Mobile Positioning System using a Mathematical Approach

Akansha Rao, Vijay Trivedi, Vineet Richaria

Abstract— ***In this era of advanced communication, there are large number of location and positioning based applications which are introduced and implemented practically and theoretically. In this paper, a design and implementation of new location measurement technology is being proposed by which this parameter could easily be estimated. This proposed system is based on trigonometric theory, projectile path estimation and iterative error correction methodology. After implementation, a comparative study is being provided for justification of the results, with distance weighted method being taken as bench mark, based on previous location estimation technique. The results analysis of both these systems is being provided.***

Keywords— ***AOA, TOA, Regression, Comparative Study, Mathematical Approach.***

I. INTRODUCTION

Positioning in Wireless Networks presently is being mainly used for different kinds of application level services. It is also reasonable to assume that future resource management algorithms may rely on position estimation and prediction. In this paper, we discuss and demonstrate different prospects and limitations related to mobile positioning based on existing wireless network measurements. This includes as well a trigonometric calculation approach for AOA and TOA estimation, whilst the limitations provide some hard bounds on the accuracy of position estimation and the information in the measurements in the most positive situation.

The focus is on exemplifying the relation between performance necessities, and the available measurements. Particular issues on limitation in each measurement, a geometrical example, as well as a realistic example adopted from NS2 network simulator tool, are used for designing.

Wireless network refers to type of computer network that is not connected by cables. It is a method by which networks and enterprise installations avoid the costly process of introducing cables or as a connection between various equipment positions. In Wireless communication, networks are generally implemented and administered using radio communication. This implementation involves place at the physical layer of the OSI model network structure. According to their application wireless networks are found in various different variants.

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Wireless PAN: Wireless Personal Area Networks (WPANs) interconnects devices within a small area that is generally within a person's reach. Both Bluetooth radio and invisible infrared light provides a WPAN for interconnecting a headset device such as laptops. ZigBee also supports WPAN applications.

Wireless LAN: A Wireless Local Area Network (WLAN) connects various devices over a short distance using wireless distribution methods frequently providing a connection through an access point. The use of spread-spectrum or OFDM tools may allow users to move around within a local area, and get connected to the network.

Wireless Mesh Network: A Wireless Mesh Network is a network made by the use of radio nodes organized in a mesh topology. Each node forwards their messages through some intermediate nodes. Mesh networks can automatically get re-routed around a node that has lost power.

Wireless WAN: Wireless Wide Area Networks are wireless networks which normally provide their services for large areas, such as one city and similarly in other cities. These networks can be used to connect branch offices or act as internet access. Wireless connections amongst these access points are usually point to point microwave links using parabolic dishes, rather than Omni-directional antennas used with small networks. A wireless system contains base station, access points and wireless bridging. Other configurations are mesh networks where each access point acts as a relay too and combines with renewable energy systems.

Cellular Network: A Cellular Network or mobile network is a radio network distributed over land areas known as cells, each functioned by at least one fixed-location transceiver, known as base station. In a cellular network, each cell typically uses a different set of radio frequencies from all their immediate neighbouring cells to avoid any interference.

The remaining paper is organized in the following manner:- In the next section , a brief introduction of previously proposed and implemented systems is provided. Thereafter, the proposed system details and simulation setup is discussed. The next section includes results evaluated after simulation. After that conclusion and future work is described and discussed.

II. BACKGROUND

Mobile Positioning has become a newsworthy technology simply because of its commercial potential. Looming commercial possibilities in Location-Based Services (LBS) and governmental regulations, where mobile positioning is applied, are the key reasons for the tremendous research interest in personal positioning technologies in cellular networks. Another motivating factor is the benefits like home zone calls, traffic locating and network planning as well as assistance in handover that the network operators would get from this technology.

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Many technologies are in place that can provide this information. Determining which technology to use will usually be based on a combination of accuracy and cost. In most cases, as the required level of accuracy grows, so does the cost. This cost is usually shared between the mobile user and the wireless carrier. Designers normally have to rely on the information provided to them from the handset and the carrier, precluding their ability to directly influence the accuracy of the location information.

