Demo Abstract: Testbed Infrastructure for Benchmarking RF-based Indoor Localization Solutions under Controlled Interference

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Abstract—The proliferation of RF-based indoor localization solutions raises the need for testing systems that enable objective evaluation of their functional and non-functional properties. We introduce a testbed infrastructure for automatized benchmarking of RF-based indoor localization solutions. The infrastructure leverages a robotic mobility platform which serves as a reference localization system and can transport the localized device in an autonomous and repeatable manner. Using a well defined interface, the infrastructure obtains location estimates from the System Under Test which are subsequently processed in a dedicated metrics computation engine. In this demonstration, we present the capabilities of the testbed infrastructure on the use-case of benchmarking a WiFi fingerprinting indoor localization system under the influence of controlled interference.

I. INTRODUCTION

Localization in urban environments and buildings, where people spend most of their time, draws lots of research attention nowadays. Due to the poor indoor performance of the Global Positioning System (GPS) service, a number of alternative localization approaches have been recently proposed. The performance of these solutions is usually evaluated using local ad-hoc experimental setups, mostly by the development teams themselves, using manual and laborious procedures. The results are typically captured following different evaluation scenarios and metrics, with different number and position of evaluation points, and in different environments. Due to these factors, the majority of existing evaluation approaches do not provide sufficient basis for predicting the performance of the systems in other environments and do not enable objective comparison of multiple solutions.

In this work we present a testbed infrastructure for automatized benchmarking of Radio Frequency (RF) based indoor localization solutions that aims at addressing some of these identified shortcomings. It leverages a robotic mobility platform which enables accurate and repeatable positioning of localization device. Furthermore, it integrates devices for generating controlled RF interference, which can be used to evaluate the influence of RF interference on the performance of the localization System Under Test (SUT). For validation of the resulting RF context, the infrastructure features devices that monitor the RF spectrum at different measurement points in order to guarantee equal conditions for all SUTs.

We apply the benchmarking methodology developed within the EVARILOS Project and described in [1]. It follows the principles of black-box testing and is not privy to the inner operation of the SUTs. The only direct interaction with the SUT, performed over a well defined API, is used to obtain location estimates. Combined with reference location data from the robotic mobility platform, the obtained location estimates are subsequently processed by a dedicated engine that calculates relevant evaluation metrics like geometrical and room level accuracy, latency and power consumption.

In this demonstration we showcase the possibilities of the presented testbed infrastructure on the example of benchmarking a WiFi fingerprinting localization solution with and without controlled interference.

II. TESTBED INFRASTRUCTURE

This section presents the components of our testbed infrastructure for indoor localization benchmarking. The overview of the system is given in Figure 1.

Fig. 1. Overview of the benchmarking system

a) Mobility Support: For automatic transportation of the localized device of the SUT to different evaluation points, without the presence of a human test-person and in a repeatable way, we use the Turtlebot II robotic platform [2]. It comprises of a mobile base called Kobuki, a laptop, a router and a Microsoft Kinect 3D camera sensor. On the software side we are using Robot Operating System (ROS) [3], an open source approach for robots. The Turtlebot can autonomously position itself, together with SUT, at different locations. ROS navigation stack uses the measured depth information from the Kinect sensor and an a-priori given floor plan to localize itself.
Furthermore, it provides an interface to request the robot to drive autonomously to a given coordinate. For an experiment we define a set of measurement points and the robot iterates over each of them. When a measurement point is reached, our central control engine sends a request for location estimation to the SUT. Once the SUT reports the localization results, the robot moves to the next measurement point.

b) Interference Generation: During an evaluation of the proposed localization solution the impact of external interference is mostly not considered. However, it can have an influence on the performance of the SUT. For this reason we have developed means to generate various types of interference scenarios. The most common type of wireless activity in the 2.4 GHz is the WiFi traffic. We have adapted the interference scenarios from [4], [5] and using the cOntrol and Management Framework (OMF) [6] we are able to create in our testbed the interference context of typical home or office environments.

