# Adaptive RLS-Received Signal Strength Algorithm in Wireless Network Area for Multi-Mobile Nodes Location Estimation System

Abhishek Singh
Dept. of Electronics & Communication
RGGI, Meerut, India

Rajesh Mehra
Dept. of Electronics & Communication
NITTTR, Chandigarh, India

## ABSTRACT
Recently, the current Received Signal Strength based positioning systems have been designed to monitor the location information of mobile nodes and Patients. The positioning systems are designed with different wireless communication technologies and adapted algorithms in wireless network area. The adaptive algorithms improve the accuracy of location of mobile nodes in RSS (Received Signal Strength) based positioning systems. The proposed work introduced adaptive Recursive Least Square - Received Signal Strength (RLS-RSS algorithm) algorithm to reduce the effect of multipath propagation in Trilateration Localization system. In the proposed work the entire three reference node receives the RSS-values from the multi-mobile nodes and then RLS-RSS algorithm is used to estimate the RSS-values at each reference node. The estimated RSS-value provides the coordinates of multi-mobile nodes. From the simulation results it is shown that the accuracy of the coordinate's point of the multi-mobile nodes is improved for different environments.

**Keywords—**Trilateration Localization System; Recursive Least Square Adaptive Filtering; Received Signal Strength (RSS)

## 1. INTRODUCTION
Recently, positioning systems such as GPS have become very popular in large range of applications. The GPS techniques is requiring satellite coverage, are not suitable for indoor positioning system [1]. Traditionally there are two techniques for geo location system one is Angle-Of-Arrival (AOA) and second is the Time-Difference-Of-Arrival (TDOA) of the incoming signals in multi-literation [2]. TDOA requires very accurate timing synchronization between fixed nodes and will not be able to localize narrowband type interferes. Thus it is prominent in cost, size and power consumption. RSSI based localization algorithm technology is simple, lower cost and RSSI feature present in most wireless devices [3]. In practical applications due to the actual environment, a variety of complex factors, such as reflection, antenna gain etc. make the same propagation distance may have very different propagation loss, and thus there is the RSSI distance error that is calculated by using attenuation model. The trilateration based estimation is using path-loss models and the estimated distance from various Access Points to reduce the complexity is needed the fingerprinting for WLAN systems [4]. The paper presents an RSSI based adapted Euclidean distance algorithm (AEDA) for the use in dynamically changing environments. The results shown are based on data gathered during a systematic filed trial within an office building of university of applied sciences and arts in Germany. The calibration efforts may be decreased by a factor of 4, if an increase of MLEE error from 2.12m to 2.69m is tolerated [5].

In this paper, proposed work shows adaptive RLS-RSS algorithm for solving problems on to estimate the coordinates of multi-mobile communication nodes for different environment in trilateration simulation area.

## 2. PROPOSED MULTI-MOBILE NODES LOCATION ESTIMATION MODEL
In proposed Multi-Mobile nodes Location Estimation System Model, at least three reference nodes in the network must be available to measure the RSS-values from the mobile nodes. After that, adaptive RLS-Received Signal Strength algorithm is used to estimate the coordinates of multi-mobile nodes.

### 2.1 Log-normal shadowing model
The empirical model used to define path-loss is the lognormal shadowing, as in

$$P_d\left[dBm\right] = P_0 - 10\eta log_{10}\left(\frac{d}{d_0}\right) + X_\sigma. \qquad (1)$$

Where $d$ is the distance between mobile and reference node; $d_0$ is the reference distance; $\eta$ is the path-loss exponent which defines the rate at which the power falls; $X_\sigma$ is the Gaussian random noise variables; $P_0$ is the signal strength at $d_0$ of the distance transmitter; $P_d$ is the signal strength at $d$ of the distance transmitter; $P_0$ can be obtained through the experience or from the hardware specifications. In this way for $d_0 = 1m$, the distance $d$ can be obtained through the received signal strength $P_d$ [6], as in (2).

