# Wi-Fi Based Positioning Algorithm for Indoor Environment using 802.11 Standards

Sikandar Khan, Adeel Akram, Saeeda Usman

**Abstract**— Wi-Fi based positioning approaches perform a significant role in resource localization using IEEE 802.11 standards for indoor environment without requiring specialized positioning hardware. User's position is calculated on the basis of Received Signal Strength Indicator (RSSI) from Access Points (AP's) within a coverage area by using Hata Okumara model and technique adopted is Trilateration. Experimental results indicated marked improvement in accuracy with reference to previous work using the same technique. Statistical data shows improvement of results in efficiency and being accurate enough to locate user within 1m or less in indoor environment.

**Index Terms**— Access Point (AP), Received Signal Strength Indicator (RSSI), Signal Strength (SS), Emergency Sensor Networks (ESN), Wireless Local Area Network (WLAN), Revisiting Hata Okumara (RHO), Wireless Fidelity (Wi-Fi).

## 1 INTRODUCTION

Wireless localization technologies have undergone considerable progress in the past decades for improving their performance of tracking in an indoor environment without the need of specialized positioning hardware. Location can be achieved by existing Wi-Fi devices available for network provisioning in indoor environments. Better adaptation can be achieved as we gained data from more reference Access Points (APs). The diversity of Localization data points has a direct relation with tracking accuracy of unknown targets.

Provisioning of Wireless access and data communication technologies are rapidly enhancing with time. In the recent years wireless communication has matured enormously. Users are continuously shifting from wired networks to wireless in homes and offices. Wireless access also provides the luxury of mobility which is even more attractive for mobile users. In this way we can improve the efficiency of these services.

Localization for outdoor system can be achieved easily by using GPS. Initially, it was deployed for military purposes and had very high precision in calculating its targets. Limitation occurs when the sky is not clear; detecting target position becomes almost impossible.GPS has better results for outdoor environment, for indoor environment some other technology is adopted.

The main purpose of deploying a Wi-Fi is its flexibility, mobility, connectivity at a much lower cost. Different standards for Wi-Fi system were developed by IEEE 802 working group out of which 802.11b and 802.11g have become a standard for industries that operate at 11Mbps and 54Mbps respectively in the frequency band of 2.4 GHz which is the Industrial, Scientific and Medical (ISM) band available worldwide without requiring licensing.

Fig. 1 Illustration of Indoor positioning Use Cases
(Source: http://www.gpsworld.com/wireless/indoor-positioning/)

Wi-Fi 802.11g is a standard which offers a data rate up to 54Mbps and operates at 2.4GHz having backward compatibility with the 802.11b devices. Location of the mobile user can be calculated by the Received Signal Strength Indicator (RSSI) of the Access Points (APs) or the target.

The major and minor milestones to be achieved throughout the research are, the foremost objective of this research is to adopt an approach to provide a flexible and scalable solution that will monitor and analyze the position of the objects in indoor environment with accuracy. This can be achieved by received signal strength indicator (RSSI), by removing the errors between the transmitter and receiver such as absorptions, reflections and refractions due to the propagation mediums.

Section 2 consists of related work regarding this study, then section 3 comprises of methodology which briefly describes the method and research that is used in this particular study. We will finish with an assessment and our conclusion in Section 6.

## 2 RELATED WORK

In the last decade or so, wireless local area networks WLANs gained a lot of popularity. "Wi-Fi Alliance products are based on IEEE standards (802.11)" .Indoor environment have a problem of localizing the objects. Wirelesses sensor networks are used to monitor the physical or environmental conditions such

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as temperature, sound, vibration, pressure, volcano areas, forest fire places, humidity etc these networks are called emergency sensor networks (ESN) [1]. Wireless Localization technologies have a promising future impact for serving in indoor environment [2]. The application includes real time tracking objects, emergency detections, event monitoring, remote health care, telemetry systems.

GPS is a popular technology considering outdoor environment [3] GPS provides satellite based positioning at present which is widely used in the world. GPS limitations occur in indoor environments as objects or targets can't be detected in this case. People spend most of the time in indoor environment; indoor tracking is required to fulfill the requirements for tracking indoor localization technologies have been deployed [4]. Complexity of indoor environment includes some challenges i.e. NLOS (Non Line Of Sight), reflection, scattering, refraction, multipath effect, noise interference and disturbances, walls, concrete, glass, human beings. But these influences results in weaknesses of the signals, these effects cannot be neglected. Several survey papers are for indoor localization [5][6][7].

A wireless network consists of many types (GSM, Wi-Fi, UMTS, and WiMAX) [8]. Wi-Fi technology is used in indoor environment because as for considering its accessibility and cost which is very low.

Accuracy and Precision are the required main factors in indoor localization, weak signals degrade the accuracy of positioning [9][10]. Indoor positioning detection is achieved by using Wi-Fi signal strength (SS), and formulae to locate user's position. Wi-Fi signals are of radio waves where movements of signals are dependent upon frequency [11]. Signals are transmitted by Access Point's (APs) in all directions regarding their signal strengths. Wireless router can cover an area of about 125 feet i.e. (35 m).

