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Indoor UWB localisation: LocURa4IoT testbed and dataset presentation

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Abstract—This paper introduces the Localisation and UWB-Based Ranging testbed for the Internet of Things (LocURa4IoT). This platform has been built to aid in the design and performance evaluation of proposals addressing the issue of indoor localization. The paper presents the experiment submission process and describes the demonstrations of the testbed capabilities and characteristics. The same scenario has been executed beforehand and the resulting dataset is made available online to the community.

Index Terms—Testbed, UWB, ranging, Time-of-Flight, Indoor Localization, Dataset

I. INTRODUCTION

Knowing where things are located is a key element in interacting with them. Nowadays, technological means of locating objects are becoming widely available: specifically, the Ultra-Wide Band (UWB) technology has become mainstream as it is available in smartphones, computers and various consumer goods. UWB is expected to play a role in the home environment (interaction with the house, the car [1], etc.) as well as in industrial settings [3]. The presence of multiple UWB devices highlights the need for MAC layer enhancements, among other things. In this paper, we introduce LocURa4IoT, a testbed dedicated to the study of UWB communication. We illustrate LocURa4IoT’s functionalities through a demonstration and also provide the resulting dataset to the research community.

II. THE LOCURA4IOT TESTBED

LocURa4IoT (Localisation and UWB-Based Ranging testbed for the Internet of Things) is a testbed dedicated to the evaluation of ranging and synchronisation protocols in wireless networks. The platform is also equipped to support the study of indoor localisation using the Time of Flight (ToF) of radio signals to evaluate the distance between nodes. Although initially designed around the Ultra-Wide Band technology, LocURa4IoT embarks Bluetooth Low Energy (BLE) and LoRa transceivers which are co-located with the UWB nodes. This opens the way to the study of network approaches taking advantage of heterogeneous physical layers.

The LocURa4IoT testbed has been designed and deployed to meet the demand for an evaluation platform for distance estimation (ranging) protocols between UWB nodes as well as communication paradigms using this physical layer. The ranging function is specified in the IEEE-802.15.4 standard and is found in Real Time Location Systems (RTLs) solutions offered by UWB component manufacturers like Qorvo. This

function has been integrated into recent smartphones. UWB nodes rely on 64GHz timers in order to accurately timestamp transmission and reception of frames. Several protocols can be used, such as the well-known TWR (Two-Way Ranging) [2] involving two nodes, a TWR client node and a TWR server node, exchanging 3 messages.

To date, the testbed comprises 64 nodes. The deployment was performed using laser rangefinders; this keeps the positioning error below 2 cm. Therefore, the real position of each node, fixed or mobile, can be used in the results to compute a ranging / localization error. Considering the layout of the walls on the different sites, some radio links are NLOS (Non Line-of-Sight). Two rails with respective lengths 7m and 2m make it possible to move two mobile nodes: the linear position (millimeter precision), the speed and the acceleration of the mobiles can be controlled from the experimental scenarios.

Like most testbeds, LocURa4IoT can be broken down into three layers: the nodes and controllers layers, which constitute the first two material layers of the testbed; and data and algorithms layer, which allows the processing of data during or after the experiment. A central server is responsible for running experiments on the testbed. Those experiments are described through Python scripts. More information on LocURa4IoT is available on this paper [4].

In order to illustrate the capabilities of the testbed and before its upcoming opening for public use, many open datasets are made available to the scientific community on the testbed website [5]. These datasets, under ODBL license, can be used freely by the reader. The next section introduces a scenario used to generate a new dataset as well as a few results, which will be presented in the demonstration.

III. DEMONSTRATION

The live demonstration comprises two parts: first, an introduction to the LocURa4IoT testbed will be provided. Then live measurements will be obtained: this phase and the experiment described in section IV follow the same scenario.

A. Experimentation with LocURa4IoT

1) *Submitting an experiment*: LocURa4IoT can be accessed remotely using a web interface. The first step is to select the right nodes depending on the objectives (LOS/NLOS conditions, mobility, geometry...). Then the user must verify node availability as a single node cannot be part of two

experiments at the same time. At this point, the user has the choice to either load a locally compiled code on the testbed or use the online IDE to launch the experiment. This step also involves a python script describing the scenario: it sets aside the nodes identified in the first step, uploads the firmware and manages eventual live interactions with the nodes. Those live interactions may be predefined commands sent via the serial port to the firmware as well as commands targeting the rail. At the end of the specified duration, the scenario script is also in charge of clean up activities (freeing resources, etc.).

