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An Accurate Geographic Detection Positioning using Cell-Sense for GSM Phones

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ABSTRACT

With cell phones becoming pervasive its location is difficult to achieve. As localization may occur via multi-lateration of radio signals between base station of the network and the phone. To locate phone using multi-lateration of radio signals it need to contact nearby antenna tower, where GSMis based on the signal strength to antenna towers. Hence we implement Cell Sense-Hybrid technique in which both deterministic and probabilistic technique are combined together with Received Signal Strength Indicator localization fingerprinting method for accurate energy efficient positioning to achieve high precision and low computational overhead. For evaluation process, we use Android based cell phones.

Keywords: Cell Sense-Hybrid technique, Received Signal Strength Indicator (RSSI) fingerprinting localization, Global SystemforMobileCommunication (GSM).

I.INTRODUCTION

The technology of locating is based on measuring power levels, antenna patterns and mobile phone communicates wirelessly with closest base stations, so detailsof the location of these station implies the cell phone is nearby.The main context information is location which enables a wide set of cell phone applications including location-aware applications for social networking, and security applications systems. GPS is considered to be the best well knows localization technique which uses space-based satellite navigation for providing location. Since it uses satellite communication requires direct line of sight to satellites, and consumes more battery power in cell phones.Citywide Wi-Fibased localization for cellular phones are currently available. However Wi-Fi chips and GPS are not available in all cell phones with no sufficient Wi-Ficoverage to obtain ubiquitous localization. Similarly today's popular mobile phones are coming with various sensors like, 3-axis accelerometer have been proposed. These sensors are still not widely used in many phones. On the other hand, Global System for Mobile Communication (GSM)localization is the use of multilateration to determine the location of GSM mobile phones, or trackers, with the intent to locating the user location.By its name it is available on 80–85% of today's cell phonesworks all over the world, and consumes minimal energy comparing to the standard cell phone. GSM Localization-Based Systems can be broadly divided into:

1. Network-based
2. Handset-based
3. SIM-based
4. Hybrid

In Network-based technique, utilization of service provider's network infrastructure to identify the location of mobile. Second method requires the installation of client software on the handset to determine its location. Third method using SIM in GSM and UMTS, it is possible to obtain radio measurements from the handset. Finally in Hybrid positioning system, use a combination of network-based and handset-based technologies for location determination. Many researchers' works have addressed the problem of GSM localization which includes time-based systems, angle of arrival (AOA) based system, cell-ID based systems and received signal strength indicator (RSSI)-based systems. With the advances in cell phones, GSM localization systems have been implemented. RSSI is a complex function of distance; require building an RF fingerprint of the area of interest due to the noisy wireless channel. This fingerprint stores information about the received RSSI from different base stations at

different location. It is constructed in an offline phase. The received RSSI at an unknown location is compared with the RSSI in the fingerprint and the closest location is returned as the estimated location. Construction of fingerprint is a time consuming process, so it is typically done and retrieved from various commercial systems such as Google My Location, Street View services and Skyhook which already perform scanning for other purposes. Hence constructing this fingerprint for GSM localization can be piggybacked on these systems without extra overhead.

In this paper, we propose Cell Sense Hybrid Technique for GSM localization. Unlike current techniques for GSM phones that use a deterministic approach for estimating the location, whereas Cell Sense provides accurate localization. This adds significantly to the overhead of the fingerprint construction. Cell Sense addresses challenge by using gridding approach, where the area is divided into a grid and the histogram is constructed for each cell. This helps in increasing the scalability of the technique as the size of fingerprint is reduced by its increase of grid cell length. For further reducing the computational overhead of Cell Sense-Hybrid technique also has the added advantage of its accuracy being robust even on changes in its parameter values of location.

Evaluation of Cell Sense, we implement it on Android-based cell phones and compare its performance to other fingerprinting techniques, model-based techniques, Google My Location service and Skyhook service on two different test beds area of interest respectively. Also the study on effect of different parameters is accurate.

To summarize, the contribution of this paper in threefold:

1. We combine the Cell Sense deterministic and probabilistic GSM localization system, which provides high precision and depends on a gridding technique to reduce the construction overhead.
2. We further extend Cell Sense through a hybrid technique that adds a refinement phase and rough estimation phase. Therefore, the CellSense-Hybrid technique parameters can be selected to achieve a low computational overhead maintaining the accuracy of same.
3. We finally evaluate the performance of existing Cell Sense and CellSense-Hybrid techniques both through analysis and show their significant advantage compared with other art GSM localization systems.

