# Algorithmic Strategies for Adapting 802.11 Location Fingerprinting to Environmental Changes

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## 1 Summary

This paper studies novel algorithmic strategies that enable 802.11 location fingerprinting to adapt to environmental changes. A long-standing challenge in location fingerprinting has been that dynamic changes, such as people presence, opening/closing of doors, or changing humidity levels, may influence the 802.11 signal strengths to an extent where a static radio map is rendered useless. To counter this effect, related research efforts propose to install additional sensors in order to adapt a previously built radio map to the circumstances at a given time. Although effective, this is not a viable solution for ubiquitous positioning where localization is required in many different buildings. Instead, we propose algorithmic strategies for dealing with changing environmental dynamics. We have performed an evaluation of our algorithms on signal strength data collected over a two month period at Aalborg University. The results show a vast improvement over using traditional static radio maps.

## 2 Description

In recent years outdoor positioning and navigation systems have become household commodities due to continuously dropping costs of accurate GPS equipment. To facilitate an equally wide scale consumer adoption of positioning and navigation in indoor spaces, 802.11 (Wi-Fi) is an obvious technological choice due to the ubiquity of Wi-Fi infrastructures and the proliferation of Wi-Fi- (and GPS-) enabled mobile devices. Due to the somewhat unpredictable propagation patterns of Wi-Fi signals in indoor environments, the so-called *location fingerprinting* technique, which relies on empirically measured signal strengths, has yielded the best results in terms of obtainable positioning accuracy.

The main drawback of the technique, however, lies in the manual calibration effort needed to build the radio map. The problem is compounded by the fact that the collected signal strengths often have only limited temporal validity. Dynamic environmental changes, e.g., a varying number of people present, changing humidity levels, or the opening and closing of doors, means that signal strengths collected at one time may not accurately predict the signal strengths at other times. As a result, positioning accuracy decreases and the time and effort in building the radio map is essentially wasted. While the majority of research has assumed a static radio map, i.e., a radio map which is built once, Yin et al. [2005] and Chen et al. [2005] take the dynamic aspects into account by adding additional sensors to query the dynamics at a given time. While this approach does capture the signal strength changes, it is not well suited to ubiquitous positioning because only few buildings can be expected to accommodate the required, additional hardware.

The algorithms studied in this paper are part of the Streamspin system, a platform that supplies ubiquitous, user-driven indoor-outdoor positioning [Hansen et al. 2009]. The user-driven aspect of Streamspin refers to the fact that users upload fingerprints to an ever-evolving radio map with the aim of providing up-to-date signal strength information. We consider two distinct algorithms for adapting to different signal strengths caused by dynamic changes in the environment. To evaluate the accuracy of the algorithms, we apply them to signal-strength data collected over a two-month period at Aalborg University.

The algorithms are compared with two traditional approaches: a baseline approach that builds a radio map once (called Baseline-Single in Table 1) and a baseline approach that combines all received fingerprints into a single fingerprint (Baseline-Collected). Our first algorithm uses the notion of interval trees. Here, the fingerprints supplied by Streamspin users are sorted according to the time of day they were measured and split into several subtrees that capture the characteristics at different time periods. Our second algorithm does not explicitly consider the temporal aspect, but instead uses a divisive clustering technique with a single linkage criterion to group similar fingerprints together.

Table 1 outlines the main results. Scenario 1 depicts the case when there is little variation in the signal strengths. In this case, our two algorithms perform only marginally better than the Baseline-Collected approach. Using a single fingerprint results in the worst accuracy as the average positioning error is ca. 5 meters. A substantial difference is evident in Scenario 2 where signal strength variations occur. The accuracy of the Baseline-Single approach deteriorates by 1.5 meters, while the Baseline-Collected is affected particularly severely because it now contains widely differing signal strengths. In contrast, our two algorithms are more or less able to retain the accuracy. The very minor deterioration can be attributed to a loss of signal strength information as the information has been distributed in several clusters and interval tree nodes, respectively. These results demonstrate that the adverse effects of changing signal strengths have been avoided. Moreover, due to the algorithmic nature of our solutions, they are a perfect fit for systems that are meant to scale to several buildings without incurring any additional hardware costs.

Table 1: Average accuracy of the different algorithms in meters

| | Baseline-Single | Baseline-Collected | Interval Tree | Clustering |
|---|---|---|---|---|
| Scenario 1 | 5,16 | 1,48 | 1,13 | 1,42 |
| Scenario 2 | 6,68 | 9,99 | 1,30 | 1,71 |

## 3 References


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