S. Rottmann, F. Büsching, and L. C. Wolf, "No-Cost distance estimation using standard WSN radios," in *The 35th Annual IEEE International Conference on Computer Communications (INFOCOM 2016)*, San Francisco, USA, Apr. 2016.

[2] Y. Schröder, D. Reimers, and L. Wolf, "Accurate and precise distance estimation from phase-based ranging data," in *2018 International Conference on Indoor Positioning and Indoor Navigation (IPIN)*, Sep. 2018.

[3] W. Kluge and E. Sachse, "System, method, and circuit for distance measurement between two nodes of a radio network," Feb. 2014, US Patent 8,644,768.

[4] *Low Power, 2.4GHz Transceiver for ZigBee, RF4CE, IEEE 802.15.4, 6LoWPAN, and ISM Applications*, Atmel Corporation, San Jose, Jul. 2014.

[5] Y. Schröder, D. Reimers, and L. Wolf, "Demo: InPhase – no-cost phase-based ranging and localization in wireless sensor networks," in *3rd KuVS/GI Expert Talk on Localization*, Jul. 2018.