INDOOR POSITION DETECTION USING WIFI AND TRILATERATION TECHNIQUE

Nor Aida Mahiddin, Noaizan Safie, Elissa Nadia, Suhailan Safei, Engku Fadzli.
Faculty of Informatics, University Sultan ZainalAbidin, Gong Badak
Campus, Terengganu, Malaysia
{aidamahiddin, aizan, elissa, suhailan, fadzlihasan}@unisza.edu.my

ABSTRACT

Various techniques that employ GPS signals such as A-GPS and GPS transmitters [4, 7] have been introduced with the hope to provide a solution for indoor positioning detection. We proposed the implementation of trilateration technique to determine the position of users in indoor areas based on Wi-Fi signal strengths from access points (AP) within the indoor vicinity. In this paper, percentage of signal strengths obtained from Wi-Fi analyzer in a smartphone were converted into distance between users and each AP. A user's indoor position could then be determined using a formula proposed based on trilateration technique.

KEYWORDS

Indoor Position detection, WI-Fi, Trilateration Technique.

1 INTRODUCTION

Global Positioning System (GPS) is a technology developed by United States of Defense (DoD) that has been used for military purposed. It is also the main technology that plays an important role in satellite navigation. The main purpose of GPS is to determine the position or coordinate of an object based on location, time and speed [2, 6] which provide Location Based Services (LBS) [5, 6]. Nowadays, the technology has been used widely in outdoor environment such as in navigation and coordinate measurements. GPS depends on satellites to communicate using radio signals. Common example of GPS receivers such as GARMIN, NAVMAN and TOM TOM are capable to determine the accuracy of a position in the range of 10 meter. Optimum signal performance can be achieved outdoor but not in indoor environment. Multipath interference is a problem that exists in indoor environment which happens when transmitted signal from satellite is reflected due to barriers such as buildings or trees. Weak signal also affect the accuracy of the position [2, 3]. Wi-Fi Positioning concepts [4] are among the most famous solution. Weyn, Maarten, Schrooyen and Frederik used the combination of assisted global positioning system (A-GPS) and Wi-Fi positioning technique using Wireless Local Area Network (WLAN) to achieve the accurate coordinates in indoor environment [4], However A-GPS also have limitations in indoor environment [6] because of A-GPS is unable to decode data from satellites [3]. This paper proposes indoor position detection using Wi-Fi signal strength with trilateration technique.

2 RELATED WORKS

Indoor GPS positioning system is a modular system used to track and locate persons or objects inside buildings. Nowadays, Indoor GPS plays an important role in various domain including consumer's applications, emergency services, machines or gadgets and for military purposes [1]. Referring to the Federal Communication Committee

(FCC) and due to the requirements of Enhanced 911 (E911) system, GPS is now embedded into mobile phones which provide Location Based Services (LBS) [3, 4]. It is known as assisted GPS or A-GPS which is built to overcome the limitation of GPS. GPS is only good for outdoor environment activities and work poorly in indoor environment [2]. One of the limitations of indoor GPS is weak signal acquisition because GPS signal is weak inside buildings and cannot penetrate building wall structures [2, 3] which affect performance in coordinate measurement or position detection [2].

On the other hand, finger printing is another alternative in position determination. It requires comparison of signals from current measurements with a pre-measured data in particular locations [5]. There are two phases in fingerprinting which is offline training phase and online estimation phase. Wi-Fi signal strength is an example of offline training phase in finger printing method.

Another solution for position determination involves detection of proximity such as Radio-Frequency Identification (RFID) and Bluetooth technology. Most of the researcher tries to apply mobile devices in their study. In Mobile Adhoc Network (MANET), devices can randomly move in any directions. Stationary nodes broadcast the hello massages signals and the node received the signal automatically determines the location position itself based on three signals received from 3 anchor nodes and run the Kernel AODV platform [9]. Woo et al., [11] have done experiments at a shield tunnel construction site using the fingerprint method of Received Signal Strength Indication (RSSI) from each Access Point (AP). Another way to determine position of object is by using RFID. Based on RFID concept, Daniel [8] have proposed new method using a Radial Basis Function Neural Network (RBFNN) and Localized Generalization Error (L-GEM). In a variety of method, [10] Pseudolite system is used as an alternative to find the solution of position location in indoor.

