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Location Fingerprinting of Mobile Terminals by Using Wi-Fi Device

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Abstract— **The increasing demand for location-aware services inside buildings has made indoor positioning a significant research topic. While the outdoor location can be easily calculated, using technologies such as GPS. The location using fingerprinting technique is consist of two different phases: the first phase is the calibration phase at specific points called calibration points within the environment, the signal strength at each point is recorded and saved in a database; the second phase is the location estimation phase where the object measures the signal strength at its current position and then, using a location estimation algorithm, the measured signal is estimated with values stored in the database in order to obtain an approximation on the user's current position. In this paper a fingerprinting based localization of mobile terminals is done by using Wi-Fi device. For this approach a data collection was made without the presence of the user near the laptop. For each calibration point, the RSS for each access point was taken and stored in the database. After collecting the data the Fingerprint Map is generated to test the chosen LEA. The chosen Location Estimation Algorithm is k-Nearest Neighbor Algorithm with Euclidean, Manhattan Distance and Chebychev Distance.**

Index Terms— *fingerprinting, Wi-Fi, wireless network, location estimation algorithm*.

I. Introduction

For the past few years, there has been a high interest in mobile terminal (MT) positioning. The primary motivation for the development of mobile positioning systems was due to the mandatory requirement of security services. Although the starting was because of security-emergency need, later it has found various applications in many fields, e.g., to increase data throughput in cellular systems. There exist many algorithms developed for the MT localization problem. The traditional geometrical localization methods are designed to work under line-of-sight (LoS) conditions. However, LoS conditions might not always be present between the base station (BS) and the MT. Therefore, fingerprinting-based localization techniques which are also the subject of this paper attract attention because of their ability to work also in multipath and non-line-of-sight (NLoS) environments. The effectiveness of Location Based Systems depends on the correct location of users and mobile devices. While the outdoor location can be easily calculated, using Technologies such as GPS (Global Positioning System), it is more difficult to obtain when the location scenario is an indoor environment. One of these techniques is fingerprinting technique. From the several wireless communications technologies IEEE802.11 is probably the most used in Wireless Local Area Networks, so it was chosen for this work [5].

The techniques used to determine the location of a mobile terminal can be divided into three main categories Triangulation, Proximity and Scene Analysis. When using wireless networks to do the location estimation, any property of the wireless signal can be used in the process, as long as it is possible to establish a relation between the property of the wireless signal used to determine the location and the actual coordinates of the mobile device. Fingerprinting is a location technique that uses the scene analysis technique. It consists in observing and analysing the patterns of electromagnetic signals and their variations along time. A given property of the electromagnetic signal received from a set of references are read and then are compared with a set of previously stored values, called the Fingerprint Map (FM). From this comparison, the Location Estimation Algorithm (LEA) outputs the current location. Two different concepts of domain exist in this technique: the signals domain and the spatial domain. The signals domain is an n-dimensional space, where the number of dimensions equals the number of references that exist in the scene under analysis. The second domain is related to the space where the mobile node to locate is. The number of dimensions of this space depends on the type of output of the Location estimation Algorithm (LEA) [6]. It can be a single label indicating the location of the user (e.g. classroom 1); can be a two dimension coordinates system (x; y), a three dimensional coordinates system (x; y; z), etc. Location fingerprinting comprises of two distinct phases as shown in Figure 1., one is calibration phase on which data is collected and the Fingerprint Map (FM) is generated and a second phase, is location estimation phase also called as on-line phase when data is collected from the wireless communication transceiver are compared with information on the FM and the location is made.

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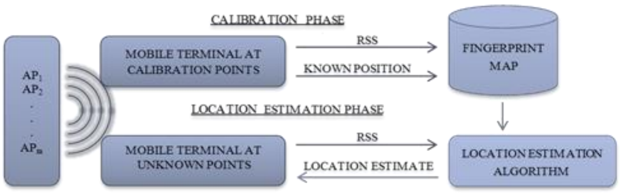

Figure 1. The two phases of location fingerprinting

II. LOCATION USING WIRELESS NETWORKS

A. Location using Trilateration

Trilateration falls under the category of Triangulation where the geometric properties of triangles are used to compute the objects' locations. The lateration technique works by measuring the distance to three distinct non-collinear reference points from the object of interest X and then applying a triangulation algorithm to obtain the position of the object. The triangulation algorithm is achieved by drawing a circle of radius d which centered at the reference point, where d is the measured distance from the access point to the object of interest at X. Using three access points, three circles could be drawn which would intersect at a point X. This point would indicate the location of the user. In order to measure such distance, three general approaches exist [4].

