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Poster Paper

Evaluation of RF-based Indoor Localization Solutions for the Future Internet

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Abstract: RF-based indoor localization solutions enjoy consistent efforts of researchers to provide more accurate and sustainable solutions. The multiplicity of RF-based indoor localization solutions makes their evaluation an indispensable part of future Internet. However no unified scheme has been devised for evaluation of these solutions and their robustness against various parameters. In this work, we present an overview of the EVARILOS project whose objectives are the development and validation of standardized experiment-based benchmarks for localization solutions.

Keywords: RF-based indoor localization, performance evaluation, benchmarking, RF interference robustness

1. Introduction

Despite the abundance of works on RF-based indoor localization solutions, the numerous published solutions are evaluated under individual, not comparable, and not repeatable conditions. No unified scheme is provided for the fair comparison and evaluation of various solutions. Moreover, accurate and robust indoor localization is a key enabler for context-aware Future Internet applications, whereby robust means that the localization solution should perform well in diverse physical indoor environments under realistic RF interference conditions. Therefore it is necessary to develop and establish a comprehensive benchmarking methodology which is able to consider variety of existing solutions and their significant features. EVARILOS project (Evaluation of RF-based Indoor Localization Solutions for the Future Internet) [1, 2] focuses on the development of the benchmarking methodology which consists of providing first metrics for evaluation of RF-based indoor localization solutions and second a set of benchmarks which we recommend to use for experimental performance evaluation according to the previous metrics for a given solution. The goal is to verify if it is possible to precisely implement the benchmark conditions on independent facilities, and make available to the research community software tools facilitating creation of such benchmarks. The benchmarks are executed on selected RF-based indoor localization solutions. It will be demonstrated that results of the benchmarking process achieved on different testbeds following our methodology are repeatable. The main outcomes of the project are a public handbook on the use of the EVARILOS benchmarking methodology and the EVARILOS benchmarking suite. The benchmarking suite will be publicly available under open source licenses and implemented in two different testbeds belonging to the FIRE facilities (CREW[3] and OpenLab[4]), more specifically on the testbeds in Berlin and Gent. The EVARILOS project uses the OMF control and management framework and mobility support features developed in OpenLab and will further use and extend the benchmarking features from CREW. An open challenge is also envisaged using the above mentioned testbeds to invite external experimenters for evaluation of their localization solutions and use their feedback and results together with the results of our own experiments to create the first repository of localization solutions evaluated using a unified methodology. EVARILOS project is contributing to the international standardization project such as the standard ***Real Time Locating Systems***, in particular ***ISO/IEC 18305, Test and Evaluation of Localization and Tracking Systems***.The aim of EVARILOS project is the development and validation of standardized experiment-based benchmarks that allow a fair comparison of different localization solutions, not only under ideal, but also under extreme conditions (e.g. environments with heavy RF interference from co-located wireless devices). Such procedures should give objective scores for accuracy and robustness under various benchmarked conditions. As a part of evaluation, the reproducibility of experiments is addressed as one of the problems of indoor localization research due the effect of uncontrolled parameters such as RF interference.

2. Benchmarking Methodology

The accuracy is currently the main parameter for evaluation of various localization schemes. However, the EVARILOS benchmarking methodology takes into account the multifaceted nature of localization schemes and strive to define an adequate ensemble of metrics for evaluation process. For each individual metric, a definition is given, together with instructions for collecting the necessary underlying measurements and a mathematical formula that should be used for processing those measurements in order to calculate the metric value. The metrics are organized in three generic categories: performance metrics, deployment metrics and functional metrics. The first and largest category is comprised by several metrics that try to capture different performance aspects of the system under test, such as its accuracy, robustness, scalability, etc. In contrast, the functional metrics focus on non-performance related attributes like the underlying technology, licensing modalities, open-source availability, etc. Finally, the deployment metrics capture important properties related to the efforts and costs needed for physical installation, configuration, and replacement time. After collecting a set of measurements necessary for the calculation of the individual metrics, the EVARILOS methodology allows application of specific weighting factors for the calculation of the final ranking score that reflects the different impact of the metrics for the different application scenarios of interest. After defining proper metrics, a set of benchmarks are recommended for experimental assessment of performance for a given localization solution according to the above metrics. Selected localization solutions are taken as representative samples from different classes of existing RF-based indoor localization solutions. The EVARILOS benchmarking methodology is implemented on two testbeds (3 different locations) belonging to the FP7 FIRE facility project CREW: Berlin testbed and Gent testbed using IEEE 802.11, IEEE 802.15.1, and IEEE 802.15.4 technologies.