Indoor environment faces a lot of problems due to which weakness in the strength of the signal occurs due to path loss as it becomes weaker as the distance increases from the origin [12]. Loss is related to the size of material, focusing on its thickness, attenuation effect of glass is higher than brick walls [13]. These factors have a critical impact especially by using the methods to measure distances by measuring the signal strengths [14].

By experiments it is concluded that with the presence of users the signal strength is changed [15]. The signal strength is thus weakening due to the human's in an environment. The radiations are partially absorbed as human body contains water in their bodies and this attenuation occurs in the signal strengths. Location of a mobile device with signal strength map relates measurements with a SS map. Two approaches are for measurement matching either Deterministic [16] or by Probabilistic [17] Positioning is a main factor in deploying a Wireless Local Area Network (WLAN) [18].

## 3 METHODOLOGY

Localization is achieved in indoor environment using the already available infrastructure within a building or campus. The experiment consists of three APs. The Access Points are set as more area must be covered. The routers are first configured by 802.11n Wi-Fi standards. During setting the routers it must be noticed that for each AP the channel must be different so that interference may not occurs and the RSSI provided by the AP must be accurate. First of all a client server application is developed in C sharp. The reason behind developing this application is that we cannot find the RSSI value of the user at the server. This value is only available at the users or client system.

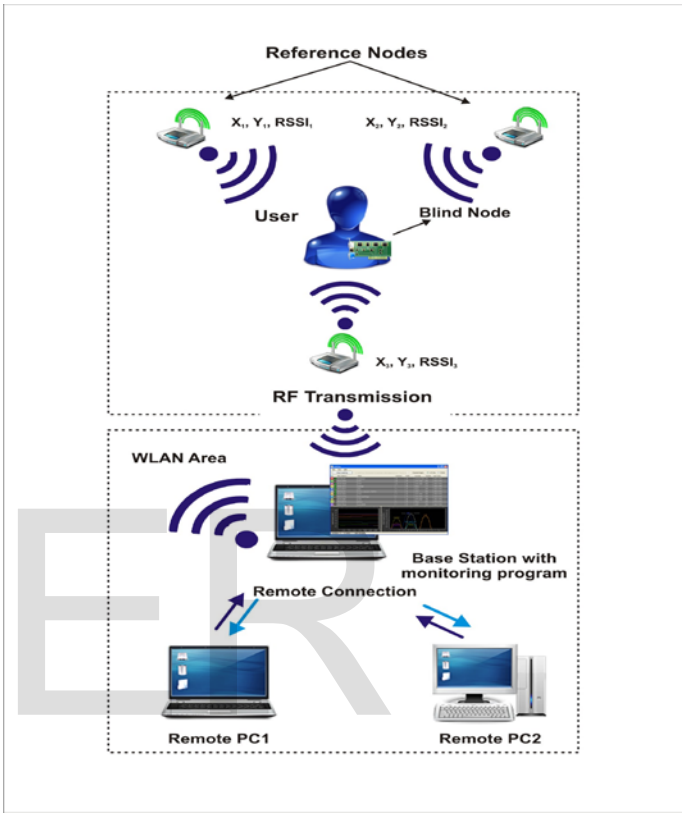


Fig. 2 System Model

Client side application consists of wireless network name in which all the available and working Access Points are seen in the table with respect to each AP, its signal strength is also calculated. It will give a sheet which will include the names of all available Access points, but in our experiment we will need only three Access points, so there is a block of filtering of networks that is our desired. Our client must be attached with the primary Access point. The RSSI value of the primary AP, Secondary AP1 and Secondary AP2 is shown. These values of RSSI must be available at the server to find the distance of the unknown user from each of the APs. At the server part it starts monitoring the data which is sent by the user side which includes all the RSSI values of the Access Points and their respective received power in dBm.

After these basic values we will look into the influence of obstacles which is from walls, partitions, doors etc. Usually path loss exponent is 4 but for free space it is equal to 2 but in our environment there are obstacles such as tables, chairs, computers, glass, looking into all these obstacles the value of "n" is taken between (3.6 to 4.0) . Standard deviation "Xa" has a

value of (2 to3) but as signal power varies its value is set (3 to 4) and 20 are taken when there are huge obstacles in the environment. The dBm factor is set as 100 and the maximum RSSI is taken as 100. Actually it is not 100 but it is due to the software of the computer as it shows us its upper limit. The empirical constant has a value of -15. As for 802.11n standard the frequency is 2.4GHz. The value wavelength is equal to 0.125.

The main formula to find distance calculation is Hata Okumara model in which logarithmic distance model is the simplest one [19]. The value of RHO Cisco gives us quite accurate results but they are designed for an environment where there are no influences of obstacles. Distance is calculated by the given formula

$$d = \frac{1}{10n}\left(P_{TX} - P_{RX} + G_{TX} + G_{RX} - X_a + 20\log\lambda - 20\log(4\pi)\right) \quad (1)$$

By putting the values in the above formula the distance of the user is calculated from each AP.