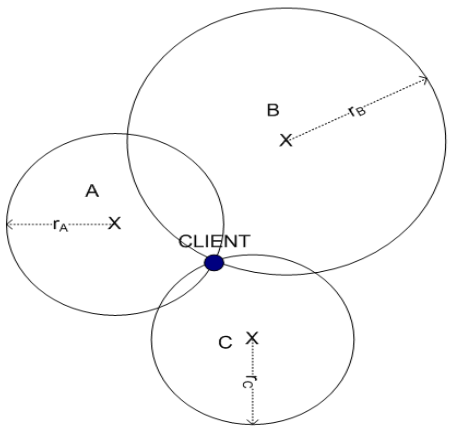

Figure 2.3: Triangulation

i. Direct - This method involves physically measuring the distance between the mobile object and three different reference points which is infeasible and inapplicable to the applications of indoor positioning. It generally involves robots that measure the distances through extension of probes.

ii. Time-of-Flight - Time-of-Flight works by recording the time it takes for a signal to propagate from a transmitter to a receiver at a known velocity. Since this method involves time measurement, a specific clock resolution must be attainable by the system according to the timing technology used.

iii. Attenuation - The intensity of the emitted signal is inversely proportional to the square of the distance from the source. Using this relation and given the signal strength at the source, the measured signal strength could be used to estimate the distance of the object from the source. Measuring the distance using attenuation is usually less accurate than using time-of-flight specially in environments with many obstructions which cause a lot of signal reflection.

B. Location using Angulation

In angulation, angles instead of distances are used to determine the location of an object. To compute the position, two angle measurements in addition to one length measurement between the two reference points are required. Using an array of multiple phased antennas with a known distance between them, by measuring the phase shift angle between the signal arriving at the first antenna and the signal arriving at the second antenna and given the differences in arrival time and the geometry of the array, the system can compute the angle from which the transmission was emitted [4].

C. Location using Fingerprinting

The scene analysis technique depends on analyzing the “scene” to obtain features that are easily compared and represented. A scene can be described either by images for the location or by the signal strength at that location. In static scene analysis, the observed features are looked up in the database that maps objects to locations. In differential scene analysis, the difference between successive scenes is tracked. Those differences will imply that the user has moved. If features are known to be at specific locations, the observer can compute its location relative to them. The advantage of such system is that it can act independently from an external server by storing the database locally which means that less power is required for data transmission and the privacy of the user could be maintained. The disadvantages include the need for a pre built lookup database of the features that might need to be rebuilt if the features of the scene change [5].
Fingerprinting is a type of scene analysis. Usually, the Fingerprinting approach consists of two stages:

i. Calibration Phase - At specific points called calibration points within the environment, the signal strength, along with other parameters such as the signal to noise ratio at each point is recorded and saved in a database. For the Fingerprinting database to be accurate, a significant number of calibration points should be made available which increases the time needed for the calibration phase.

ii. Location Estimation Phase - The object measures the signal strength at its current position and then, using a location estimation algorithm, the measured signal is estimated with values stored in the database in order to obtain an approximation on the user's current position.

The estimation could be done on the client side which requires that the database of fingerprints is stored locally, thus increasing the storage and memory requirements on the client. The other option is estimation on the server side which increases the load on the server and possibly the load on the network.

D. *Location using Proximity*

The proximity technique is useful in knowing whether an object is near a specific location rather than knowing the exact location. One type of proximity detection relies on the presence of physical proximity detectors such as pressure pads. Another type of proximity detection relies on the usage of automatic ID systems such as ATM machines or point-of-sale credit card machines where accessing an ATM at a certain time gives an indicator of the place of that user at that time. In a university for example, the use of computer login history can help in estimating the possible user location. The accuracy of the proximity detection system is usually lower than other methods so it cannot be used alone and could be used together with another method [4].

III. LOCATION USING FINGERPRINTING

In this section some details about the procedures used to determine the location of a mobile node using fingerprinting and the above mentioned LEA algorithms are presented. To do the location, the two phases required by fingerprinting must be made [7]. Although any property of the wireless signal can be used in this type of analysis, in this work the fingerprinting analysis will be made based on the RSS values.