II. PROBLEM ANALYSIS

Problem is that inefficient accuracy of signal strength which explains the difficulty of understanding and indentifying the location of user on exact terminals of base station with respect to change on location of user from one terminal to another gives improper parametric values for evaluation and estimation phase. Since localization of this system explains and tracks onlythe number of the user, the location the user of unknown area is not identified. Because the received RSSI signatures emphasize the signal quality of particular bandwidth, it doesn't compare or store any information on its database. The difficulty of retrieving the fingerprints on different area of interest and storing it in a data collection database is not made and this reduces the precision and computational overhead. Doing this in online phase (i.e.) on the system makes it a time consuming process for evaluation metrics.

Hence GSM Cell Sense localization of this system is a failure one because of its localization error and running time complexity comparing with other services available on the commercial systems.

III. RELATED WORKS

In this section, we discuss the different techniques for localization and how they differ from the proposed work. We categorize these techniques as time based system,Cell-Id based system AOA based system, City-wide Wi-Fi localization, and augmented sensor based, and finally on signal strength based system.

A. Time-of-Arrival (ToA) based system

In this systems, the cell phone estimates its distance to a fixed reference point based on the time for a signal takes to travel from the point to it. Similarly, time-difference-of-arrival based systems uses the principle that the emitter location can be estimated by the intersection of the drawn hyperbolae of differential constant ToA of the signal on two or more pairs of the base stations.

B. AOA based system

AOA-based systems use triangulation based estimation AOA of a signal at two or more base stations for the location of the desired transmitter. In this antenna arrays are usually used to estimate the AOA. It's less attractive for a large deployment on cell phones.

C. Cell-ID based system

Cell-ID based techniques do not explicitly use RSSI but rather estimate the cell phone location

as the location of the cell tower the phone is currently associated with. This requires a database of cell tower location.

D. City-Wide Wi-Fi based system

City-wide Wi-Fi based localization has been proposed and it's currently available in commercial products. However it's similar to GPS, is not available in the majority of cell phones and requires larger coverage to obtain ubiquitous localization.

E. RSSI based system

Recent developments of RSSI have been implemented for cell phone localization. Since these information is readily available to user's application on almost GSM phones which consume minimal energy when comparing to standard cell phone operation. Even though it's a complex function of distance usually require building an RF fingerprint at different area of interest. This is usually constructed in an offline phase. During the tracking, the received RSSI at an unknown location is compared with the RSSI signatures in the databases and the closest location is returned as the estimated location. This is typically done in a process called war driving, where cars drive the area of interest continuously scans for cell towers and records the tower ID, RSSI and GPS location. Current systems, such as Skyhook, Google My Location, and Street View services perform the scanning for other purposes. So construction of fingerprint GSM can be piggybacked without extra overhead.

1. Deterministic Fingerprinting Techniques:
Current fingerprinting techniques for GSM localization use only deterministic approaches. For example, each location in the fingerprint stores a vector representing the RSSI value from cell tower at this location each. During the tracking, the K-nearest neighbour (KNN) classification algorithm is used, where the received RSSI at unknown location is compared with the vector closest stored in databases. This technique requires searching a larger database, but provide high precision
2. Modelling based technique:
Modelling-based technique tries to capture the relationship between strength of the signal and received distance using a model. Example: Let us consider the work uses a Gaussian process (GP) to capture relation assuming that the received signal y_i at location x_i is $y_i = f(x_i) + \epsilon_i$, where ϵ_i is zero-mean additive Gaussian noise with known variance σ^2_n

Building a GP estimator requires constructing a fingerprint, although a less sparse one. It's used to estimate the parameters (l, σ^2_n, and σ^2_f) to compute $f(x_*)$ for any location x_*.

This estimator reduces the size of the fingerprint and provides a way for extending a sparse fingerprint to a denser based on the assumed model. Moreover, the assumed model may not fit to the real environment thus reducing the accuracy of returned location.

G. Summary

Compared with the above techniques, our proposed system Cell Sense requires no specialized hardware and is more ubiquitous.

Compared with cell-ID based systems and the current fingerprinting techniques, our technique is hybrid. Using the probabilistic approach enhance the accuracy of localization compared with a deterministic approach. Our proposed technique addresses these challenges and provides precision better than all of the current techniques with low computational requirements.

IV.SYSTEM ARCHITECTURE-CELLSENSE SYSTEM

In this section, we describe Cell Sense technique for GSM phone localization. Starting with an overview of the system followed by the details of different phases. Finally we propose a hybrid approach that combines basic cell sense of deterministic approach and probalistic to achieve both accurate localization and low computational overhead.

A. Overview

Fig.1 shows our Cell Sense system architecture. Cell Sense works in two phases: 1) Construction of an offline fingerprint phase, and 2) Tracking phase online. During the offline, a probabilistic approach is constructed, where the RSSI histogram for each cell tower at given location of area of interest is estimated.