### 2.2 Relation between RSSI and distance d
The radio signal strength is gradually weakened with the propagation distance increases and there is a certain relationship between the RSSI (Received Signal Strength Indication) and the distance $d$ due to lognormal propagation model. The relation between RSSI and distance, as in

$$d = 10^{\left(\frac{P_d[dBm] - P_0 - X_\sigma}{10\eta}\right)} \qquad (2)$$

### 2.3 Trilateration Localization Method
Trilateration method is used to determine the location of the mobile node based on simultaneous range measurements from three reference nodes at known location. If the distance between the mobile communication node and three reference nodes is known then triangle algorithm is used to calculate the position of the mobile communication nodes, which use the three reference nodes for center of circle and their respective distance to the mobile node as the radius [7]. Fig. 1 shows the

basis of trilateration is the calculation of the intersection points of three circles with radius $r_1$, $r_2$ and $r_3$. Here define circles $P_1$, $P_2$ and $P_3$ have radius $r_1$, $r_2$ and $r_3$ respectively. The center of $P_1$ locates at (0, 0), the center of $P_2$ locates at (a, 0) and the center of $P_3$ located at (0, b). The intersection point by the simple circle equation is, as in (3-7).

$$r_2^2 = (x-a)^2 + y^2 \quad (3)$$

$$r_1^2 = x^2 + y^2 \quad (4)$$

$$r_3^2 = x^2 + (y-b)^2 \quad (5)$$

$$x = \frac{r_1^2 - r_2^2 + a^2}{2a} \quad (6)$$

$$y = \frac{r_1^2 - r_3^2 + b^2}{2b} \quad (7)$$

Now, the intersection point can be determined by solving equation (4-6). The results of calculation are the Cartesian coordinate (x, y) of the mobile communication nodes.

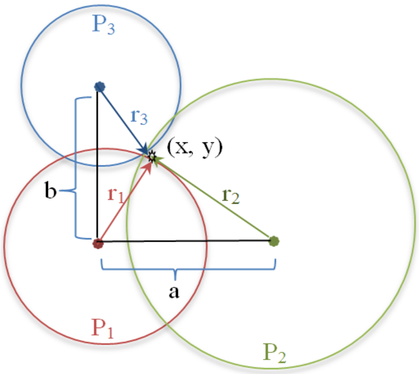


**Fig. 1: Trilateration Method**

## 2.4 RLS-RSS algorithm for Localization

In the first phase, the RSS-value measurement system, path loss log-normal shadowing model with the Gaussian random noise variables is built, which has non-linear function between the distance values and the RSSI values, as

$$RSSI_{dBm} = -20\eta log_{10}\left(\frac{4\pi cd_0}{f}\right) - 10\eta log_{10}\left(\frac{d}{d_0}\right) + X_\sigma . \quad (9)$$

In the RSS measurement system that includes three reference communication nodes, denote the received shadow faded RSSI vector of the *i*th mobile communication node, as in (10-12).

$$RSSI_{i,r1}[dBm] = (RSSI_{i1}, RSSI_{i2}, \ldots\ldots\ldots\ldots, RSSI_{iN}) \quad (10)$$

$$RSSI_{i,r2}[dBm] = (RSSI_{i1}, RSSI_{i2}, \ldots\ldots\ldots\ldots, RSSI_{iN}) \quad (11)$$

$$RSSI_{i,r3}[dBm] = (RSSI_{i1}, RSSI_{i2}, \ldots\ldots\ldots\ldots, RSSI_{iN}) \quad (12)$$

In the second phase, the RLS-RSS algorithm is applied on the received RSS values from the multi-mobile nodes.

Then $(x_i , y_i)$ coordinate point of *i*th mobile node is calculated, as in

$$x_i = \frac{r_{i,1}^2 - r_{i,2}^2 + X\_length^2}{2X\_length} \quad (13)$$

$$y_i = \frac{r_{i,1}^2 - r_{i,3}^2 + Y\_length^2}{2Y\_length} . \quad (14)$$

where *X_length* and *Y_length* is the outer parameters of trilateration location system. $r_{i,1}$, $r_{i,2}$ and $r_{i,3}$ is the distance from *i*th mobile node to reference node1, reference node2 and reference node3 respectively.

# 3. SIMULATION AND RESULTS

The proposed algorithm for Multi-Mobile Nodes Location Estimation System Model has been implemented in MATLAB7.9 for validation and testing.

## 3.1 Simulation Environment

Here assumed three simulation environments with 3 reference nodes and 10 mobile-nodes. Table I shows the path loss exponent and standard deviation for different environment.

