MOBILE INDOOR POSITIONING USING WI-FI LOCALIZATION

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Abstract: *The goal of this paper is to build an application that describes the Wi-Fi trilateration method for indoor positioning using Android-based mobile devices. Objectives, scopes, limitations and the significance of this research are also topics covered in this article. The indoor signal propagation problem is resolved by receiving a collection of signal strength measurements that improves localization accuracy. The accuracy subject involves the well-known problem of indoor signal propagation which is resolved by collecting received signal strength measurements and using them in the trilateration algorithm. Indoor positioning technique opens possibilities for development of various intelligent systems that provide the user with location-based information inside buildings.*

Keywords: *Wi-Fi, indoor positioning, trilateration, Android*

1. INTRODUCTION

In the past few years, localization of mobile phones has become a true necessity for which a variety of technologies have been used in order to obtain it with a good accuracy. The problem requires creating map based floor plans of interiors, choosing the effective positioning technology and algorithms and deploying the appropriate positioning devices inside buildings [1].

Most of the existing systems that offer indoor localization services use different wireless technologies like Bluetooth, Wi-Fi, signals of cellular towers and ZigBee. The methods using Wi-Fi are of more preferable because Wi-Fi networks are prevalent in most public buildings and its use doesn't require additional infrastructure and it allows determination of the location of each mobile device.

The Wi-Fi Localization technique that was considered was Wi-Fi Trilateration which will be illustrated in the current paper.

This technology uses Wi-Fi signals to estimate the distance between the user and the transmitter. The distance was used to generate a circle around each transmitter. Then, by getting the intersection of the three circles, the location of the user was pinpointed. If given the correct information, it will produce a unique answer.

On the other hand, the circles generated will not intersect at a single point or will not intersect at all when the information given is imperfect. Another problem is that Wi-Fi signals are variable.

Blocks, such as walls and equipment found inside a building, and other factors like the number of people around may affect the signal strengths [2,3].

In this paper the indoor localization method based on Wi-Fi signal strength trilateration technique is considered. It is simple in realization and estimation and can localize position of a mobile device within one room.

2. THE INDOOR LOCALIZATION

2.1 Wi-Fi trilateration approach. Wi-Fi Trilateration uses the strength of signals to estimate the distance of the user from each of the three transmitters. The method that has been implemented is the Spherical Trilateration Algorithm which uses parameters of known Wi-Fi networks like frequency of Wi-Fi signal, its signal strength, the network MAC - address and real coordinates of Wi-Fi access points in the location.

The received signal strength by the mobile device can be used for distance estimation between access point and mobile device. This method involves three or more access points disposed in the building. The signal strengths of these points are decreasing exponentially and depend on the distance between transmitter, receiver and the random noise factor.

Therefore, this dependency can be considered as a function of distance. The distance estimated by the signal strength is presented as a circle with a radius around the access point.

The intersection of three access point radiuses provides a point or an area of receiver. This model can be shown as such equation system [4]:

$$d1^2 = (x - x1)^2 + (y - y1)^2$$

$$d2^2 = (x - x2)^2 + (y - y2)^2$$

$$d3^2 = (x - x3)^2 + (y - y3)^2$$

where $x1, x2, x3, y1, y2, y3$ are the coordinates of access points, d1, d2, d3 is the estimated distances. The solution of these equations gives points of circles intersection providing an area of indoor localization (Fig. 1).

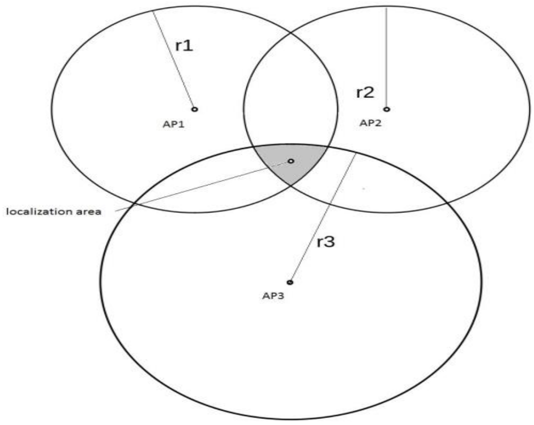

Fig. 1. Indoor localization area provided by trilateration approach

2.2 Wi-Fi trilateration based on RSS measurement collection. In the present paper, signal strength levels of three access points allocated in the three rooms within the floor were measured with the application implemented in the Android smartphone, using the WifiManager API with the function calculateSignalLevel.

This data is collected to estimate distance for the trilateration method described above. These measurements are made in 15 points at the 1 meter interval for each access point using developed Android application.