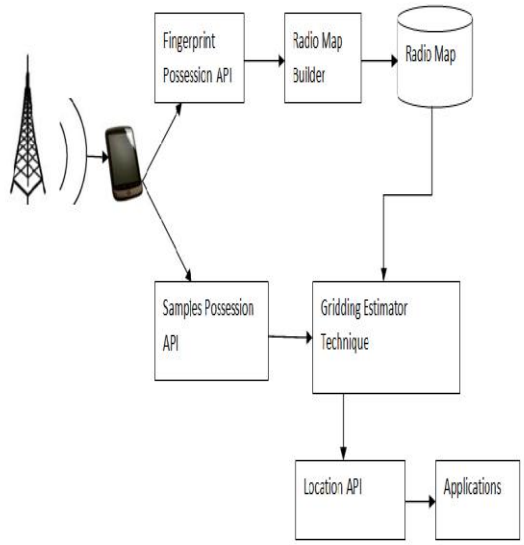


Fig 1. Cell Sense components.

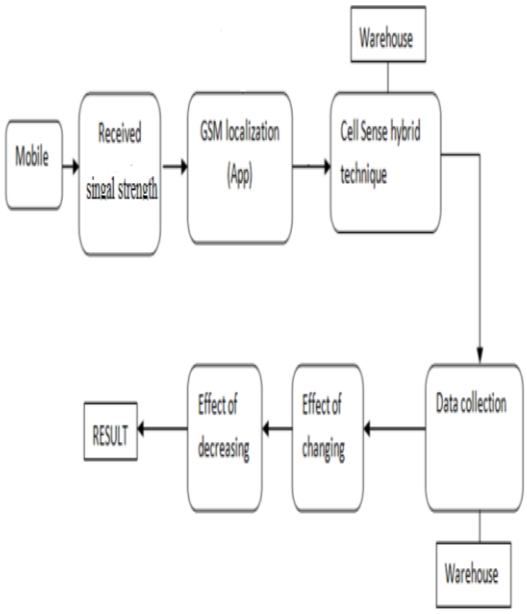


Fig 2. System architecture

During the tracking phase online, the estimated location module uses the fingerprint to calculate the most probable location at which the user maybe standing

The received RSSI samples are collected with Fingerprint Acquisition API that interacts with phone modem to get the RSSI data from up to seven neighbouring base station towers. Finally the location API is used by the application to query on current estimated location.

B. Construction of an offline fingerprint

The purpose of offline phase is to construct the signal strength histogram for the received RSSI at each location in the fingerprint of each base station tower. Typically, the user requires standing at different location in the fingerprint for a certain amount of period of time to collect samples enough for to construct the histogram for RSSI. This increases the construction work as the war-driving car has done.

To avoid overhead, we use a gridding approach in which the area of interest is divided into cells. Histogram is then constructed for each base station tower in a given cell using all the fingerprint values inside the cell rather than for each point. This gridding approach reduces the resolution factor of fingerprint size in the database. The centre of mass of all values of fingerprint inside grid is used to represent the cell[1].

Fig. 3 shows gridding of cell sense approach for fingerprint construction

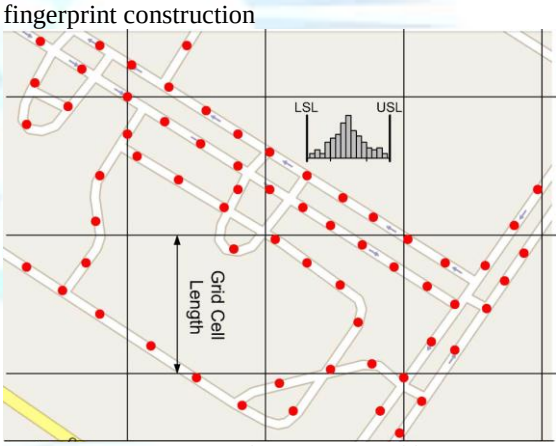


Fig 3. Cell sense approach for construction of fingerprint. The grid length cell parameter can be used to trade off accuracy and scalability measures

The gridding approach not only removes the overhead but increases the scalability measure of Cell sense.

1We use the term “fingerprint point” to refer to an individual point collected using the war driving car method and use the term “fingerprint cell” to denote the collection of fingerprintusing all points inside a given cell.

C. Tracking phase online

The user stands at an unknown location *l*receives signal strength of vector s = (s_1, . . . , s_q) which contains one entry for each cell tower. Now to find the location in fingerprint (l ∈ L) that has the maximum probability of given vector s. That is, to find

$$\text{argmax}_l\ [P(l|s)]$$

Using Bayes theorem assume that all the locations are probable, can be written as,

$$\text{argmax}_l [P(l|s)] = \text{argmax}_l [P(s|l)]$$

In this case, P(s|*l*) can be expressed as follows:

$$P(s|l) = {}^{q}\pi_{i=1}{}^{Ns}\pi_{j=1} P(s_{i,j}|l)$$

Where $s_{i,j}$ represents the *j*th sample from the *i*th term.

