Indoor Localization Method Based on Wi-Fi Trilateration Technique

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***Abstract*—This paper describes a Wi-Fi trilateration method for indoor localization using Android-based mobile device. Approaches based on signal propagation model and received signal strength measurement collection are considered. The indoor signal propagation problem is resolved by received signal strength measurement collection that improves localization accuracy. Indoor positioning technique opens possibilities for development various intelligent systems that provide the user location-based information inside buildings. These systems include positioning functionality based on such technologies as Wi-Fi, Bluetooth, and GSM.**

I. Introduction

Development of systems and solutions for solving the problem of indoor positioning is a promising and complex task. This problem requires of creating maps based on floor plans of indoors, choosing the effective positioning technology and algorithms, deploying the appropriate positioning devices inside buildings. Modern systems like a Navizon or WiFiSLAM can offer much more than just positioning with acceptable accuracy (about 3m). Indoor positioning techniques using radio signal based approaches for localization can use different wireless technologies like Bluetooth, Wi-Fi, signals of cellular towers and ZigBee. The methods using Wi-Fi are more preferred because Wi-Fi networks are prevalent in most public buildings and its use don’t requires an additional infrastructure and allows determine a location of each user of mobile device [1].

There are a lot of algorithms based on Wi-Fi trilateration approach. Trilateration is the determination of absolute or relative locations by measurement of distances, using geometry. By the using of this method there are three fixed points is needed to determine an indoor position. The main idea is the calculating distances between access points (AP) and mobile device to provide an area of localization. This distances can be provided by such signal measurement techniques like a received signal strength (RSS), time of arrival of radio signals from transmitters (ToA) or time difference of arrival of several radio signals (TDoA). Similar approaches are based on triangulation method and using measurement of arriving signal angle.

Fingerprinting is the popular approach that is not based on radio signal propagation geometry and providing high accuracy. This approach requires the building of signal strength database and map. The signal strength map have to consist of real coordinates and related to these signal strength values of accessible transmitters (Wi-Fi access points). The position estimation can be realized as a measure of accessible radio signals and the searching matches in the database or the nearest point to the receiver [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 mobile device within one room.

II. Indoor localization approaches

A. Wi-Fi trilateration

The trilateration method uses parameters of known Wi-Fi networks like a frequency of Wi-Fi signal, its signal strength, the network MAC-addressee and real coordinates of Wi-Fi access points in the location. The received by mobile device signal strength can be used for distance estimation between the access point and mobile device. By using this method one considers three or more access points allocated in the building. The signal strengths of this points are decreasing exponentially depends on distance between transmitter and receiver and random noise factor. Thus this dependency can be considered as function of distance. The distance estimated by 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]:

$$d_1^2 = (x-x_1)^2 + (y-y_1)^2$$
$$d_2^2 = (x-x_2)^2 + (y-y_2)^2$$
$$d_3^2 = (x-x_3)^2 + (y-y_3)^2$$

where x_1 , x_2, x_3, y_1, y_2, y_3 is the coordinates of access points, d_1, d_2, d_3.is the estimated distances.

The solution of this equations gives points of circles intersection providing an area of indoor localization (Fig. 1).

In addition, it is necessary to determine an approximate radius with same values of RSS for each access point. This problem requires the signal prediction model building. Path loss of radio signal is the largest and most variable quantity of gains and losses from the transmitter to the receiver. It depends on frequency, antenna height, receive terminal location relative to obstacles and reflectors, and link distance, among many other factors [6].

B. Wi-Fi trilateration based on signal propagation model

The simplest way for estimation distances between receiver and transmitter is a using of free-space path loss model [2, 5]:

$$FSPL = 20log_{10}(d) + 20log_{10}(f) - 27.55 \qquad (1)$$

where, d is the transmitter-receiver separation distance in meters, f is the signal frequency in megahertz, FSPL is received signal strength path loss in dBm.