In search of finding best scheme for AOA estimation, some papers and articles have been studied which are given and discussed in the literature survey, and it is found that there are large numbers of AOA estimation algorithms and methods which are previously proposed, but most of them are not efficient and accurate method, even most of the methods are much more expensive in implementation. This paper is thus motivated by "HYBRID TOA/AOA SCHEMES FOR MOBILE LOCATION IN CELLULAR COMMUNICATION SYSTEMS" In this paper; author proposes a hybrid scheme for estimating the AOA for mobile location.

The model proposed is according to the above given scenario, where only one BS is required to locate the MS. In reality, due to NLOS propagation, both TOA and AOA estimation contains errors. Thus more than one BS is required for MS location of reasonable accuracy. Here TOA measurements from seven BSs and the AOA information at the serving BS is used to give a location estimation of the MS, as shown in Fig.1.

Let $\mathbf{t_i}$ denotes the propagation time from the MS to $\mathbf{BS_i}$ and the coordinates for $\mathbf{BS_i}$ are given by (Xi, Yi) i=1,2…..7 The distances between $\mathbf{BS_i}$ and the MS can be expressed as

$$r_i = c \cdot t_i = \sqrt{(x - X_i)^2 + (y - Y_i)^2}$$

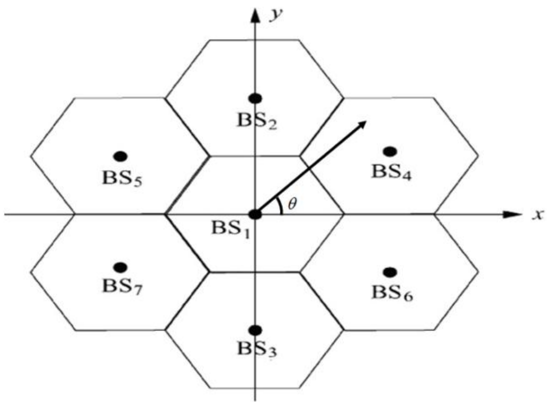


Fig.1 Geometric layout of the seven circles

In order to achieve high accuracy of MS location with fewer efforts, several better approaches which we have proposed are applied in seven BSs as follows:

Distance-Weighted Method

The weights can be dynamically adjusted with reference to the distance square between the estimated MS location and the average MS location. The detailed steps in this are provided below.

1. Find all feasible intersection of the seven circles and a line.
2. The MS location is estimated by averaging these remaining feasible intersections, where

$$\bar{x}_N = \frac{1}{N}\sum_{i=1}^{N} x_i \quad \text{and} \quad \bar{y}_N = \frac{1}{N}\sum_{i=1}^{N} y_i$$

3. Calculate the distance id between each remaining feasible intersection (xi, yi) and the average location (XN , YN).

$$d_i = \sqrt{(x_i - \bar{x}_N)^2 + (y_i - \bar{y}_N)^2},\ 1 \le i \le N$$

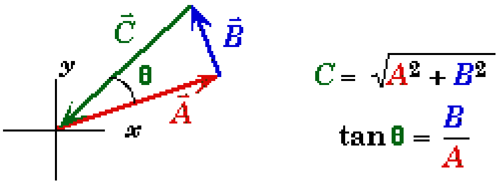
4. Set the weight for the $\mathbf{i^{th}}$ remaining feasible intersection to di^2 ^-1. Then the MS location (X_d, Y_d) is determined by

$$x_d = \frac{\sum_{i=1}^{N} (d_i^2)^{-1} \cdot x_i}{\sum_{i=1}^{N} (d_i^2)^{-1}} \quad \text{and} \quad y_d = \frac{\sum_{i=1}^{N} (d_i^2)^{-1} \cdot y_i}{\sum_{i=1}^{N} (d_i^2)^{-1}}$$

III.PROPOSED TECHNIQUE

The two vectors plus their sum forms a triangle which can be analysed using trigonometry. Trigonometric analysis is useful in that it keeps you in visual contact with problem. Its limitation is that it works only if you are adding two vectors.

