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RSSI BASED LOCATION ESTIMATION IN A WI-FI ENVIRONMENT: AN EXPERIMENTAL STUDY

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Abstract

In real life situations, location estimation of moving objects, armed personnel are of great importance. In this paper, we have attempted to locate targets which are mobile in a Wi-Fi environment. Radio Frequency (RF) localization techniques based on Received Signal Strength Indication (RSSI) algorithms are used. This study utilises Wireless Mon tool, software to provide complete technical information regarding received signal strength obtained from different wireless access points available in a campus Wi-Fi environment, considered for the study. All simulations have been done in MATLAB. The target location estimated by this approach agrees well with the actual GPS data.

Keywords:
RSSI, Access Point (AP), Root Mean Square Error (RMSE), Signal Strength Set Identifier (SSID), RF Localisation

1. INTRODUCTION

Wireless communication has become an inevitable part of our life. It has significant impact in high end applications such as complex defence operations as well as simple application of accessing internet or remote control. In the present era of wireless communication seamless connectivity, accessibility and portability are essential requirements [1]. A large number of electronic systems ranging from mobile phones to missiles have to be tracked. This brings in the need for location identification in the first stage. Under these circumstances, an optimal solution for target detection and tracking becomes necessary.

Traditional methods of target detection and positioning include the use of satellite based Global Positioning System (GPS). But there do exist certain constraints in satellite navigation that cannot be overlooked. In urban and indoor environments, the signals are too weak and suffer from severe multipath and interference degradation making GPS ineffective [2][3]. Hence alternate methods for localization were investigated.

A widespread deployment of Wireless Local Area Networks (WLANs) for establishment of point to point and multipoint communication links has been quite successful in urban areas. Using such wireless networks along with their receiver signal strength information, target positioning becomes easy and can be used in those areas where GPS is not effective. The advantage of this alternative approach is the ease of accessibility and cost effectiveness.

There are different localization estimation and identification techniques like RSSI, Time of Arrival (TOA), Time Difference of Arrival (TDOA) and Angle of Arrival (AOA) [2]. Of all the above schemes RSSI based algorithms are preferred as they require minimum hardware and software without the need for synchronisation as in TOA and TDOA. Moreover their implementation is easier. Thus, RSSI based location estimation is a better choice in a Wi-Fi environment. RSSI based techniques require accurate signal power measurement to infer the range using appropriate path loss models. Using RSSI, any of the algorithms such as trilateration, multilateration and triangulation [2] can be applied to achieve localization. In this paper, RSSI technique for position estimation has been used to determine the target location in a Wi-Fi environment. Further the target location obtained in this approach is compared with actual location coordinates derived from GPS.

2. NETWORK ARCHITECTURE

Target detection and tracking is achieved by designing a cooperative network. In order to implement Received Signal Strength (RSS) algorithm, we consider the following requirements and the scenario is depicted in Fig.1.

- Minimum of three base cum control stations (APs)
- A mobile device (target) which can access these stations and transmit to stations the information regarding the received signal strength from them

This will let the control stations know about the RSS at the device due to itself and due to other stations. This information will help in localizing the target device.

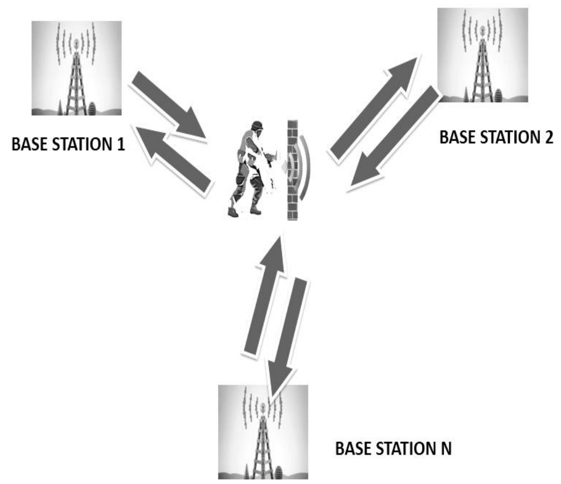

Fig.1. Network Scenario

The mobile device i.e. the target sends the RSS information due to every access point to all the control-base stations. Based on this RSS information, target is localized by employing RSSI algorithm, which provides a means to calculate distance of target from access point, when receiver signal strength is available.

3. EXPERIMENT AND MODELLING

To implement RSSI algorithms [2], a path loss model is needed. An experiment was conducted in the area of investigation at academic campus (MIT, Chennai) to study about the environment characteristics by determining the received signal strength from various Wi-Fi access points. For this, 'Wireless Mon' [4] software was used. "Wireless Mon" is a software tool which identifies the wireless RF signals from different routers. It identifies each router individually using their SSID and displays the received signal strength in dBm from each Wi-Fi router.

