InPhase: A Low Cost Indoor Localization System for IoT Devices

Georg von Zengen
TU Braunschweig, IBR
Mühlenpfordtstr. 23
38106 Braunschweig, Germany
vonzengen@ibr.cs.tu-bs.de

Yannic Schröder
TU Braunschweig, IBR
Mühlenpfordtstr. 23
38106 Braunschweig, Germany
schroeder@ibr.cs.tu-bs.de

Lars Wolf
TU Braunschweig, IBR
Mühlenpfordtstr. 23
38106 Braunschweig, Germany
wolf@ibr.cs.tu-bs.de

ABSTRACT

Indoor localization is an active research topic in wireless networking. In typical Internet of Things deployments all components are supposed to be low cost. Thus, we propose a system capable to localize nodes of the network using off-the-shelf transceiver chips. It is based on phase measurements in the 2.4 GHz ISM band.

Categories and Subject Descriptors

C.2.1 [**Network Architecture and Design**]: Wireless communication

General Terms

Measurement, Experimentation

Keywords

Indoor Localization, IoT, WSN

1. INTRODUCTION

Indoor localization became an important topic in wireless networking over the recent years as there are a large variety of usages in deployed networks. For Example, location information can be used as input for indoor navigation systems or in the network logic itself to improve routing protocols.

Especially in the Internet of Things (IoT) with its resource constraint devices, localization of nodes is a challenging task. Due to low cost requirements of typical IoT scenarios complex measurements like Time Difference of Arrival (TDoA) are not possible as only a single transceiver is available. As described by Boukerche et al. [2] different transmission channels like a radio pulse and a ultrasonic pulse are needed to realize TDoA measurements. TDoA measurements can also be realized using multiple transceivers for the same channel at different locations which results in rather large devices. Some transceivers support Time of Arrival (ToA) measurements but using this for ranging is complicated as a synchronized clock between the nodes is needed.

We propose an indoor localization system that fulfills the special requirements for IoT devices. It is capable to work with off-the-shelf transceiver chips like the AT86RF233 [1] by Atmel. The transceiver is equipped with a Phase Measurement Unit (PMU) which is used to acquire phase information and calculate the distance to several *reference nodes* at known positions. We believe that in future IoT installations and according networks no extra infrastructure will be needed, because in such setups nodes like radio equipped light bulbs or HVAC systems can be used as *reference nodes*.

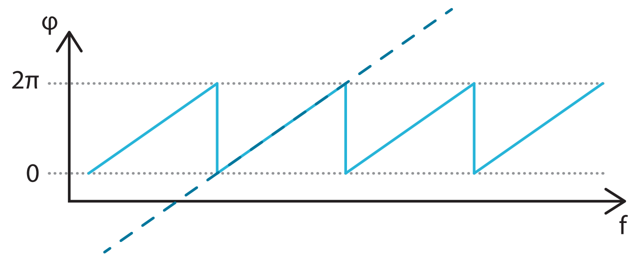

Figure 1: Ideal phase response from PMU used for distance calculation. The indicated slope is proportional to the distance between the nodes.

2. SYSTEM DESIGN

Our system consists of multiple INGA [3] sensor nodes forming a Wireless Sensor Network (WSN). The sensor nodes are equipped with an AT86RF233 [1]. This is an IEEE 802.15.4 compliant transceiver chip that features a PMU.

We have implemented the Active-Reflector-Principle as proposed by Kluge and Eggert [5] as distance sensor for the Contiki operating system [4]. The Active-Reflector-Principle uses two wireless sensor nodes to measure the phases of a transmitted continuous wave signal between them.

For an Active-Reflector-Measurement two nodes are needed. In our setup we use a *reference node* and a mobile node. In the first step the *reference node* acts as receiver and measures the phase of the signal transmitted by the mobile node. To mitigate the effect of unsynchronized clocks both nodes switch roles. Therefore, in the second step the mobile node

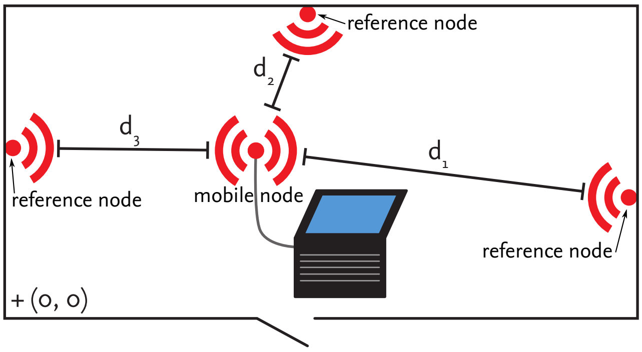

Figure 2: Example deployment of our system. Three nodes are used as *reference nodes*. A fourth node is connected to a mobile device.

measures the phase of the signal transmitted by the *reference node*. As both transceiver's Phase Locked Loop (PLL) run at the same frequency in transmission and reception mode, any phase shift due to not synchronized clocks is irrelevant.

From the phase measurement our approach calculates the distance between both nodes via autocorrelation and Fast Fourier Transform (FFT). A schematic plot of such a measurement is shown in Figure 1. The dashed blue line represents the slope of the phase response (solid blue line) of the channel measured by the system. This slope is proportional to the distance between the nodes. To start a measurement we designed a protocol where the mobile node asks a *reference node* to participate in a measurement of the channel's phase response. After the measurement is completed the results stored at the *reference node* are transmitted to mobile node. This phase measurement is repeated with different *reference nodes* deployed at known positions. Afterwards, the position of the mobile node is computed using trilateration. The position can then be displayed to a user or used for other purposes.

3. DEPLOYMENT

As shown Figure 2 our *reference nodes* will be mounted to the walls of the setup area. This simulates a real world IoT network where devices are likely to be placed near the walls or mounted to them. The position of the *reference nodes* must be measured as exactly as possible to ensure an accurate localization of the mobile node.

Depending on the size and layout of the area to cover at least three *reference nodes* are needed. This is due to low transmission power used by IEEE 802.15.4 transceivers. Even thin walls can have a harmful effect on the signal quality and therefore on the measurement. The mobile node that is supposed to be located is connected to a device to perform the calculations and to display its results.

4. REFERENCES

[1] Atmel Corporation, San Jose. *Low Power, 2.4GHz Transceiver for ZigBee, RF4CE, IEEE 802.15.4, 6LoWPAN, and ISM Applications*, 8351-mcu wireless-08/2013 edition, August 2013.

[2] A. Boukerche, H. Oliveira, E. Nakamura, and A. Loureiro. Localization systems for wireless sensor networks. *Wireless Communications, IEEE*, 14(6):6–12, December 2007.

[3] F. Büsching, U. Kulau, and L. Wolf. Architecture and evaluation of INGA - an inexpensive node for general applications. In *Sensors, 2012 IEEE*, pages 842–845, Taipei, Taiwan, October 2012. IEEE.

[4] A. Dunkels, B. Gronvall, and T. Voigt. Contiki - a lightweight and flexible operating system for tiny networked sensors. In *Local Computer Networks, 2004. 29th Annual IEEE International Conference on*, pages 455–462, November 2004.

[5] W. Kluge and D. Eggert. Ranging with IEEE 802.15.4 narrow-band PHY. https://mentor.ieee.org/802.15/dcn/09/15-09-0613-01-004f-ranging-with-ieee-802-15-4-narrow-band-phy.ppt, September 2009.