A. *Building the Fingerprint Map*

Prior to the acquisition of the fingerprint map, it must be established the location of the points (spatial domain) where the RSS readings are going to be made. Data is then acquired for each one of the previously defined points. Data collected and stored in this phase includes the value of the RSS for each reference found by the mobile terminal, for each point of the spatial domain. The number of references (and therefore dimensions) might be different for each point in the spatial domain [5]. After collecting all data, the FM is generated. This is made by calculating the average value of the RSS for every reference at each point. In the database it is then stored for each point and reference the corresponding values of the average RSS.

B. *K-nearest neighbor Algorithm*

K-nearest neighbor (KNN) method is one of the simplest ways to determine the location of the MU by using the fingerprint map. KNN algorithm is a location fingerprinting method that considers K CPs (Calibration Points) to calculate the approximate position of the user. The idea is to compare the fingerprints in the fingerprint map to the observed measurements and to select K calibration points with the "nearest" RSSI values. In the KNN approach, the vector $\overline{y}$ used as a measurement and compared to the fingerprint map, which includes only the sample averages. Let the list

$$L_k^2 = \{p_1, p_2, \dots, p_k\}$$

be the list of calibration point coordinates corresponding the list of K fingerprints

$$\bar{a}_{1:K} = \{\bar{a}_1, \dots, \bar{a}_k\}$$

which satisfy

$$d(\bar{y} - \bar{a}_i) \le d(\bar{y}, \bar{a}_j)$$

where $\bar{a}_i \in \bar{a}_{1:K}, \bar{a}_j \in \bar{a}_{1:K}$ and the function d (·) is a chosen distance measure. The Euclidean norm is widely used, but the Manhattan norm is also common. The most common choice as a MU's location estimator $\hat{x}$ is the average of the coordinates of the K "nearest" fingerprints, that is

$$\hat{x} = \frac{1}{K}\sum_{i=1}^{K} P_i, \qquad P_i \in L_{1:K}$$

The estimator is a very restricted approach to compute the location estimate, because the number of possible estimates is always finite and is a function of the number of CPs.

The location estimation is done by using the value K = 1, which leads to the nearest neighbor (NN) method. The Euclidean norm is used as a distance measure, but the estimate is rejected if

$$\left|\bar{y}_j - \bar{a}_{ij}\right| > 2\hat{\sigma}_{ij}$$

where CP_i is the "nearest" calibration point.

C. *Euclidean distance*

The Euclidean distance between two vectors,

$\vec{R} = (r_1, r_2, \dots, r_n)$ and $\vec{F} = (f_1, f_2, \dots, f_n)$ can be represented by

$$distance = \sqrt{\sum_{i=1}^{n} (r_i - f_i)^2}$$

where n represents the *fingerprint size* and the *observation size*. The fingerprint size is the number of access points that has been saved in the database for a particular reading vector. The observation size is the number of access points that have been "seen" in this observation. The value of n is equal to the length of the vectors $\vec{R}$ and $\vec{F}$, where $|\vec{R}| = |\vec{F}|$. The length of the vectors be equal to 3, 2 or 1.

D. *Chebychev Distance*

The Chebychev distance between two vectors, $\vec{R} = (r_1, r_2, \dots, r_n)$ and $\vec{F} = (f_1, f_2, \dots, f_n)$, is given by
$distance = \max_i |r_i - f_i|$

This equals the limit of the L_p metrics. The L_p metrics/ spaces are function spaces defined using a natural generalization of the *p*-norm for finite-dimensional vector spaces.

$$distance = \lim_{k\to\infty}\left(\sum_{i=1}^{n} |r_i - f_i|^k\right)^{1/k}$$

Hence it is also known as the L_∞ metrics.

E. *Manhattan Distance*

The Manhattan distance, between two vectors r_i and f_i in an *n*-dimensional real vector space with fixed Cartesian coordinate system, is the sum of the lengths of the projections of the line segment between the points onto the coordinate axes. More formally,

$$distance = \sum_{i=1}^{n} |r_i - f_i|$$

Finally, after calculating the Euclidean distance, Chebychev distance, Manhattan distance between the observation vector and all the fingerprints that were returned, the fingerprint vector that yields the minimum distance is considered the best match. The SSID (Signal Strength ID) associated with this fingerprint is returned to the client, as well as the X and Y coordinates for the map that is associated with that area.

IV. TESTS AND RESULTS

The chosen scenario (Figure 3.) consists of four rooms and a hall connecting them. The small circles on the map represent the calibration points where data was collected and for which the Fingerprint Map was generated. Also the location of the three Access Points used as references are presented in the map.