The distance of all APs is shown in meters and feet's; The results of the distances calculated from all the Access points are shown on a map. This map is sketched for a university campus which includes lecture halls, offices, library, labs and stairs so there is huge influence of obstacles. There are two methods by which the location of the user can be found i.e. Triangulation and Trilateration. But in this experiment the method adopted is Trilateration.

However in Trilateration we work with distances a type of measurements used for finding the location of point by using geometry of spheres, circles or triangles [20], [21], [22], [23].

## 4 Experimental Study

Set up of experiment basically consists of three Access Points (AP), two computers or laptops. Experiment is done by placing the Access points in an area depending upon the coverage area of Wi-Fi in an indoor environment which is almost 32 meters or 120 feet's. APs are placed at different places such that SS must be high when received by user devices. To make Signal strength high we can use of directional antenna with the Access Point.

In our practical deployment scenario, the first one is Primary AP "skhan1" similarly the second is Secondary AP1 "skhan2" and the third is Secondary AP2 "skhan3" which are filtered at the client side.

For each AP its RSSI value is shown and its respective Received Power (PRX) value. Calculation of the distance is the main part of the experiment. By putting the value of (PRX) which is found for each Access Point, putting its values in RHO model d1, d2, and d3 is calculated. After distance calculation Trilateration technique is used to find the location of unknown user.

After finding the distance the value of "i" and "j" are found which is found by their respective formula such as

$$i = x_3 - x_1 \quad (2)$$

And

$$j = y_3 - y_2 \quad (3)$$

When the values of "I" and "j' are found the last step is to calculate the coordinates of the user on the map, which simply means finding its ("x" and "y") values. To find "x" and "y" coordinates we have the following formulae

For x

$$x = \frac{r_1^2 - r_2^2 + d^2}{2d} \quad (4)$$

Also for y

$$y = \frac{r_1^2 - r_3^2 - x^2 + (x-i)^2 + j^2}{2j} \quad (5)$$

Where:

"d" is the distance between Primary AP and Secondary AP

"r1" is the distance of Primary Access Point which is d1

"r2" is the distance of Secondary Access Point 1 which is d2

"r3" is the distance of Secondary Access Point 2 which is d3

When the coordinates of the user on the map are derived its radius are drawn from each Access Point. User is located where all the three radii of circles cut each other. User location is at a single point so there must be a single point where all the radii of circles will cut each other which is the common point among all circles of the three AP's.

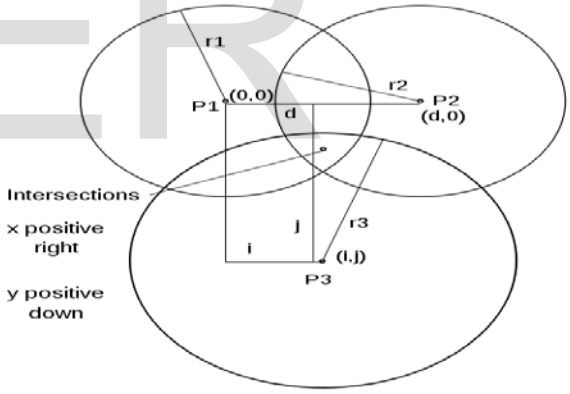


Fig. 3 Trilateration technique for distance estimation

## 5 Experimental Results

Distances are calculated by (RHO) formula. The results founded on the basis of Received Rower (PRX) values are given below. Total number of experiments conducted is 16 some of them is shown in the table given below.

Fig. 4 Calculated results of distances and localization of mapping using 3 AP's

| S.No | Received Power from AP's | Distance from AP's | Map Location | Localization (Accuracy) |
|---|---|---|---|---|
| 1 | Prx1= -10dBm<br>Prx2= -47dBm<br>Prx3= -50dBm | D1=1.093m<br>D2=15.523m<br>D3=15.633m | X=342<br>Y=222 | 0.80m |
| 2 | Prx1= -8dBm<br>Prx2= -44dBm<br>Prx3= -58dBm | D1=0.353m<br>D2=14.043m<br>D3=18.853m | X=354<br>Y=192 | 0.85m |
| 3 | Prx1= -37dBm<br>Prx2= -19dBm<br>Prx3= -32dBm | D1=10.713m<br>D2=5.903m<br>D3=9.233m | X=385<br>Y=270 | 0.80m |
| 4 | Prx1= -15dBm<br>Prx2= -42dBm<br>Prx3= -55Dbm | D1=5.133m<br>D2=13.983m<br>D3=18.253m | X=362<br>Y=228 | 0.83m |

## 6 Conclusions

The proposed method adopted is to calculate location of an unknown target or user in an indoor environment using Wi-Fi Signal Strength (SS) with IEEE 802.11 standards. Experimental study was done in a university campus building for an indoor environment where influences of obstacles were huge. The technique adopted here is Trilateration. Accurate enough to locate a user within 1m or less.

*Innovative research efforts are required to tackle these kinds of issues in the nearby future.*

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