3 PROPOSED METHOD

This paper proposes an indoor position detection using Wi-Fi signal strength and a formula to determine position of a user. Based on the concept of GPS, minimum of three access points (AP) are needed to determine the position of a user in an indoor location. The Wi-Fi signals are in the form of radio wave where the movements of the signals are highly dependent on the frequency. Signals with different diameters are transmitted by APs in all direction according to the respective signal strength. Since wireless routers provide coverage of about 100 feet (30.5 meters), signal strength is used to find the collision point in order to specify the accurate position of an object.

The standard protocol of Wi-Fi is 802.11 which was introduced by Institute of Electrical and Electronic Engineering (IEEE) and it is used in wireless LAN [7]. The standards come in several flavors which are 802.11a that transmits at 5 GHz and can move up to 54 megabits of data per second. On the other hand, 802.11b is the slowest and slightly less expensive and transmits in the 2.4 GHz frequency and can carry 11 megabits of data per second. Networking standard 802.11g also transmits at 2.4 GHz like 802.11b but it is much faster and theoretically can handle up to 54 megabits of data per second. 802.11n is the newest standard to improve speed and range. These kinds of protocol standards allow communication via internet through channels of communication medium that is available in Wi-Fi. There are 14 channels available in Wi-Fi where the use of each channel can be selected to avoid interferences in the wireless transmissions.

This study deploys Wi-Fi technique in conjunction with IEEE 802.11g networking standard. Here, we assume the three APs are known as AP_1, AP_2, and AP_3.

Assume that the coordinates of the three APs as Figure 1:

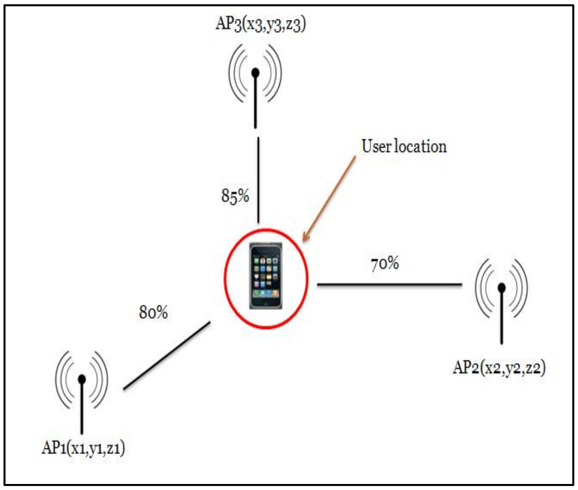

Figure 1: Illustration WiFi signal strenght from three access points

Then, based on three coordinates of the APs, we need to find the coordinates of the user's position that is represented as *Z*.

Let's assume that a user is using a smart phones that serves as a receiver of the signals transmitted from the access points. Application of Wi-Fi analyzer in the smart phone presents the signal strength in terms of percentage. The highest percentage of signal strength indicates that *Z* is closest to the AP whereas the lowest percentage implies that Z is maximum range of AP.

The percentage of signal strength obtained from the Wi-Fi analyzer can be converted to distance between a user's to each AP using this equation (Equation 1):

$$\textit{Distance},\ d_i = p\,(1 - m_i) \qquad (1)$$

Where;
m = is the percentage of signal strength
p = is the maximum coverage of signal strength
i = 1,2,3

From Figure 1, let each AP be placed at the center. Assume a scenario where a student who uses a smart phone, is looking for a book in a library. Then, we assuming that signal strength for each AP will spread the signal in wave forms. The signal strength will form 3 circles and intersect each other. The intersection of 3 circles is the position of user and we want to determine the location of user who is labeled by *B* (*x*, *y*). To simplify the calculations, the equations are formulated so intersection of circle is occurred at Cartesian plane (see Figure 2). The equation for any of these circle is as follow (assuming $z = 0$):

$$(x - x_i)^2 + (y - y_i)^2 = r_i^2 \qquad (2)$$

The intersection of 3 circles is obtained by solving systems of linear equations for 2 variables simultaneously. The linear systems are solved in order to determine the coordinates *x* and *y*.

