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A Test Environment for Phase-Based Ranging and Localization

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Requirements

Phase-based ranging and localization have requirements that are not fulfilled by conventional Wireless Sensor Network (WSN) testbeds:

Radio channel conditions Phase-based ranging is sensitive to varying radio channel conditions like reflections, refractions and interference with other radio signals. Ranging performance degrades when there is no direct Line-of-Sight (LOS) between both participating sensor nodes. A testbed must feature LOS and Non-Line-of-Sight (NLOS) channel conditions.

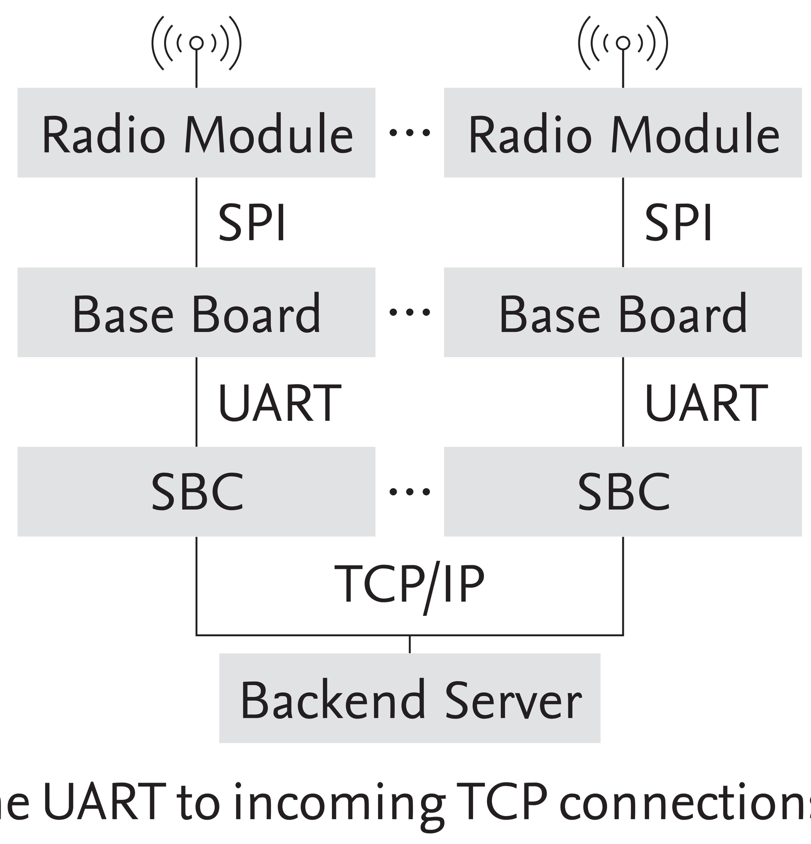
Ground truth locations Conventional WSN testbeds and applications do not need a precise ground truth position of the sensor nodes. For ranging evaluations reference positions of nodes are required with high accuracy. Deviations should be in centimeter range.

Realistic environment A testbed should feature changing environments like people moving around or doors being opened and closed. Distances between nodes should cover multiple distances as found in real deployments. We expect distances between 5 and 50 meters.

Easy reconfiguration Different experiments need different hardware and software. A testbed should allow easy reconfiguration both hardware- and software-wise. This can be achieved by a modular approach and automated setup and deployment of testbed software.

Architecture

The architecture consists of different modules with well-defined interfaces. Each sensor node, consisting of a base board and a radio module is connected to its own Single-Board Computer (SBC). The SBC reads measurement results and uploads new software.



The SBC relays serial data from the UART to incoming TCP connections and vice versa. This allows multiple clients to connect to one sensor node's serial output simultaneously. The experimenter can debug the serial data stream while the backend server runs an experiment. The reset pin of the sensor node's micro controller is connected to a GPIO of the SBC to allow hard resets.

All SBCs compile and upload new firmware to their respective sensor node concurrently. This allows unique configuration parameters like network addresses. Software deployment is automated via Ansible[a].