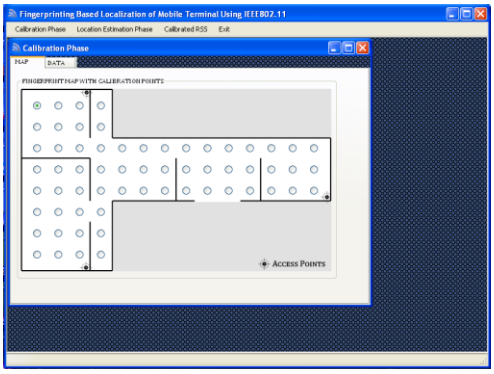

Figure 3. Map of the area where the location tests were made, the circles represent the location of the points considered for the fingerprint map.

The acquisition of the data to build the FM. It was made by using an application developed in Visual C# 3.0 with .NET Framework 3.5, by using a laptop computer (HP G6 Notebook with Wireless Network Adapter) running Windows 7. The data collection was made without the presence of the user near the laptop. For each calibration point, the RSS for each access point was taken and stored in the database. After collecting the data the Fingerprint Map is generated to test the chosen LEA. The chosen LEA is k-nearest neighbor algorithm.

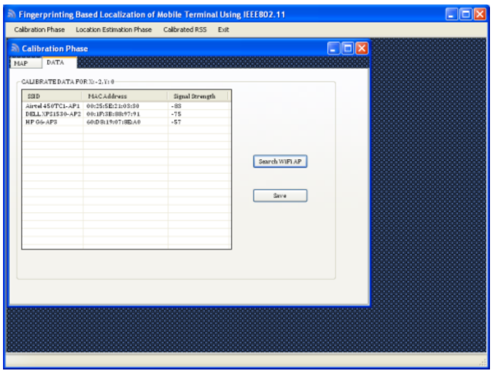

Figure 4. Calibrate data to test the Location Estimation Algorithm to estimate the user's location.

V. CONCLUSION AND FUTURE WORK

In this research, a Fingerprinting approach is proposed that provides a location aware service. The approach is based on the single tier architecture that is both Calibration Phase and Location Estimation Phase is carried out by using same application. The Location Estimation is done by using the k-Nearest Neighbor Algorithm with Euclidean Distance, Manhattan Distance and Chebychev Distance. The accuracy of Euclidean Distance and Manhattan Distance are better as compare to Chebychev Distance.

The current prototype is implemented on a laptop. For a truly mobile application, this project could be implemented on mobile operating system, so that it works on mobile devices like iPhone, Windows Phone 7, Black Berry10, Android. In the future, the system's accuracy could be enhanced by using some other probabilistic approach. Some of the improvements will be made related with the calibration procedure for each mobile terminal, and the use of other type of LEA, such as based on pattern search.

REFERENCES

[1] P. Bahl and V. Padmanabhan, "RADAR: an in-building RF-based user location and tracking system,"INFOCOM 2000. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE, vol. 2, pp. 775–784 vol.2, 2000

[2] C. Komar and C. Ersoy, "Location tracking and location based service using IEEE 802.11 WLAN infrastructure," in *European Wireless, Barcelona Spain, February 2004.*

[3] Taheri, A. Singh, and E. Agu, "Location fingerprinting on infrastructure 802.11 wireless local area networks," in LCN '04: Proceedings of the 29th Annual IEEE International Conference on Local Computer Networks. Washington, DC, USA: IEEE Computer Society, 2004

[4] H. Liu, H. Darabi, P. Banerjee, and J. Liu, "Survey of wireless indoor positioning techniques and systems, *"Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on, vol. 37, 2007.*

[5] Serodio, L. Coutinho, H. Pinto, and P. Mestre, "A Comparison of Multiple Algorithms for Fingerprinting using IEEE802.11," in Lecture Notes in Engineering and Computer Science: Proceedings of The World Congress on Engineering 2011, WCE 2011, 6 -8 July, 2011, London, U.K., 2011

[6] Pedro Mestre, Luis Coutinhoy, Luis Reigotoy, Joao Matiasz and Carlos Serodio, "Hybrid technique for Fingerprinting using IEEE802.11 Wireless Networks,"*2011 International Conference On Indoor Positioning And Indoor Navigation (IPIN), 21-23 September 2011.*

[7] M. Satyanarayanan, "Pervasive computing: vision and challenges", *Personal Communications, IEEE [see also IEEE Wireless Communications], vol. 8, no. 4, pp. 10-17, 2001.*