2) *Retrieving the experiment results:* During the experiment, the controllers act as gateways between the serial port of the nodes and the MQTT bus. Metadata such as real node positions, ranging error are added to the initial output and published on MQTT topics such as (where + is the node number):

- `testbed/node/+/out`
- `ranging/+/+/indication`

Accessing the data is therefore simply a matter of implementing a subscriber to the appropriate topic in the user's favourite programming language.

B. Experimentation scenario

Seven nodes are involved in the experiment. Nodes 184, 180, 150, 100, 101 and 171 are 6 anchors. Node 183 is a mobile node on the 7m rail. Figure 1 shows the map of the testbed and the placement of the 7 nodes. In the demonstration scenario, the mobile node is the 3-messages TWR client, while the 6 anchors are ranging servers. The chosen nodes illustrate various radio propagation conditions in terms of Line-Of-Sight (LOS) and Non Line-Of-Sight (NLOS):

- Link 183-184 is always LOS,
- Link 183-150 is always NLOS because of one or two walls made of terracotta bricks,
- Links 183-100 and 183-101 are always NLOS because of one drywall,
- Links 183-180 and 183-171 are LOS or NLOS, depending of the course on the rail.

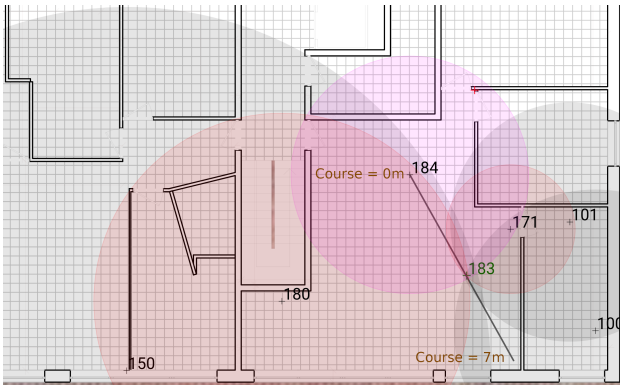


Fig. 1. The experiment map

During the experiment, the mobile node is moved along a 7 m line in 10 cm increments. While motionless, the mobile runs the ranging protocol 10 times with each of the anchors.

A successful execution of the ranging protocol triggers the publication of a dataset element as a JSON string. This string contains fields such as:

- `protocol`: this field indicates which protocol is used to estimate the distance. In the current dataset, we use the Two-Way Ranging (TWR) protocol,
- `t1, t2, t3` and `t4`: the raw value of the 4 timestamps generated by the TWR protocol,
- `range`: this is the distance estimation obtained by the ranging protocol.
- `rangingError`: this is the ranging error which is computed by an MQTT agent using the live distance estimation and the a priori knowledge of the nodes' positions,
- `CIR`: the Channel Impulse Response has been retrieved from the transceiver registers. It shows the multipath that affects the communication and ranging estimation.

During the live demo, we will run this experiment scenario, extract those fields and use them to present interesting characteristics from the testbed. Some results from the pre-generated dataset are presented in the next section and will be reproduced live during the demonstration.

IV. RESULTS

The experiment described in the previous section has been executed on the LocURa4IoT testbed. The resulting dataset is available on this page [6]. A complete description of the JSON data is available as well as a python script for data extraction. The remainder of this section is devoted to the discussion of a subset of the results obtained in the experiment.

Figure 2 shows the ranging error measured between nodes 101 and 183. This link is a good example of the propagation diversity that can be observed in our testbed: the shortest path between nodes 101 and 183 goes through at least 2 drywalls when the course is below 1.5m, while there is only one drywall between the nodes on the remainder of the course. The behavior of the ranging error, as shown on figure 2, reflects the evolution of the obstructions.

Figures 4 and 5 represent the Channel Impulse Response register of the DecaWave transceiver. In general, the first part of the graph has a relatively low amplitude and corresponds to the noise on the channel. The second part of the graph is a succession of peaks of variable amplitude. Each peak corresponds to a multipath version of the received preamble. The first peak is used to compute the ToF.

- In figure 4, the sender is 184 and the receiver is the mobile. The mobile is placed in the middle of the rail, at $course = 3.5m$. The link is LOS, with few multipath components. The first path is the strongest, there is no difficulty for the transceiver to timestamp the reception of the message,
- In figure 5, the sender is 150 and the receiver is the mobile. The mobile is placed at $course = 1.5m$. The link is NLOS: the shortest path goes through the thick corner of the brick wall to reach the receiver. In this situation,