We will experimentally apply the above benchmarks to selected solutions on the two testbeds, in order to prove that the EVARILOS benchmarking methodology is generally applicable in different testbeds.

3. Metrics for Evaluation of Localization Solutions

3.1 Accuracy

In the EVARILOS benchmarking, two different accuracy metrics are usually used: point and room accuracy. With point accuracy, the actual Euclidean error distance between a reference point and a measured point is calculated. Second accuracy metric is room accuracy, which is a variant of the previous one and concerns the room in which the node is placed. A distinction is also made between different floor levels.

3.2 Latency and Energy Efficiency

Latency is a metric defined by the response time of the localization system, i.e. the time that system needs in order to update the location after the request for location estimation. Latency is measured by the time interval between the beginning and end of localization procedure of a node. Latency of the localization can be an important metric because some localization use-cases require fast response time. Energy efficiency is another metric which can be important particularly for wireless sensor networks (WSNs) where nodes must function completely wireless, and therefore are not connected to the power grid. In the EVRILOS benchmarking the infrastructure and client nodes are distinguished because the clients are not connected to power grid.

3.3 Interference and Environmental Robustness

The RF indoor localization approaches are subject to exogenous interference caused by coexisting devices and technologies and endogenous interference caused by the other nodes using the same technology. The interference effect on the performance of localization schemes is characterized through the study of accuracy which will be used and compared under different circumstances. Different kinds and amounts of interference is specified and used to study the interference robustness of this scheme. Specific types like microwaves and synthetic interference is also used. On the other hand, the RF indoor localization approaches are naturally exposed to the difficulties of indoor environment. Indoor environments are susceptible to change by variation of network topology, room layout, walls, and channel conditions. The environment robustness determines if a solution is stable operating in different environments.

3.4 Mobility, Scalability and Repeatability

One feature of wireless networks is their variable topology due to the mobility and varying user density. The mobility metric is defined as the variation of primary metrics with the speed of the localized node and characterizes how the performance of the localization schemes changes from low-mobility regime to high-mobility one. Scalability metric is concerned with the density of nodes and characterizes the performance of the localization schemes in sparse and dense networks. To measure these metrics, two scenarios should be defined for each case corresponding to low/high mobility regimes and low/high density regimes. Repeatability implies that the same benchmark run twice results in the same score under well determined conditions. The equality is not strict in wireless benchmarking due to a certain level of indeterminism. For repeatability to apply, acceptable error margins should be formally defined. To evaluate this metric, the solution is reinstalled multiple times in the same testbed under the same conditions and the variation in the primary metrics is checked.

4. Interference Robustness and Environmental Awareness

Second part of the EVARILOS project concerns the development and evaluation of solutions that add RF interference robustness to indoor localization, so that indoor localization schemes also perform well in real-life Future Internet environments, subject to uncontrolled interference. There is a broad understanding that the RF interference might affect the localization metrics, although, in general, investigations have not been conducted so far. Environmental awareness and coexistence with other users and/or technologies is one of the core requirements of the Future Wireless Internet. This can be seen by the great push towards cognitive radio/dynamic spectrum access in the wireless research community. One approach to enhance the robustness of indoor localization is to utilize the information gathered for environmental awareness and coexistence for the assessment of the quality of the localization process. A wireless device operating in the Future Internet will typically have detailed information about its spectral environment, either through spectrum sensing, or information retrieved from a database. Based on this information it can e.g. choose the best (i.e. least interfered) frequency to be used for the localization procedure. Alternatively, it can at least adjust the expected precision of the result based on the amount of expected interference. The goal of the evaluation of interference robustness in EVARILOS project is adding a new class of approaches to RF-based localization to combat interference drawbacks. The solutions will be evaluated using the above described benchmarking methodology. We investigate to which extent such cognitive functionality of environmental awareness can improve the robustness of indoor localization against interference. We also derive guidelines for the different classes of localization schemes on how to increase the interference robustness.

5. Conclusion

This work presents the overview of EVARILOS project which targets benchmarking and evaluation of indoor localization solutions. Benchmarking methodology is presented including different evaluation metrics. The effect of environmental awareness on robustness of localization solutions is discussed.

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References

[1] "EVARILOS Project." http://www.evarilos.eu/.

[2] EVARILOS Consortium, "EVARILOS Description of Work," 2012.

[3] "The CREW Project." http://www.crew-project.eu.

[4] "OpenLab." http://www.ict-openlab.eu.