1) Using this software, the following details were obtained
2) Number of APs available and its security status
3) Identify all the detected APs with their SSID
4) The channel occupied by each access point
5) RSSI, MAC address, network type and data rate of each access point

Wireless Mon software was installed in a laptop supported with Wi-Fi adapter. A map of the area under study was downloaded from Google maps and the GPS navigator mobile application was activated. A reference point was fixed. The laptop acts as the receiver and was moved inside the campus. The received signal strength from different routers is observed at various locations and the distance between them and the chosen reference location are noted down. Fig.2 is a screenshot of the software showing the different Wi-Fi networks inside campus and Table.1 shows the obtained details for a particular router "Linksys".

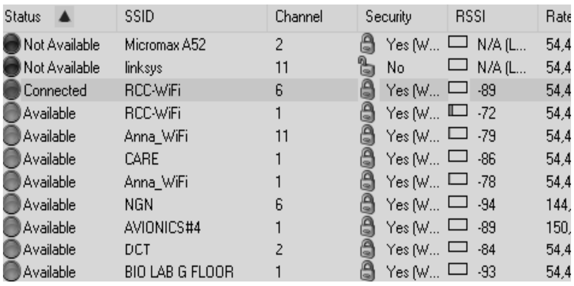

Fig.2. Screenshot of campus Wi-Fi networks as shown by Wireless Mon software in a laptop

Table.1. Statistics obtained for Linksys Router

Sl. No.	Parameter	Value
1	Latitude and Longitude	12°56'51.27" N 80°08'24.43" E
2	SSID	LINKSYS
3	MAC Address	00-12-17-6B-38-74
4	Strength	-59 dBm
5	Speed	59 Mbps
6	Frequency	2412 MHz
7	Channel	11
8	Security	Open – Unsecure
9	Maximum RSSI	-17 dBm

A plot of maximum signal strength at different locations from the six different APs namely Linksys, Care, Au-KBC, RCC, Anna, Nlp Wi-Fi, is given in Fig.3.

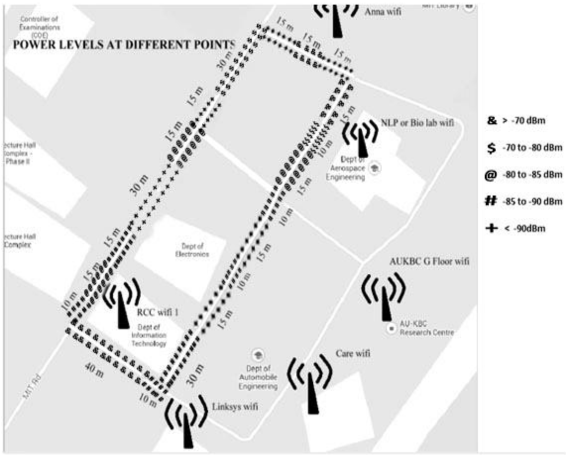

Fig.3. Maximum received signal strength in the mobility area due to all APs

Table.2 provides the geographical location of the dominant access points identified in the study area (Fig.4 and Fig.5).

Table.2. Geographical Location of Dominant APs

Access Point	Latitude	Longitude
AP 1	12°56'52.89 N	80°08'24.29 E
AP 2	12°56'58.05 N	80°08'28.20 E
AP 3	12°56'55.03 N	80°08'27.13 E

From the database it was identified that RCC and Anna Wi-Fi routers are the dominant APs present in the campus. Hence these two Wi-Fi routers are considered for algorithm implementation. Fig.4 and Fig.5 represent the power maps due to the RCC and Anna Wi-Fi respectively. The areas marked with "-" symbol represents locations with no connectivity. Hence another access point is chosen such that locations with nil connectivity are covered by it. This AP is denoted as access point 3 in Fig.4 and Fig.5.