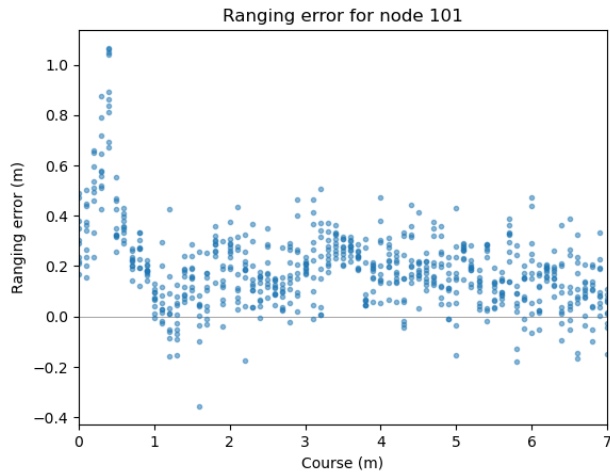


Fig. 2. Ranging error on the link 183-101 (NLOS)

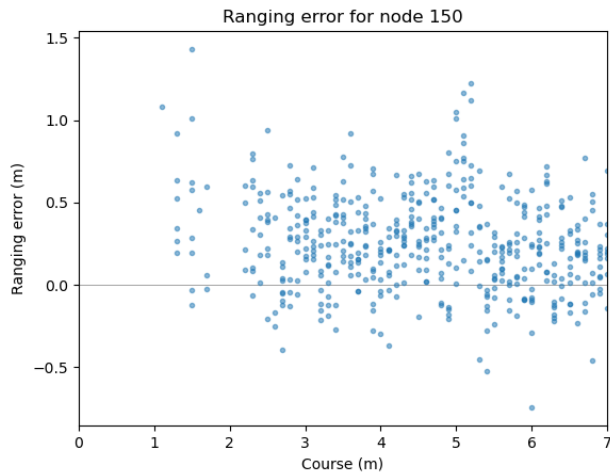


Fig. 3. Ranging error on the link 183-150 (NLOS)

the first path is small but strong enough to be detected by the transceiver.

V. CONCLUSION

As the technological means of performing precise indoor localization are becoming mainstream, there is a need for proper evaluation of the innumerable solutions. The LocURa4IoT testbed has been developed as a response to such a challenge: it offers tens of UWB-enabled nodes deployed on a 300m² surface with various radio links (LOS/NLOS). In this paper, we presented the process for running an experiment and collecting the measurements on the platform. The resulting dataset is provided to the community in the hopes of motivating fellow researchers to explore possible enhancements to localization algorithms or protocols. In the near future, we plan on exploiting the tested in the study of NLOS detection but remain open to request for generating datasets with specific fields.

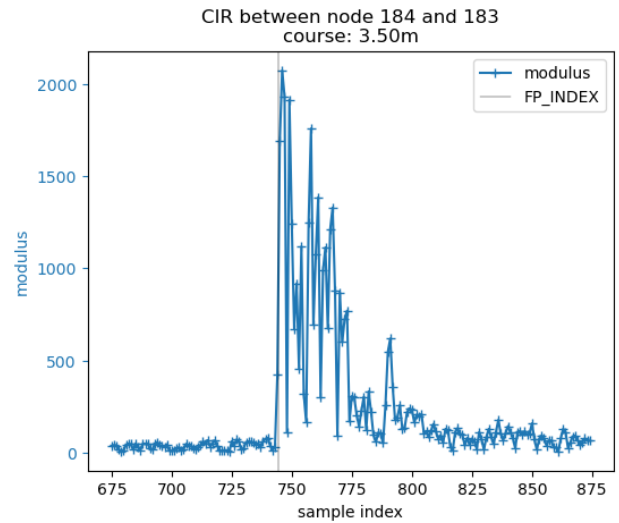


Fig. 4. CIR modulus on the link 183-184 for course = 3.5m

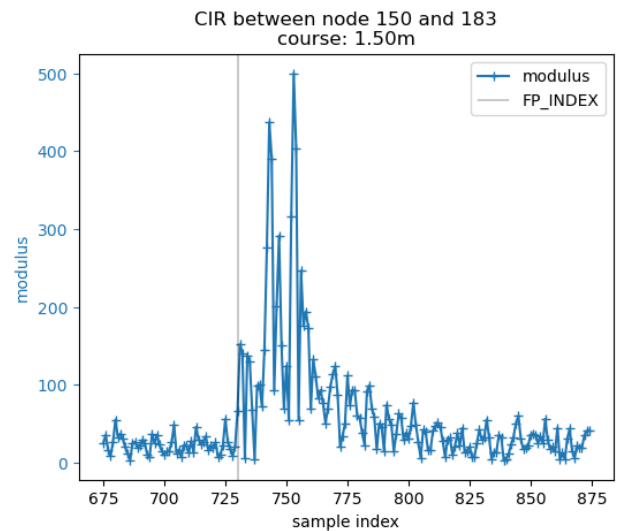


Fig. 5. CIR modulus on the link 183-150 for course = 1.5m

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