**Table 1. Path loss and Standard deviation**

| Environment | Path loss exponent (η) | Standard deviation |
|---|---|---|
| Free Space | 2.0 | - |
| Retail store | 2.2 | 8.7 |
| Grocery store | 1.8 | 5.7 |
| Office, soft partitions | 2.6 | 14.1 |

Fig. 2 shows the relation between radio signal strength in dBm and distance of mobile nodes in meter. Here Red curve shows the lognormal propagation behavior without Gaussian random noise, Black dot shows the multi mobile nodes RSSI with shadow fading at different distance point and Blue circle is the estimated RSSI value of related mobile node.

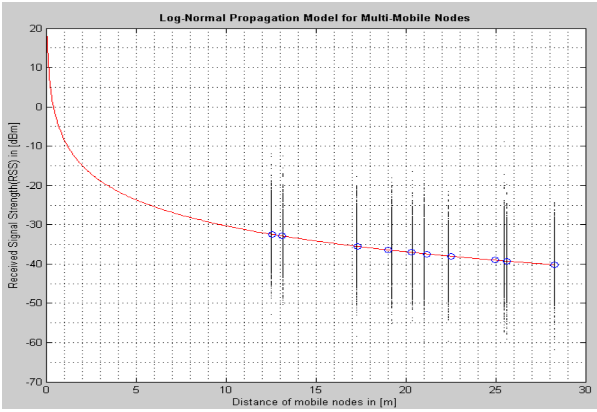


**Fig. 2: Lognormal model for multi-mobile nodes**

In first simulation environment, virtual area 20x20m for Retail store environment. From Table 1 retail store path exponent (η) = 2.2 and standard deviation 8.7dBm. Fig. 3 shows the three reference nodes, actual, measured and estimated mobile nodes. Table 2 shows the actual, estimated coordinates of multi-mobile nodes and Mean Square Error (MSE). In second simulation environment, virtual area 50x50m for Grocery store environment. Grocery store path exponent (η) = 1.8 and standard deviation 5.7dBm. Fig. 4 shows the three reference nodes, actual, measured and estimated mobile nodes. Table 3 shows the actual, estimated coordinates of multi-mobile nodes and Mean Square Error. In third simulation environment, virtual area 20x20m for Office Soft partitions environment. Office soft partitions path exponent (η) = 2.6 and standard deviation 14.1dBm. Fig. 5 shows the three reference nodes, actual, measured and estimated mobile nodes. Table 4 shows the actual, estimated coordinates of multi-mobile nodes and Mean Square Error.

