HiLoc: A TDoA-Fingerprint Hybrid Indoor Localization System

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ABSTRACT

In this short paper, we introduce our ongoing work **HiLoc**, a hybrid indoor localization schema based on Time Difference of Arrival (TDoA) and wideband Wi-Fi Fingerprints.

1. INTRODUCTION

Our system consists of 10 modified APs as anchors deployed in the environment, and a laptop is used as client. We implement a TDoA ranging system based on Wi-Fi and sound signal. The AP is equipped with a speaker, and it is programmed to emit high frequency pulses acoustic wave (> 16kHz and 0.1s). At the client side, an real-time capturing tool is developed to obtain the precise time difference. In multipath environment, the distance measured by TDoA may not be the direct path, wideband Wi-Fi Fingerprint based approach is used to correct the error. After that, we develop an Ranging-Quality Aware Least Squse Estimate (RQA-LSE) scheme to precisely estimate clients' location.

2. TDOA RANGING

On AP Side: The key point for AP is to ensure that the time interval between Wi-Fi Beacon message and sound pulse is constant. The beacon message is injected to Wi-Fi card directly bypassing the MAC layer. For sound signal, the AP is continuously playing the sound, and the sound pulse is generated by tuning the amplitude, which avoids the process invocation time.

On Client Side: The key point on client side is to precisely measure the arrival time of both signals. For Wi-Fi signal, the arrival time is directly obtained through monitor interface. For sound signal, we developed a dedicated sound capture APP. it run the sound capture and disk logging simultaneously in parallel threads.

based on above setting the time difference t_d is defined as:

$$t_d = t_{rs} - t_{rw} - t_{ss} + t_{sw} \tag{1}$$

where t_{rs} and t_{rw} denote the received time for Wi-Fi beacons and sound pulse, while t_{ss} and t_{sw} denote the sent time.

3. WIDEBAND FINGERPRINT

Due to different wavelength and reflection profile, signal strength varies along the channel shifting. our wideband fingerprint system works on 5G band from Channel 40 to 165 of nearly 600Mbps bandwidth. Such wide channel shifting provides sufficient distinction in fingerprint.

In this way, the traditional 2-D fingerprint now becomes a 3-D surface fingerprint $f_{i,j}$, where i and j denotes the i-th AP and j-th channel respectively. Assuming the fingerprint site-survey is done, when client has measured a 3-D fingerprint f, the localization is to find the best candidate reference fingerprint in the database denoted by f^R which minimizes the following function

$$\arg\min_{f^R \in F} \sum_i \sum_j |f_{i,j} - f^R_{i,j}| \tag{2}$$

TDoA Error correction: The sound pulse may reflect through the multipath environment before reaching the client, which introduce ranging error. Based on the coarse estimation of client's location, we plan to use ray-tracing algorithm to find the shortest NLoS paths where the sound pulse may go through. By removing the multipath components, we get the LoS distance.

4. ROBUST LOCALIZATION

Given the range measurements to several nearby APs, we use RQA-LSE to obtain client's location. RQA-LSE works by minimizing an objective function f^* over AP-client pairs , which is denoted by

$$f^* = \sum_i w_i (l_i - d_i)^2 \tag{3}$$

where l_i and d_i is the distance measured by LSE and TDoA respectively, w_i is the weight factor, which is determined by the RQA algorithm. The RQA will combine the TDOA ranging result and wideband localization result, and plan to give an even trade-off.

5. EVALUATION

For TDOA ranging accuracy, 20 random ranging test in LoS environment is carried out, the average error is at most 0.6m. We then evaluate the localization error for 10 times in LoS environment. In each test 5 APs are randomly placed. the results show the, in most of time, the error is within 3m.

6. CONCLUSIONS

In this short paper, we introduce our onging work **HiLoc**, a TDoA-Fingerprint hybrid indoor localization system. Our system requires little modification to AP and it can achieve high localization accuracy.