This application found three different access points by MAC addresses and measured the RSS levels 10 times for each of 15 distances for every access point.

The RSS level changes at time therefore it is necessary to use its average value.

The AP RSS levels are displayed in the Table I and the AP's signal strength depend of distance is shown in the figure bellow (Fig. 2).

The RSS – distance dependency of each AP was measured taking as reference point the 0 m distance from each AP.

Table 1. RSS levels

Distance (m)	AP1 RSS (dBm)	AP2 RSS (dBm)	AP3 RSS (dBm)
1	-33.3	-38.8	-43
2	-45.7	-43.1	-50.3
3	-50.9	-48.9	-65.7
4	-51.7	-55.2	-61.2
5	-51.8	-75.1	-62.5
6	-53.4	-75.5	-66.4
7	-57.8	-76.4	-70.5
8	-62.4	-80.4	-72.3
9	-65.7	-80.8	-74.7
10	-62.9	-76	-78
11	-72.9	-88.6	-76.07
12	-72.7	-88.2	-86.02
13	-63.9	-91	-79.03
14	-74	-91.9	-85.08
15	-76.7	-92.1	-82.05

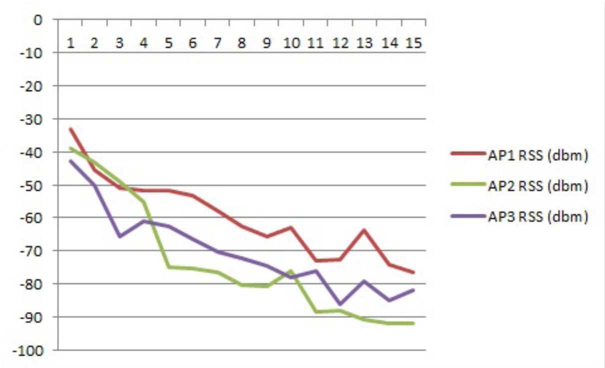

Fig. 2. APs RSS levels

Proceeded measurement points may be selected for distance estimation as reference points. The reference points are the points with RSS level difference more than observational error calculated for each of 15 measurement points. Thus it is possible to determine the distance by the RSS as a segment between two values. The observational error is calculated with formula:

$$\Delta = \sqrt{(\sigma \cdot t) + A^2}$$

where Δ is the observational error in dBm, σ is the standard deviation divided by square root of number of measurements and A is the observational error of the mobile device.

3. SYSTEM DESIGN

3.1 Description of the system architecture. The system is designed by following a client-server architecture which consists of three main modules, the network which contains at least three Wi-fi Access Points, the client device (which can be also be a Wi-Fi enabled device like mobile, smartphone, PDA, etc.) which is an Android operating system smartphone and the server (Fig. 3.).

3.2 The client. The mobile device is presumed to have Wi-Fi connection capabilities, which are automatically turned on as the application starts. Using Android's WifiManager API, the device will scan all available connections it can detect. This information will contain the Service Set Identifier (SSID), the Received Signal Strength Indicator (RSSI) and MAC Address of each router. This module will select only the pre-defined SSIDs and plug their RSSIs into the Wi-Fi Localization algorithm as mentioned in the theoretical framework. The resulting coordinate values (x,y) would be used on the server side. Figure 4 shows the application running on the client side.

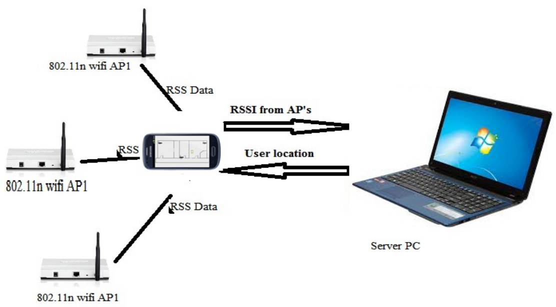

Fig. 3. Framework of indoor positioning system

Fig. 4. Application running on Samsung mini

3.2 The server. The server runs the positioning algorithms which calculate the location co-ordinates of the user. The server runs two types of algorithms a) To calculate distance of user from respective AP and b) Trilateration algorithm to find exact location of user from distance. The server then sends these location co-ordinates back to the client device. The Android device has the front end application showing the indoor map of the system. The indoor map in this system is developed using HTML5 Canvas element and invoked in an android application. The location co-ordinates calculated by server are shown in the indoor map as the user position.

This is a part of user positioning in indoor environment. Navigation involves the choice of destination in the system. The co-ordinates of destination are known and programmed in the indoor map itself. Using the user co-ordinates and destination co-ordinates the application helps you to navigate in the system.