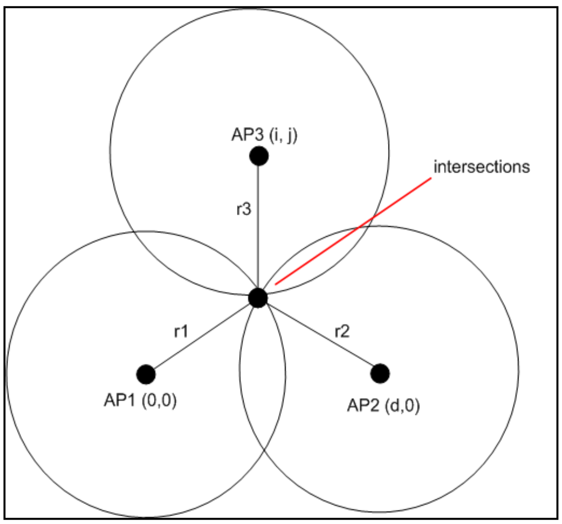

Figure 2: Intersections of 3 circles

Based on Figure 2, we start with the equations for three circles:

$$r_1^2 = x^2 + y^2 + z^2 \quad (3)$$

$$r_2^2 = (x-d)^2 + y^2 + z^2 \quad (4)$$

$$r_3^2 = (z-i)^2 + (y-j)^2 + z^2 \quad (5)$$

To determine the location of B, we have to solve for (*x, y, z*).

The method to do it is by using systems of linear equations for 2 variables and solve these eaquation of linear system $\tilde{A}\ x = b$. By using this method, the j^{th} constraints is used as a linearizing tool. Adding and subtracting x_j, y_j and z_j in (3), gives:

$$(x - x_j + x_j - x_i)^2 + (y - y_j + y_j - y_i)$$

$$(z - z_j + z_j - z_i)^2 = r_i^2 \quad (6)$$

With (*i = 1, 2,... , j+1 , ... , n*).

Linear system is easily written in matrix form $\tilde{A}x = b$,

With

$$A = \begin{bmatrix} x_2 - x_1 & y_2 - y_1 & z_2 - z_1 \\ \vdots & \ddots & \vdots \\ x_n - x_1 & y_n - y_1 & z_n - z_1 \end{bmatrix}$$

$$\vec{x} = \begin{bmatrix} x - x_1 \\ y - y_1 \\ z - z_1 \end{bmatrix}, \vec{b} = \begin{bmatrix} b_{21} \\ \vdots \\ b_{n1} \end{bmatrix} \quad (7)$$

Based on the calculation by using (7), the position of *B* is given by (*x, y, z*).

4 EXPECTED RESULT

From the Figure 1, assuming that all 3 centers are in the fixed Cartesian plane and *z = 0*, the 3 coordinates respectively as follow, AP1 is at (4,4), AP2 is at (26, 10) and AP3 at (16,26) and B is the user unknown position at (*x,y*).

With the signal strength that received from the APS, the distance between each APs and the B can be calculate as follow.

Lets consider, the maximun range of these APs is 30 meter. Then, from (1), we get the distance between center of each AP and B as follow:

d_1 = 30 (1 – 0.8) = 6*m*
d_2 = 30 (1 – 0.7) = 9*m*
d_3 = 30 (1 – 0.85) = 4.5*m*

Then, 3 lines are formed from the 3 circles. Then, construct the new equation by using the 3 lines. The equations are as follow:

AP_1: $(x - 4)^2 + (y - 4)^2 = 6^2$
AP_2: $(x - 26)^2 + (y - 10)^2 = 9^2$
AP_3: $(x - 16)^2 + (y - 26)^2 = 4.5^2$

A linear system in 2 variables determines a collection of planes. The intersection point is the solution. By solving this equation using systems of linear equation of 2 variables, we get a solution for the systems as:

x = 11.97

y = 14.31

Thus, the position of user labeled as *B* in the Cartesian plane is (11.97, 14.31). To determine the exact location in reality, where is the exact location with coordinates (11.97, 14.31) in the library, we have to perform a simulation showing the exact Cartesian planes on library. The simulation part is not cover in this paper.

5 CONCLUSION AND FUTURE WORKS

This paper proposed a method to calculate the location of a user in an indoor area using Wi-Fi signal strength with IEEE 802.11g networking standard based on trilateration technique. The proposed method serves as a preliminary step that could be integrated in future work where we envisage applying the method by taking into account transmission barriers such as walls or blocks of large items.

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