

Signal Propagation Scenario Simulator for Planning Measurement Points to Improve Positioning Performance

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Abstract—

Since the modern buildings are permeated with WiFi Access Points, the position information of WiFi APs can enable a variety of Location Based Services. A popular design pattern is to estimate AP position by measuring its signal strength at several Measurement Points. In order to acquire this information, the location and formation of signal Measurement Points (MP) is very critical. It is very important to plan the site survey ahead of actually executing it. This paper presents a scenario simulator that allows creating a probable survey site along with measurement points, access points and propagation environment. A Graphical User Interface (GUI) allows site configuration, survey planning and performance evaluation in terms of accuracy. This capability is very useful for the companies/individuals who are interested in development of APDB for providing WiFi based positioning and Location Based Services.

Keywords— Site Survey, Estimation, Simulation, Graphical User Interface, LBS

I. INTRODUCTION

The deployment of mobile computing and communications infrastructure is exponentially increasing in urban areas especially inside the buildings. It is quite practical to utilize these abundant radio signal sources to locate mobile devices. One of the most potent examples of such positioning is to improvise signals of the IEEE 802.11 WiFi Access Points that can be found in every modern building these days. As a result, WiFi signal strength based positioning technology has matured and being deployed in metropolitans by many of futuristic telecom service providers.

One of the common approaches to build WiFi based positioning system requires developing access point database (APDB) containing unique identity and location of each of Access Points. Whenever a mobile device receives WiFi signals, the location information of the detected Access Points is extracted from the database and is used to calculate position of the device by using a variety of ranging methods.

The APDB is developed by surveying the area of interest and measuring the signal parameters at several measurement points. Any error in location information of an AP in the database is directly translated to the positioning error. Therefore, the positioning accuracy depends on the correctness of the location information in the APDB.

This paper presents a Scenario Simulator tool for creating arbitrary propagation environment, signal sources (APs), signal measurement points (MPs) to evaluate different surveying strategies.

II. RELATED WORK

WiFi based location finding has gained a lot of momentum. Several efforts have been reported to improvise WiFi signals for positioning such as RADAR system by Microsoft [1], PlaceLab by intel [2], Skyhook [3] and Ekahau [4]. Two important design patterns emerge out of a decade long efforts of building such systems.

Firstly, the fingerprinting based design that involves measuring the signal strengths on a fine grid-scale, 1 to 5 meters, to create power profiles. Later, these power profiles are kept in a database. The mobile terminals received signal vectors are matched for closest clones in the database to infer the probable location of the device. A number of approaches have been proposed to enhance accuracy of fingerprinting based positioning such as Bayesian Networks [5], Fuzzy logic and Neural Networks [6]. This design requires a laborious task of measuring ever-changing radio fingerprints. This requirement has restricted the wide-scale applicability of such system despite high accuracy reports in literature.

The second design pattern strives to estimate the location of Access Points via a speedy measurement process. The estimated locations of Access Points are kept in a database, referred to as APDB in this paper. Later the position of a device is estimated via a variety of method, e.g. multilateration, whenever a device reports detected Access Points. Intel's PlaceLab[2] and Skyhook [3] have developed metropolitan scale APDB for enabling Location Based Services in the urban areas. These systems employ scanning vehicle that drive through the roads to measure signal parameters. The AP position estimation is based upon simple triangulation or detection-spot algorithms. Due to possible large errors in AP position estimates such systems can provide position information of a mobile device within tens of meters given that a sufficient number of detected APs are found in the APDB. This design, however, is not applied to the indoor environments where accuracy requirement is strictly within several meters.

The position of the signal source, e.g. Access Point, can be specified selecting the “*Draw Access Point*” mode of the GUI. Once selected, the GUI can respond to the pointing device for installing an AP at any location similar to the MPs.

An example scenario is drawn as shown in Figure 1. Here a survey site of 40x40 meters dimension is simulated and formation of five measurement points, represented as green squares, is planned. The Access Point, represented as red star, is located at (7, 32).