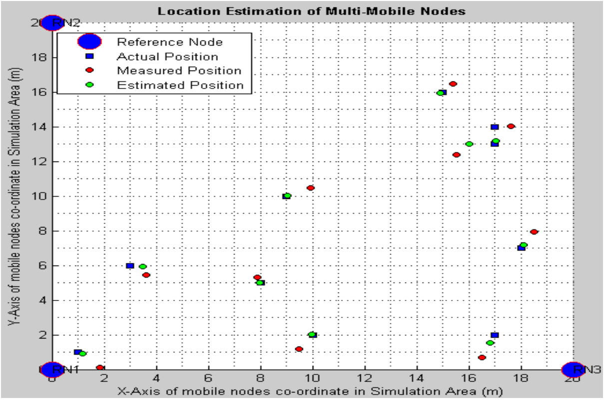


**Fig. 3: Simulation results for Retail environment**

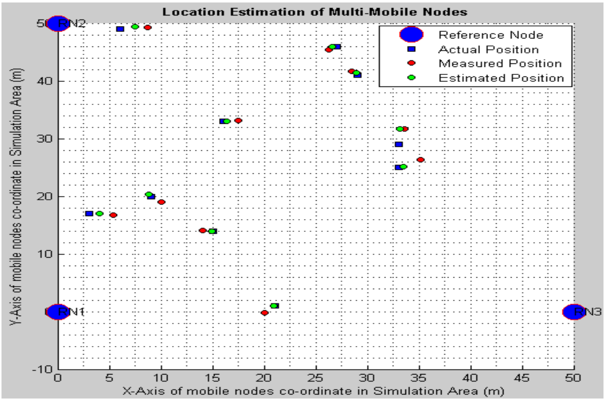


**Fig. 4: Simulation results for Grocery environment**

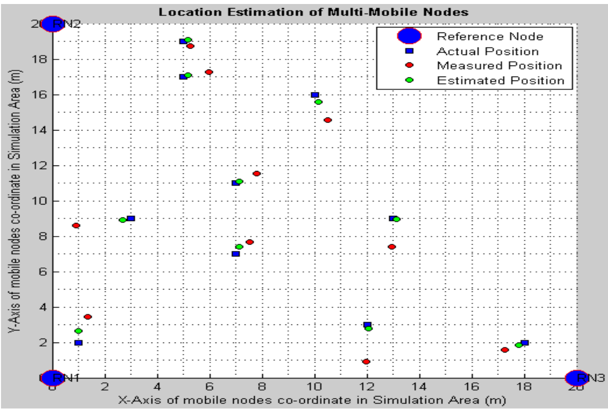


**Fig. 5: Simulation results for Office environment**

## 3.2 Results

Fig. 6 shows performance analysis of proposed work, the accuracy for all path loss exponents is approximately equal to 85%. The error is about 0.32m for retail store, 0.7m for grocery store and 0.3m for office soft partition simulation environment. The multi-Aps method makes the high accuracy for only selected path loss exponent η = 1.6 and η = 1.8 [8]. The location error of calibration strategy based Probabilistic Neural Network algorithm is within about 4m when the confidence level is 80%, while for the Proximity in Signal Space algorithm the localization error is more than 6m under the same 80% confidence level.

**Table 2. Actual and estimated location of mobile nodes for Retail environment**

| Mobile nodes | Actual coordinated | | Estimated coordinates | | MSE |
|---|---|---|---|---|---|
| | X(m) | Y(m) | X(m) | Y(m) | (m) |
| M1 | 8 | 5 | 7.9875 | 4.9783 | 0.0250 |
| M2 | 10 | 2 | 9.9727 | 2.0265 | 0.0380 |
| M3 | 3 | 6 | 3.4767 | 5.9328 | 0.4814 |
| M4 | 9 | 10 | 9.0450 | 10.0154 | 0.0476 |
| M5 | 17 | 2 | 16.8148 | 1.5131 | 0.5209 |
| M6 | 1 | 1 | 1.1869 | 0.9089 | 0.2079 |
| M7 | 17 | 14 | 16.0409 | 12.9925 | 1.3910 |
| M8 | 15 | 16 | 14.9324 | 15.9404 | 0.0901 |
| M9 | 17 | 13 | 17.0382 | 13.1979 | 0.2016 |
| M10 | 18 | 7 | 18.0911 | 7.1908 | 0.2114 |

**Table 3. Actual and estimated location of mobile node for Grocery environment**

| Mobile nodes | Actual coordinated | | Estimated coordinates | | MSE |
|---|---|---|---|---|---|
| | X(m) | Y(m) | X(m) | Y(m) | (m) |
| M1 | 33 | 29 | 33.1493 | 31.6229 | 2.6271 |
| M2 | 27 | 46 | 26.5779 | 45.9535 | 0.4247 |
| M3 | 15 | 14 | 14.9444 | 13.9671 | 0.0646 |
| M4 | 16 | 33 | 16.3906 | 32.9542 | 0.3933 |
| M5 | 3 | 17 | 4.0800 | 16.9806 | 1.0802 |
| M6 | 9 | 20 | 8.8848 | 20.3380 | 0.3571 |
| M7 | 29 | 41 | 28.9929 | 41.3599 | 0.3600 |
| M8 | 33 | 25 | 33.5521 | 25.1487 | 0.5718 |
| M9 | 21 | 1 | 20.9897 | 0.9635 | 0.0379 |
| M10 | 6 | 49 | 7.4714 | 49.4114 | 1.5278 |