D. Cell Sense-Hybrid Technique

It targets maintenance of accurate low grid size while reducing its computational requirements.This technique runs in two phases: 1) estimation phase and 2) refinement phase.

1) In first phase of estimation, uses the probabilistic estimation technique to obtain the most probable cell in which the user may be located is identified. Instead of returning the centre of mass of points of fingerprint inside cell as estimated location as in the basic cell sense.
2) In second phase of refinement, KNN approach is used for the estimation of closest fingerprint point in the signal space to the user location on the cell estimated phase of one. We do not use a probabilistic method in this phase.

V. PERFORMANCE EVALUATION

We study the different parameters effect over cell sense and compare it with other RSSI based system for performance evaluation.

A. Data Collection

We implemented the scanning process program using Android SDK. This program records all necessary details like the cell-ID, strength of signal and timestamp for base station to which it is connected along with six neighbouring towers. Our experience shows that visiting of same area or point more than once doesn't enhance its accuracy.

B. Effect of changing parameters

We find the effect of changing the different parameters of cell sense performance shows mainly,

1) Effect of grid cell length and effect of the number of samples used N_s
2) Effect of the number of averaged fingerprint locations K
3) Effect of cell towers density
4) Effect of decreasing the radio map density of data collection
5) Effect of using different service providers

C. Results of the Cell Sense Hybrid approach

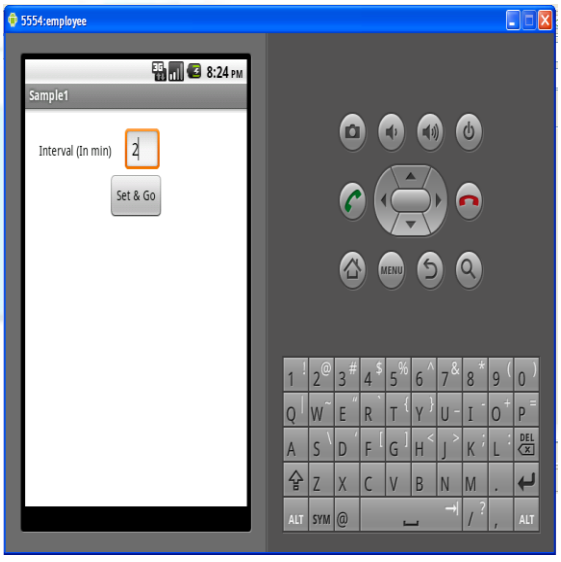
Shows that the accuracy of this technique degrades as the grid cell increases since the values inside a cell become centroid, increases the estimation error and reduces accuracy. It has robust performance, due to refinement estimation phase.

D. Comparison with other techniques

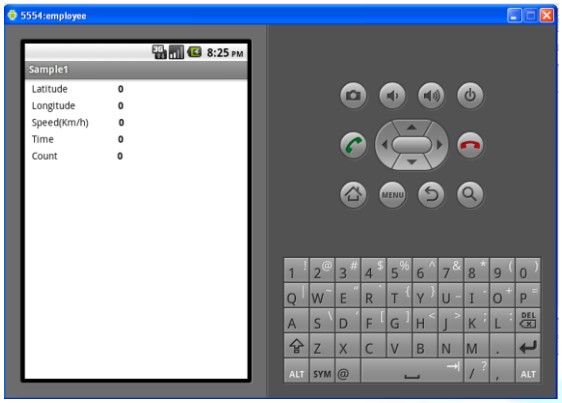
Here we compare the performance measure of standard cell sense and cell sense hybrid approach in terms of running time of process, complexity and localization error.

1. Localization Error: It shows the cumulative distributive function (CDF) of distance error on different area of interest over location. And performs better in urban than rural due to high density of base stations.
2. Running time: All other technique takes more time on average in the urban than rural due to the increase of number of base station towers. Our cell sense-hybrid provides about three to five times enhancement over the running time comparing others.

VI. IMPLEMENTATION LOGIN SCREEN:



FINDING THE LOCATION OF MOBILE:



VII. CONCLUSION

We have proposed Cell Sense Hybrid approach which combines the deterministic technique and probabilistic technique to achieve both high precision and low computational requirements. We implemented our system on Android-based cell phones and comparison is made with other localization system on area of interest over two different test beds. Our results shows greater accuracy with more than 5.4 times savings over the running time compared with others.

In future work, we can extend for different directions that includes the parametric distributions of fingerprint, exploring with larger data sets and making it in-built application in all low-end phones.

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