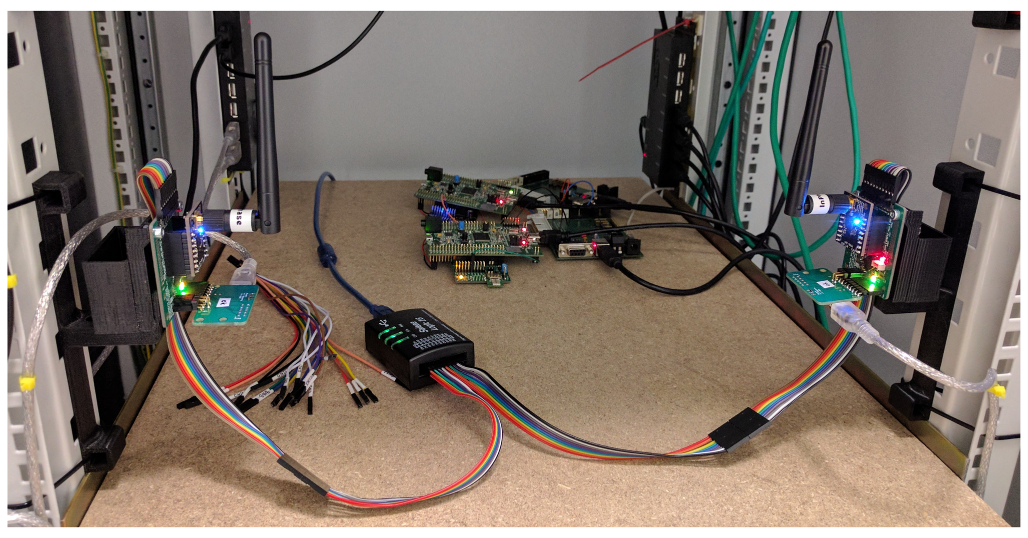
The backend server runs experiments and controls the sensor nodes. It is connected to the SBCs via standard TCP/IP. We developed a software library that can be used by experimenters to control ranging parameters of the sensor nodes.

[a] https://www.ansible.com/

InPhase Sensor Node

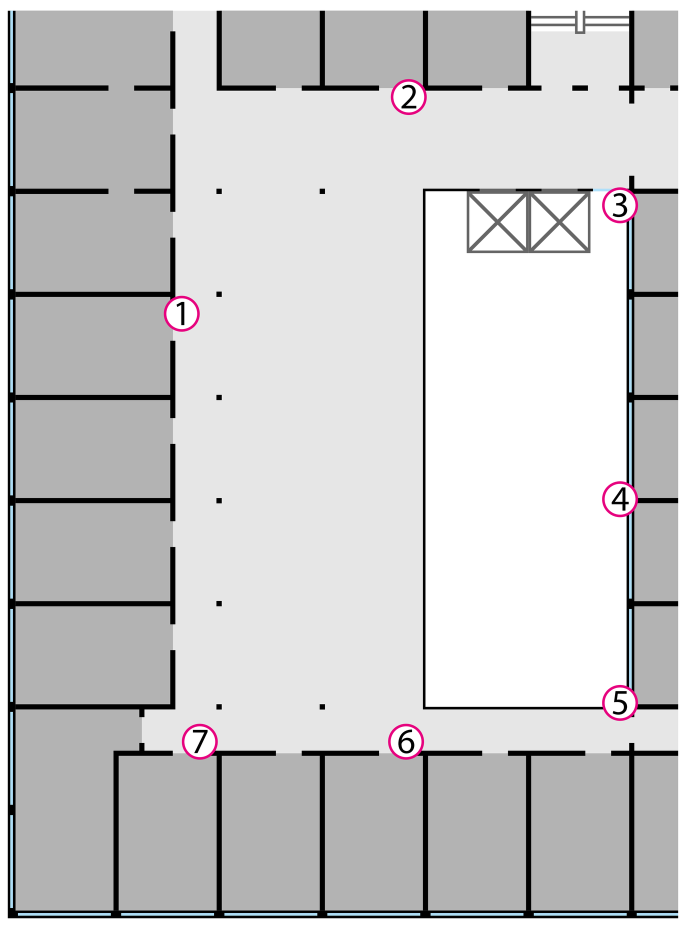
We implemented our own version of the Active Reflector (AR) principle proposed by Kluge et. al. on our own wireless sensor node. The sensor node is tailored to localization experiments. The hardware consists of a base board containing the micro controller (ATMEGA1284p) running Contiki OS and a radio module with an AT86RF233 radio transceiver that is capable of measuring the phase angle of incoming signals. This design allows to swap the radio module for future experiments with other radio transceivers.

Continuous Integration



A Continuous Integration (CI) server tests every new software revision on real hardware. Two sensor nodes are mounted in a server rack and connected via USB to the CI machine. A logic analyzer samples SPI and GPIO signals between radio and micro controller of both nodes. The data is automatically evaluated and a performance report is generated. It contains general fitness information of the ranging algorithm and regression test results. Raw data and the report are stored for later inspection.

Deployment Scenario



We deployed the testbed architecture at the first floor of our office building. The area features a large open space, spanning four floors surrounded by structural concrete columns, glass panes, elevator shafts and drywall to adjacent offices. This allows both LOS and NLOS measurements. The large open space allows 3D deployments for our future work. Multiple WiFi networks on the different floors result in strong radio channel interference.