B. Propagation Parameters

The signal strength of a wireless signal exponentially decreases with respect to the distance it travels from transmitter to receiver. Additionally, a variety of factors in propagation environment affects the wireless signal travelling through it. It is computationally prohibitive to calculate the affect of each factor on signal strength. The relationship between distance and received signal strength is given as (3)

$$P_r = P_o - 10 \times \alpha \times \log_{10}(d) + N \quad (3)$$

Here P_o is the nominal signal strength. The α is the attenuation factor. The d is the distance between transmitter and receiver. The N is the noise parameter which embodies the environmental factors.

Above parameters can be specified in scenario simulator GUI in the input controls grouped as “*Propagation Parameters*”.

1) Environment Noise Spread

The value of environment noise parameter is modelled as Gaussian distribution with zero mean and spread input in the Noise Standard Deviation.

2) Nominal Transmission Power

The nominal transmission power is the received signal strength at a standard distance, i.e. 1 meter, and can be input into the given control.

3) Attenuation Factor

Scenario simulator deals with two types of attenuation factors. Firstly, the actual value of α which is applicable to the environment but unknown to the estimator. Secondly, the assumed value of α which is taken as initial value by estimator. The assumed value of α is iteratively updated along with other parameters during the estimation process such that the final estimated value is closer to the actual one.

C. Signal Measurement Parameters

The measurement of signal strength at specified Measurement Points can be configured using “*Signal Measurement Parameters*” group of input controls.

1) Weight Scaling Factor

The weight scaling factor can be configured within the range of 1 to 10.

2) Measurement Scans per MP

Signal strength measurements at a Measurement Point may contain noise due to environmental factors. Increasing the number of measurements is possible in order to reduce the effect of noise. The “*Scans per Point*” input control can be used to specify the number of measurements.

3) Simulation Time

The “*Simulation Time*” input control can be used to specify the number iterations for simulation.

D. Simulation Functions

Following functions can be invoked once the Measurement Points location/formation as well as the Access Points location is drawn on the GUI.

- i) Simulate Received Power
- ii) Import/Export of Simulation Data
- iii) Estimation of AP Position
- iv) Resetting the Environment

E. Measurement Points Information

The information about measurement points drawn in the “*Survey Site GUI (Access Point & Measurement Points)*” figuratively appears in the “*Measurement Points Information*” table shown at the bottom-left corner of the main GUI. The MP related information is tabulated into following columns.

- i) Measurement point coordinates (X-Coord & Y-Coord).
- ii) Received signal strength (RSS).
- iii) Distance between AP and MP (RangeActual).
- iv) Error in estimated and actual distance (RangeEst).
- v) Actual Attenuation Factor (AlphaActual).
- vi) Estimated Attenuation Factor (AlphaEst).

Figure 2 shows the enlarged contents of this table.

Measurement Points Information							
MPID	X-Coord	Y-Coord	RSS	RangeActual	RangeEst	AlphaActual	AlphaEst
1	20	40	-53	15.2643	0.0224	2.8000	2.7000
2	20	25	-53	14.7648	0.0224	2.8000	2.7000
3	20	10	-59	25.5539	0.0112	2.8000	2.7000
4	5	10	-58	22.0907	0.0126	2.8000	2.7000
5	35	10	-64	35.6090	0.0063	2.8000	2.7000

Figure 2. Measurement Points Information Table

F. Estimation Results

Upon invoking the “*Estimate AP Info*” function, the simulator initiates the AP position estimation process as described in section III. The visual feed back of the estimation results is rendered in the “*Survey Site GUI*”. An example scenario is drawn as shown in Figure 1. The received signal strength measurements are simulated using “*Simulate*” function. The simulated measurements results are displayed along with respective measurement point. The AP position estimation function is invoked once the measurements are simulated. Both the weighted-centroid based initial estimate and refined iterative least-squares based estimates. Figure 3 shows the figurative output of refinement estimates of each iteration.