c) Interference Monitoring: In the previous section we have described that we can generate different interference scenarios based on the needs of an experiment. Still, the spectrum in the ISM 2.4 GHz band is free for use and we do not have full control over all devices operating in those frequencies. We have disabled the university infrastructure WiFi network in the 2.4 GHz band in the building but the signal from the surroundings can still be received. That is why it is necessary to monitor the spectral environment to tell if it is looking as expected. We can use OMF to orchestrate WiSpy [7] devices to perform spectrum sensing. We are using one of them connected to the robot to make sure that the measured interference is not exceeding planned one.

d) Location estimation requests and metrics calculation:
One part of our testbed infrastructure is an engine for requesting a location estimation from the SUT. Based on the accurate location obtained from the robotic platform and the location estimation obtained from the SUT, the engine calculates the performance metrics. The set of benchmarking metrics that can be calculated or estimated consists of geometrical and room level localization accuracy, latency of location estimation and the power consumption of the SUT. Geometrical accuracy is the distance between the accurate location reported by the robotic platform and the one reported by the SUT. The room level accuracy is a binary metrics containing the correctness of the estimated room. Furthermore, the latency of location estimation is the time that SUT needs in order to report a location estimation. Finally, the power consumption is the power used by the SUT for location estimation, assuming that SUT exposes interfaces to access this information.

III. DEMO DESCRIPTION
In the demo we use our testbed infrastructure to show two experiments remotely over the Internet. The hardware components used for this demo are given in Figure 2. Namely, we show the usage of our indoor localization benchmarking infrastructure with a WiFi fingerprinting localization system as the example of SUT. The control of the experiment is done in a centralized way, using the central control engine. First, we demonstrate the usage of our infrastructure for benchmarking in the environment without controlled interference. The coordinates of the evaluation points are sequentially given to the robotic platform. When the point is reached, the robot reports its current location to the central engine. Central engine then requests the location estimation from the SUT. When the estimated location is reported from the SUT, the central engine calculates the evaluation metrics. The whole experiment is monitored for a RF interference. Secondly, we repeat the whole experiment with the presence of an artificially created WiFi interference.

IV. CONCLUSION
In this demonstration we introduce a testbed infrastructure for objective benchmarking of RF-based indoor localization solutions. We showcase how four important evaluation metrics can be captured in entirely automated and repeatable way, under two evaluation scenarios, one without and one with exposure to controlled WiFi interference.

V. ACKNOWLEDGEMENTS
This work has been partially funded by the European Commission (FP7-ICT-FIRE) within the projects EVAIRILOS (grant No. 317989) and CREW (grant No. 258301) and EIT ICT Labs, as part of the activity 12149, “From WSN Testbeds to CPS Testbeds”.

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Introduction
Objective benchmarking and comparison of different Radio Frequency (RF)-based indoor localization Systems Under Test (SUTs) is hardly achievable due to:
• Different environments (usually researcher's testbed);
• Different benchmarking scenarios (number and locations of measurement points);
• Unrepeatable conditions in different experiments;
• Unmonitored or marginalized interference effects.

We present an infrastructure for objective benchmarking of RF based indoor localization solutions in an autonomous way without the presence of a test-person.

Testbed Infrastructure

Autonomous Mobility
Navigation is done by correlating given floor map with the distance measurements obtained from the Kinect camera sensor.

System Under Test
SUT is considered a black-box in our approach. The interface that indoor localization SUTs have to provide is rather simple and the only requirement is to report the location estimate when requested. The communication is done using standard HTTP requests.

Interference Monitoring
The spectrum in the ISM 2.4 GHz band is free and numerous devices are operating in those frequencies. That is why it is necessary to monitor if spectral environment looks as expected in terms of controlled and uncontrolled interference. We can use OMFP to orchestrate Wlspy devices, the low-cost wireless spectrum analyzers. We mount one device on the robot and one on the interference traffic sink.

Interference Generation
We have developed means to generate various types of interference scenarios, and in this demo we generate interference context of typical home or office environments. Namely, interference is generated using 4 WiFi embedded PCs, representing a server, email client, data client, and video client.

Demo Description
• Example SUT - RSSI based fingerprinting algorithm;
• Two example experiments:
  → Experiment without controlled interference;
  → Experiment with controlled WiFi interference;

Acknowledgement
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EWSSN 2014
The 11th European Conference on Wireless Sensor Networks
February 17-19, 2014
University of Oxford, Oxford, UK.