3.3 The Routers. The routers installed in the network are TP-LINK TL-WR841N. In compliance with the IEEE 802.11n standard, TL-WR841N can easily establish a wireless network and may reach a transmission speed and 15x coverage, 5x higher than that of conventional 11g products. With a transmission speed of up to 300 Mbps, it provides excellent capabilities to mitigate data loss over long distances and crossing of obstacles in small offices or apartments, even in buildings with reinforced concrete structure. Moreover, the wireless signal can be detected easily over extended distances where conventional 11g products do not allow this. The router provides bandwidth-intensive applications.

4. RESULTS

The test environment is as shown in the picture below:

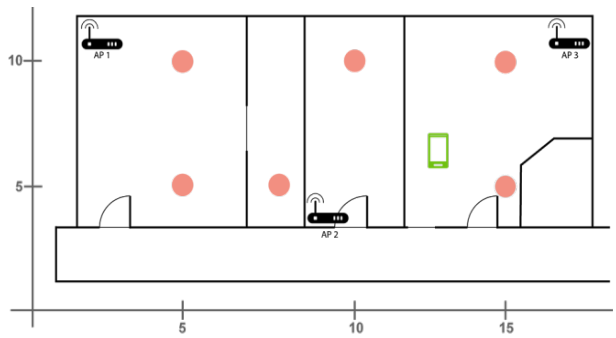

Fig. 5. Partial map of the building

The results were taken in the K Building, Transilvania University of Brasov, Electronics and Computers Department. The map only illustrates three of the rooms which each have an AP installed in. The red dot in the figure shows the test locations where results were taken. RSS data samples were taken over a period of time and used for positioning. Table 2 shows the actual distance (m), system calculated distance (m), positions and accuracy. The accuracy in calculating the distance and exact location is as follows:

Results show that the positioning accuracy of Wi-Fi indoor positioning using tri-lateration method is around 2-2.5 m (Fig 6) The Accuracy of the system can be further improved if more number of similar access points is deployed in the system. Complex nature of indoor environment is the big hurdle for doing positioning in indoor system. Obstacles like walls, glass, metal objects, and moving objects need to be handled very carefully while positioning.

Table 2: Actual distance, system calculated distance, positions and accuracy. It can be observed that the RSS values go higher once the client gets further from an AP.

No. test dot	Location	RSS Values (dBm)	Exact Location (x,y) (m)	Observed values (x,y) (m)
1	Room AP3	(-90,-71,-68)	(15;5)	(15;8.8)
2	Room AP3	(-89,-73,-70)	(15;10)	(13.02;10.72)
3	Room AP2	(-78,-65,-80)	(10;10)	(9.02;8.25)
4	Room AP2	(-79,-55,-82)	(8;5)	(8.89;6.23)
5	Room AP1	(-55,-76,-81)	(5;6)	(7.96;7.25)
6	Room AP1	(-65,-84,-90)	(5;10)	(6.04;10.25)

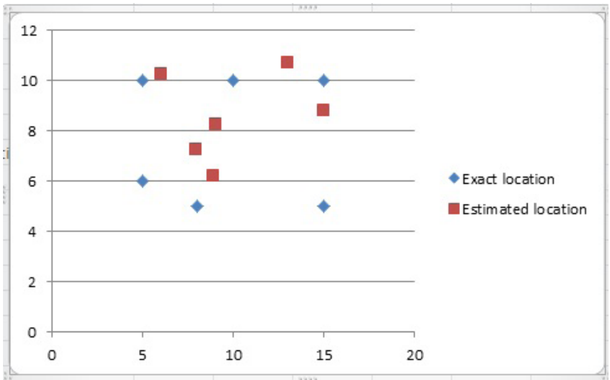

Fig. 6. Positioning accuracy around 2- 2.5 m

CONCLUSIONS AND FUTURE WORK

The Wi-Fi trilateration method is using for indoor positioning and provides low accurate localization.

For its improving more accurate signal propagation models can be used or expanded measures of signal strength including most number of reference point. Moreover, the further work can be continued on the Wi- Fi fingerprinting approach because the indoor localization algorithm described above may be considered as a special case of fingerprinting.

The realization of fingerprinting approach requires also advanced measurement of RSS and building the radio map and can provide high accurate indoor localization.

Future scope of the system lies there in the efficient indoor navigation system which can be useful in many places. Accuracy in positioning can be improved a lot with the combination various technologies like Bluetooth, GSM and RFID's. Indoor system for user and device tracking for security reasons can also be the future scope of the system.

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