EstNumber	X-Error	Y-Error	Error	Po	Increment	Fw
10	1	0	1	-21.5703	0.0699	1.6193
9	1	0	1	-21.5691	0.1419	1.5939
8	1	0	1	-21.5701	0.2794	1.5450
7	1	0	1	-21.5835	0.5204	1.4583
6	1	0	1	-21.6401	0.8897	1.3236
5	2	1	2	-21.8005	1.3620	1.1492
4	3	2	4	-22.1350	1.8526	0.9680
3	5	3	6	-22.6639	2.2450	0.8209
2	7	4	8	-23.2990	2.4009	0.7361
1	9	4	10	-23.9263	2.6616	0.7969

Figure 3. Iterative Least-squares refined estimation results.

V. REAL VS SIMULATED SCENARIO COMPARISON

In order to exhibit the effectiveness of scenario simulator an experiment is conducted in a real indoor environment situated in ETRI. Three Access Points were installed on known locations and signal strengths were measured on 8 measurement points. Similar scenario was created in the simulator to compare the signal propagation, strengths and positioning information estimation.

The experiment results are shown in figures 4, 5, 6. There are following important observations that are made.

Even though the signal strength measurements are similar in real and simulated environments, the position estimation results differ slightly due to simplistic assumption of constant attenuation rate throughout the survey site. Further research is required for more generalizable attenuation rate assumption.

The noise distribution simulated in Scenario Simulator is also varies on different places depending upon the interior design of the indoor environment. However simulator assumes a constant spread of noise throughout the environment.

Despite above limitations, the scenario simulator results provide adequate insight into a given indoor environment regarding expected positioning accuracy for certain formation of Measurement Points. This capability underlines the significance of the idea and implementation presented in this paper.



Figure 4. Real vs Simulated Scenario for AP1 Position Estimation



Figure 5. Real vs Simulated Scenario for AP2 Position Estimation



Figure 6. Real vs Simulated Scenario for AP3 Position Estimation

VI. CONCLUSIONS

The capability of simulating a probable scenario and evaluating the position estimation performance is very important requirement planning of Measurement Points. The scenario simulator presented in this paper can effectively help fulfil this requirement. The configurable parameters of target site allow creation of a variety of situation that may occur in the indoor propagation environments. However, the simulation capability lacks in some aspects that are the aim of future development. Any further development of this or similar simulator should provide enhanced capability of creating indoor environments such that the related propagation parameters in further detail. The signal strength simulation equation should also be configurable for a variety of frequencies and attenuation parameters.

ACKNOWLEDGMENT

This work was supported by the IT R&D program of MIC/IITA, Republic of Korea. [2007-F-040-01, Development of Indoor/Outdoor Seamless Positioning Technology].

REFERENCES

- [1] P. Bahl, et al. "RADAR: An in-building RF-based user location and tracking system." In IEEE INFOCOM 2000, pages 775–784, March 2000
- [2] Anthony LaMarca et al., "Place Lab: Device Positioning Using Radio Beacons in the Wild". In proceedings of Pervasive 2005, Munich, Germany.
- [3] Ekahau Positioning Engine, www.ekahau.com
- [4] Skyhook Wireless, www.skyhookwireless.com
- [5] David Madigan et al, Eiman Elnahrawy, Richard P. Martin, Wen-Hua Ju, P. Krishnan, and A. S. Krishnakumar, "Bayesian Indoor Positioning Systems", IEEE Infocom, Miami, Florida, March, 2005.
- [6] Uzair Ahmad, Andrey Gavrilov, Young-Koo Lee, and Sungyoung Lee., "Context-aware, Self-scaling Fuzzy art map for Received Signal Strength Based Location Systems", Journal of Soft Computing, Springer, 12(7):699- 713, 2008.
- [7] Uzair Ahmad, Brian J. d'Auriol, Young-Koo Lee, and Sungyoung Lee., "Multi-floor Semantically Meaningful Localization using IEEE 802.11 Network Beacons", IEICE Transactions on Communications, Special Issue on Emerging Technologies for Practical Ubiquitous and Sensor Networks. IEICE Transactions 91-B(11): 3450-3460, 2008.