AROMA: Automatic Generation of Radio Maps for Localization Systems

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ABSTRACT

Current methods for building radio maps for wireless localization systems require a tedious, manual and error-prone calibration of the area of interest. Each time the layout of the environment is changed or different hardware is used, the whole process of location fingerprinting and constructing the radio map has to be repeated. The process gets more complicated in the case of localizing multiple entities in a device-free scenario, since the radio map needs to take all possible combinations of the location of the entities into account.

In this demo, we present a novel system (AROMA) that is capable of generating accurate radio maps for a given site of interest. AROMA constructs radio maps for both deterministic and probabilistic wireless localization systems. According to our knowledge, AROMA is the first system to generate radio maps for device-free localization. It uses 3D ray tracing enhanced with the uniform theory of diffraction (UTD) to model the electric field behavior and the human shadowing effect. AROMA also automates a number of routine tasks, such as importing building models and automatic sampling of the area of interest.

Categories and Subject Descriptors
C.2.1 [Computer-Communication Networks]: Network Architecture and Design—Wireless communication

General Terms
Experimentation, Measurement, Performance

Keywords
Radio map generation, device-based localization, device-free localization, ray tracing

1. INTRODUCTION

There are two classes of WLAN location determination systems: device-based, e.g. [1] and device-free, e.g. [5]. Device-based systems track the location of a WLAN-enabled device, such as a laptop or PDA. On the other hand, device-free systems [5] do not require the tracked human to carry a device and depend on analyzing the effect of the human body on the signal strength to estimate his location. Device-free localization systems are composed of a number of access points (APs) and monitoring points (MPs). The MPs, such as standard laptops and other wireless-enabled devices, monitor the strength of the APs signals and their positions are fixed.

Both device-based and device-free systems usually work in two phases: an off-line training phase and an on-line location determination phase. During the off-line phase, the system collects signal strengths received from different streams at different selected locations in the area of interest, and tabulates them into a so-called radio map. For device-based systems, each stream represents the signal strength from an AP to the tracked device. For device-free systems, each stream represents an (AP, MP) pair and the radio map tabulates the effect of the tracked entity on the fixed streams. During the location determination phase, the system uses the information stored in the radio map to estimate the location of the tracked entity. Different location determination systems store different information in the radio map. In a deterministic radio map, the system represents the signal strength received from each AP by a single value; while for a probabilistic radio map, the system stores information about the distribution of the signal strength received from each AP.

Although being a tedious and time consuming process, current methods for building radio maps depend on manual calibration. Furthermore, each time the layout of the environment is changed or different hardware is used, the whole process of location fingerprinting and constructing the radio map has to be repeated. In addition, the process of radio map construction gets more complicated, in the device-free case, when the number of tracked entities increases, since the radio map needs to take all the combinations of the possible tracked entities’ locations into account. This emphasizes the need for a method to automatically construct the radio maps for an area of interest.

2. GOALS

In this demo, we will show the generation of radio maps for a given site and compare them to the manually constructed radio maps by feeding them to a location classifier (a MAP classifier), and comparing the classifier performance. The demo will run over two different test beds, one for the device-based and another for the device-free scenario. Additionally, the demo will show the flexibility of modifying the environment setup and configurations. The attendees will
be allowed to fiddle with these parameters and inspect their effect on the accuracy of the generated radio map accuracy.

Figure 1 shows the architecture of our system. Due to space constraints, we show only the layout of the device-free experiments (Figure 2), where the numbered dots illustrate the locations of the human body in each experiment.

2.1 Implementation

Our system combines ray tracing with the uniform theory of diffraction [4] to model both the RF propagation and human shadowing effect. Ray tracing approximates the electromagnetic waves as a set of discrete ray tubes that propagate through the area of interest and that undergo attenuation, reflection, transmission and diffraction due to the complexity of an indoor environment.

The construction of device-free radio maps requires modeling of the human body effect on the RF signals. At microwave frequencies and higher, incident waves are reflected and diffraction off the human body. Previous work in human modeling has shown a strong correlation between the RF characteristics of the human body and a metallic circular cylinder [3] in indoor radio channels. Therefore, we use a metallic cylinder to model the human body with radius \( r = 0.15 \text{m} \) and height \( h = 2 \text{m} \) [3]. The field reflected off a cylindrical surface from an incident electric field is given by [4].

The input to our system is the 3D model of the area of interest. The tool enables the user to manipulate different environment configuration easily. The configuration includes APs and MPs characteristics and human locations.

The results obtained from the ray tracer is processed to generate the radio map. A radio map is constructed by dividing the area of interest into a number of locations; each location has a corresponding cell in the radio map.

The radio map is then inputted to a MAP classifier and the results are then compared with those obtained when a measured-based radio map is used instead. summarizes the results.

A sampled scene with RF prediction levels rendered on its floor can also be generated by processing the tracing result by the Rendering Engine. At the sampling step, an isotropic antenna is virtually positioned at each sampling point and the overall sampling result is then bi-cubically interpolated over the whole floor area (Figure 3).

More information on the implementation of AROMA can be found in [2].

3. CONCLUSION

This demo allows the attendees to experience the feasibility of using computer-generated radio maps in localization systems. AROMA shows that it is possible to generate accurate radio maps that achieve high localization accuracy, without the need to manually calibrate the area of interest. We will also point out some open research problems such as generating dynamic radio maps and algorithms for multiple entity tracking.

4. REFERENCES

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