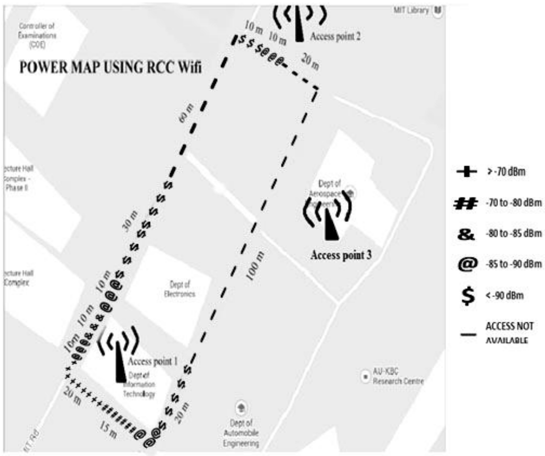

Fig.4. Signal strength due to RCC Wi-Fi network

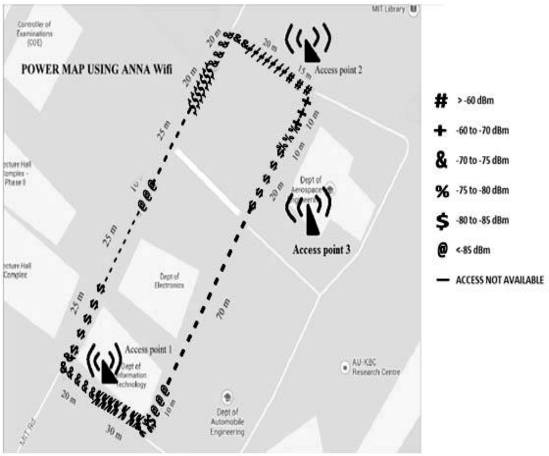

Fig.5. Signal strength due to Anna Wi-Fi network

For the environment considered in this study, the obtained path loss model is shown in Fig.6. The equation governing the model obtained using curve fitting tool in MATLAB [5] is given below,

$$F(x) = a_1 \exp\left(\left(-(x-b_1)/c_1\right)^2\right) + a_2 \exp\left(-\left((x-b_2)/c_2\right)^2\right) \quad (1)$$

where,

$F(x)$ is the RSS value and "x" is the distance between target and AP. The co-efficients are obtained as,

$$a_1 = -12.93, a_2 = -96.25 \quad (2)$$

$$b_1 = 42.25, b_2 = 221.9 \quad (3)$$

$$c_1 = 56.88, c_2 = 270.6 \quad (4)$$

The obtained path loss model has R-squared value [5] of 99.02% and RMSE of 1.124, where R-squared and RMSE are goodness of curve fitting parameters [5].

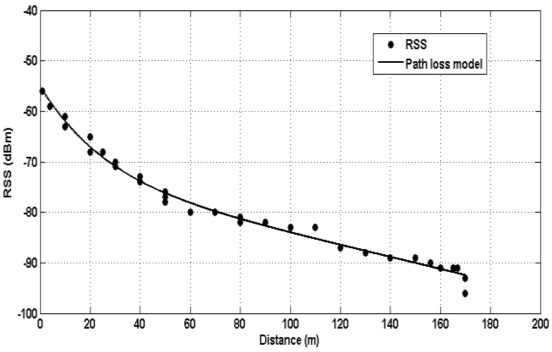

Fig.6. Path loss model

4. RSSI ALGORITHM IMPLEMENTATION

RSSI algorithms can be implemented using triangulation, trilateration or multilateration [2]. In triangulation, position of target is determined using a combination of range and angle information. In multilateration, position of target is determined using time difference of arrivals of the transmitted signal, at three different receivers. This is also called as hyperbolic positioning. There are certain shortcomings that cannot be overlooked in these techniques. In triangulation, angle information is needed apart from distances between APs. Measurement of angles subtended is difficult and either AOA or TOA information is required. In multilateration, a minimum of 4 APs are needed for localization in 3D space. These will increase the hardware complexity. To overcome these difficulties, trilateration technique is adopted. In trilateration technique, relative position of the target is determined using the range information of target from reference points. Let P be the point at which target is located, and A, B & C correspond to the access points at distances of d_1, d_2 & d_3 from the target respectively. At location A, the probable region within which the target at a distance of d_1 can reside is a circle of radius d_1. Similarly, region where the target can reside observing from locations B & C are also circles with radius d_2 & d_3 respectively. Then, target location can be determined as the point of intersection of three circles with centres at A, B and C as depicted in Fig.7. The method described here is for locating a target in a two dimensional plane.

If the target location has to be estimated in a three dimensional space, then the location of target is the intersection of spheres from each of the measured locations.

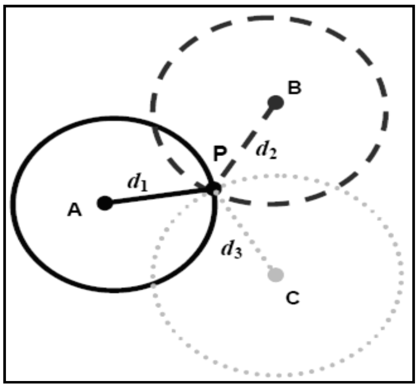

Fig.7. Illustration of trilateration

The co-ordinates of the target can be calculated as:

$$r_1^2 = x^2 + y^2 + z^2 \quad (5)$$

$$r_2^2 = (x-d)^2 + y^2 + z^2 \quad (6)$$

$$r_3^2 = (x-i)^2 + (y-j)^2 + z^2 \quad (7)$$

$$x = \left(r_1^2 - r_2^2 + d^2\right)/2d \quad (8)$$

$$y = \left(r_1^2 - r_3^2 - x^2 + (x-i)^2 + j^2/2j\right) \quad (9)$$

$$z = \pm\left(r_1^2 - x^2 - y^2\right)^{1/2} \quad (10)$$

where,

P_1, P_2, P_3 are the Access Points in Fig.8.

r_1, r_2, r_3 denote the estimated distance between target and each AP, as illustrated in Fig.8.