**Table 4. Actual and estimated location of mobile nodes for Office soft Partitions environment**

| Mobile nodes | Actual coordinated | | Estimated coordinates | | MSE |
|---|---|---|---|---|---|
| | X(m) | Y(m) | X(m) | Y(m) | (m) |
| M1 | 5 | 17 | 5.1852 | 17.0723 | 0.1988 |
| M2 | 10 | 16 | 10.1556 | 15.5825 | 0.4456 |
| M3 | 12 | 3 | 12.0452 | 2.7923 | 0.2126 |
| M4 | 7 | 11 | 7.1319 | 11.0923 | 0.1610 |
| M5 | 3 | 9 | 2.6811 | 8.8933 | 0.3363 |
| M6 | 13 | 9 | 13.1237 | 8.9374 | 0.1386 |
| M7 | 18 | 2 | 17.8027 | 1.8628 | 0.2403 |
| M8 | 1 | 2 | 1.0084 | 2.6400 | 0.6401 |
| M9 | 7 | 7 | 7.1321 | 7.3931 | 0.4147 |
| M10 | 5 | 19 | 5.1929 | 19.0979 | 0.2163 |

Algorithm is 35.4% more accurate than the multiple RDR methods [9]. Iterative trilateration results in which the distances are computed according to the filtered signal strength shows the average error of coordinates is 1.7m which is smaller than the average error of 2.8m computed by CC2431 [10]. For open space, localization algorithm with mobile reference nodes (LMRN) has MSE 4.56m [11]. The error of environment-adaptive approach has a modest increase to 2m. LANDMARC is inaccurate and error increase to 5m [12].

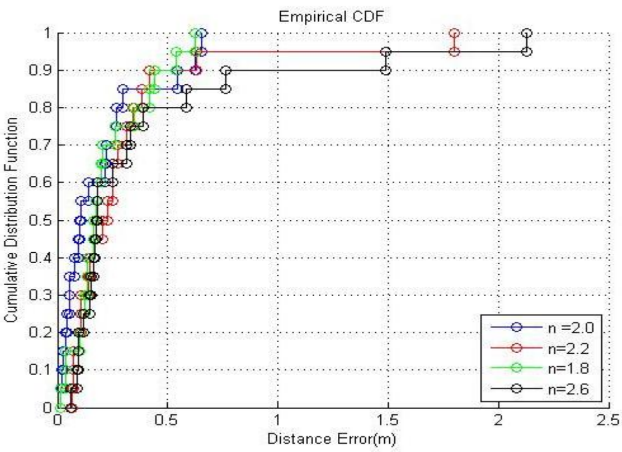


**Fig. 6: CDF for different path exponent loss (η) for Proposed method**

## 4. CONCLUSION

This paper presents a comparison between some of the most used ranging localization methods based on the Received Signal Strength Indicator (RSSI). Simulation results shows that the proposed work for adaptive RLS-RSS algorithm in wireless network for multi-mobile node location estimation is better than other present algorithms. The proposed method is 60-70% more accurate than other location estimation system. Mean Square Error is about 0.3m-0.7m for simulation environment with different standard deviation. The proposed model can be used to improve the present RSSI based location system to improve the position of multi mobile nodes and patient tracking system in hospitals.

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## AUTHOR’S PROFILE

**Abhishek Singh:** Mr. Abhishek Singh is currently Assistant Professor at Radha Govind Group of Institutions, Meerut India. He is pursuing his M.E. from NITTTR Chandigarh, PanjabUniverity, Chandigarh, India. He has completed his B.E. from B.S.A. College of Engineering and Technology Mathura, B.R. Ambedkar University, Agra, India. Mr. Abhishek Singh has 2 years of industry experience and 7 years of academic experience. Mr. Abhishek Singh’s interest areas are Embedded System Design, Advanced Digital Signal Processing, Wireless & Mobile Communication, Digital Image Processing, Artificial Neural Network. Mr. Singh is member of ICEIT.

**Rajesh Mehra:** Mr. Rajesh Mehra is currently Associate Professor at National Institute of Technical Teachers’ Training & Research, Chandigarh, India. He is pursuing his PhD from Panjab University, Chandigarh, India. He has completed his M.E. from NITTTR, Chandigarh, India and B.Tech. from NIT, Jalandhar, India. Mr. Mehra has more than 16 years of academic experience. He has authored more than 100 research papers including more than 50 in Journals. Mr. Mehra’s interest areas are VLSI Design, Embedded System Design, Advanced Digital Signal Processing. Mr. Mehra is member of IEEE & ISTE.