During the implementation average real RSS measurements for one access point produced by Android application are compared with measurements calculated by equation 1. The measurements made for distances from 1 to 6 meters in 6 points along one line within the room in which Wi-Fi access point is allocated. The signal strength is measured 10 times for each of these 6 points. The area of the room is 25 square meters. The comparison is produced for the network with signal frequency 2412 MHz and is shown in Table I.

Presented in the table comparison results show that the free-space loss model is not effective for using even within the one room because the high difference between real and estimated values. This approach requires another path loss model that would be provide higher accuracy.

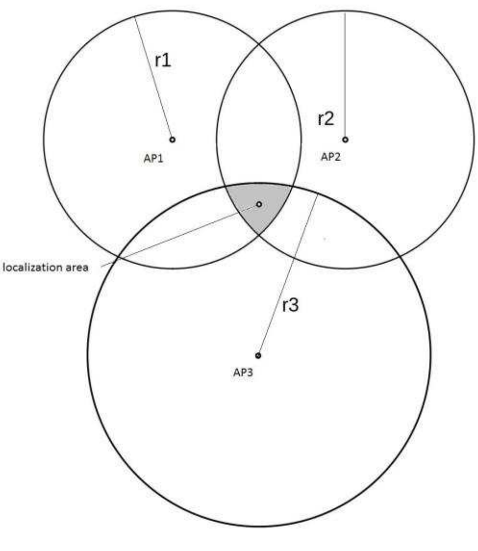

Fig. 1. Indoor localization area provided by trilateration approach

TABLE I. THE COMPARISON REAL AND ESTIMATED RSS

Distance, m	Real RSS, dBm	Estimated RSS, dBm
1	33.3	46.0
2	45.7	53.0
3	50.9	56.5
4	51.7	59.0
5	51.8	60.9
6	53.4	62.5

C. Wi-Fi trilateration based on RSS measurement collection

In presented paper signal strength levels was measured by distance of three access points allocated in the three rooms within the floor. This data are collected to distance estimation for 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 II.

TABLE II. THE RSS MEASURE RESULTS FOR THREE ACCESS POINTS

Distance, m	AP1 RSS, dBm	AP2 RSS, dBm	AP3 RSS, dBm
1	33.3	38.8	55.3
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	80.8	72.3
9	65.7	80.8	74.7
10	62.9	76.0	78.0
11	72.9	88.6	76.07
12	72.7	88.2	86.02
13	63.9	91.0	79.03
14	74.0	91.9	85.08
15	76.7	92.1	82.05

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 (Fig. 2). The observational error is calculated by formula:

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

where, Δ is the observational error in dBm, σ is the standard deviation divided by square root of number of measurements, t is the quantile function of Student's t-distribution, A is the observational error of the mobile device.

For localization the Android-based application is used that calculates an intersection of circle areas corresponding to estimated RSS level. This application uses java.awt library for building geometrical primitives and founding these intersections.

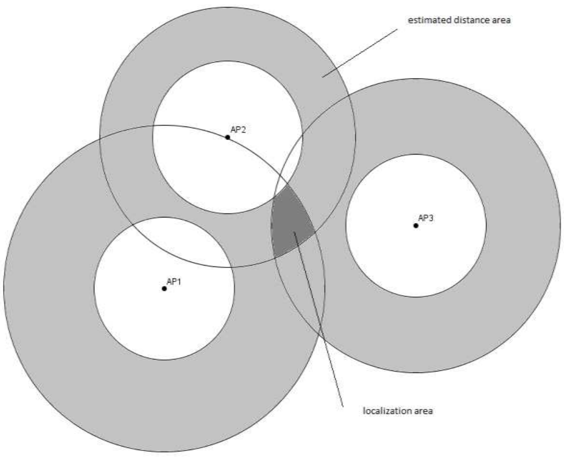

Fig. 2. Indoor localization by estimated distance segments intersection.

III. Conclusion

The Wi-Fi trilateration method is using for indoor positioning and provides low accurate localization. For its improving can be used more accurate signal propagation models 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.

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