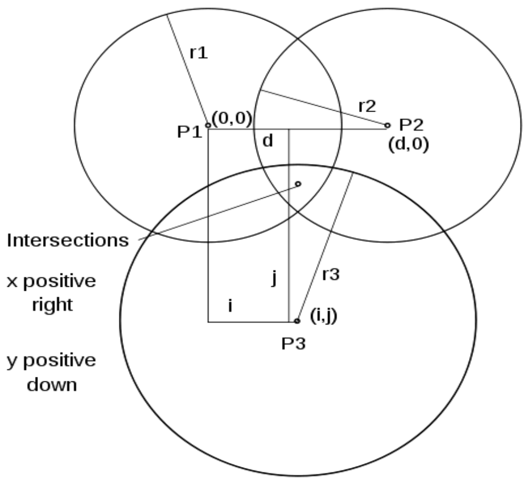

Fig.8. Location estimation by trilateration

Practical area under surveillance to localize the target using 2 APs is larger. This search region is narrowed when trilateration method is used. Ideally search region gets narrowed down to a single location as shown in Fig.7. The Eqs.(5)–(10) are implemented in MATLAB to determine the location. The screenshots of the obtained result is shown in Fig.9.

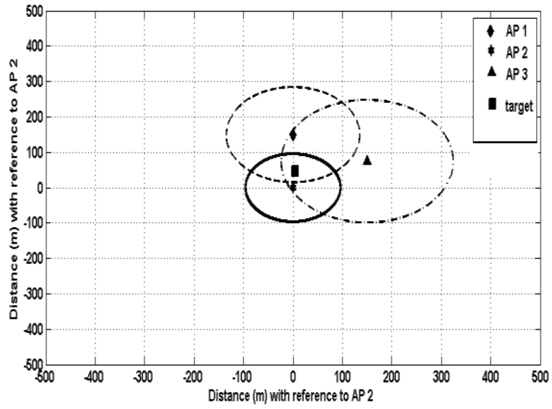

Fig.9. Screenshot of localization using trilateration

5. RESULTS

Table.3 gives some of the obtained results of localization at different locations. The terms "Act" and "Est" in Table.3 indicates actual and estimated distances respectively.

Table.3. Results

Actual Target location from GPS		Distance of Target from APs					
		AP1(m)		AP2(m)		AP3(m)	
Lat	**Long**	**Act**	**Est**	**Act**	**Est**	**Act**	**Est**
12°56' 56.05 N	80°08' 27.20 E	131.11	135	68.72	67	31.58	34
12°56' 54.05N	80°08' 26.09 E	64.96	67	138.90	143	43.55	43
12°56' 55.53 N	80°08' 25.13 E	85.37	88	128.80	120	62.15	60
12°56' 55.73 N	80°08' 26.01 E	101.90	96	97.37	104	40.05	43

These results reveal that the maximum deviation from actual positioning is about 7.66 %. In order to increase the accuracy, adaptive beam forming may be performed [6].

6. CONCLUSION

In this work, localization based on RSS algorithms was analyzed. The measurements were carried out in the WiFi environment inside Madras Institute of Technology (MIT) campus. A simple and feasible technique of trilateration was implemented and coordinate position of the target was estimated. Path loss model has a major influence on the position estimates. The derived path loss model for the area of study has R-squared value of 99.02%. A maximum deviation of 7.66% was obtained in this approach, when compared with actual data.

REFERENCES

[1] Marco Gramaglia, Carlos J Bernardos and Maria Calderon, "Seamless internet 3G and opportunistic WLAN vehicular connectivity", *EURASIP Journal on Wireless communications and Networking*, Vol. 2011, No.1, pp.1-20, 2011.

[2] Raida Al Alawi, "RSSI Based Location Estimation in Wireless Sensors Networks", *17th IEEE International Conference on Networks*, pp.118-122, 2011.

[3] Erin-Ee-Lin Lau and Wan-Young Chung, "Enhanced RSSI-Based Real-Time User Location Tracking System for Indoor and Outdoor Environments", *International Conference on Convergence Information Technology*, pp. 1213-1218, 2007.

[4] http://www.passmark.com/products/wirelessmonitor.html, Accessed on 14July 2013.

[5] User's guide to curve fitting toolbox, MATLAB2013a, http://www.mathworks.in/help/pdf_doc/curvefit/curvefit.pdf. Accessed on 30 September 2013.

[6] Don H. Johnson and Dan E. Dudgeon, "*Array Signal Processing: Concepts and Techniques*", Prentice Hall, 1993.