If the two vectors are at 90*to each other, then Pythagoras' Theorem can be used to find the magnitude of the resultant vector. The angle of the resultant vector can be found using the trigonometric relations of sine, cosine, and tangent for right triangles.



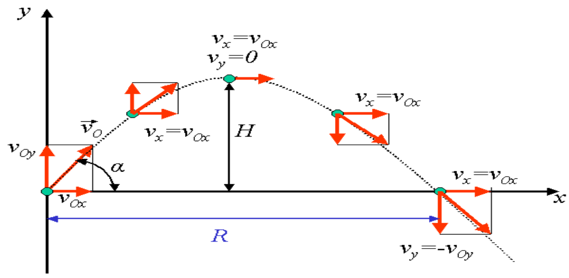


Fig.2 Projectile Preposition

When the triangle formed is not a right triangle, it still may be possible to find the magnitude of the vector sum by using the Law of Cosines or the Law of Sines.

Another example of this kind of application is given by the Fig.2. In this example, from the initial position, an object is thrown and in particular distance its position vector is divided into two parts.

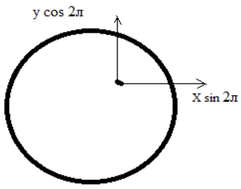


Fig.3 Two factor of Mobile station

Working on the projected object, the intermediate values such as force, speed and acceleration are estimated.

In the previous section, we have provided the basics of the previously proposed and implemented solution for estimating angle of arrival algorithm. The proposed algorithm is a robust, efficient and effective algorithm for finding geometric position of the mobile station. But the use of more than one base station may affect the implementation, installation and maintenance cost of the system proposed.

To achieve high performance and low cost AOA estimation algorithm, we propose a new trigonometric based geometric location estimation algorithm which is derived using the help of previously proposed distance weighted method.

In Fig.4, we use only one base station and others are mobile station. The complete circle forms an angle of 2л and the moveable mobile stations are moving around the range of the base station. Suppose at any time t1, position of any mobile station is defined in the circle is given as (X_p, Y_p). Where $\mathbf{X_p}$ is X coordinate of the MS and $\mathbf{Y_p}$ is Y coordinate of the MS. At any position of mobile station, there are two geometric components which are sin and cos as given in the below diagram additionally in order to find the new location of any mobile station, we use the concept of the distance weighted method where the system find the average of all the previous points. Thus we can say that

$\mathbf{X_p} = \sum X_i \cos 2\pi X_p n$ $\qquad$ $\mathbf{Y_p} = \sum Y_i \sin 2\pi Y_p n$

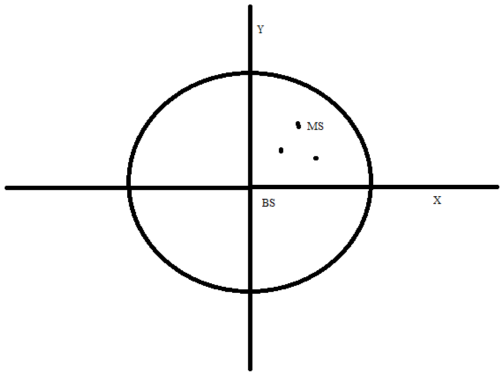


Fig.4 Multipoint Moveable Mobile Station

Thus the mobile location can be estimated using the above given formula. In the same way, we can calculate the distance between the MS and base station by the given formula

$$d_i = \sqrt{(x_i - \bar{x}_N)^2 + (y_i - \bar{y}_N)^2},\ 1 \le i \le N$$

The exact position of coordinate is found between the 1≤ I ≤ N and D_i^2. Then the MS location (X_d, Y_d) is determined By

$X_d = \sum D_i^2 (\cos^2\pi X_p n + \sin^2\pi Y_p n).X_i / \sum D_i^2 (\cos^2\pi X_p n + \sin^2\pi Y_p n)$

$Y_d = \sum D_i^2 (\cos^2\pi X_p n + \sin^2\pi Y_p n).Y_i / \sum D_i^2 (\cos^2\pi X_p n + \sin^2\pi Y_p n)$

Distance weighted method and our proposed methods are using mathematical geometric approach, and both are related to same branch of mathematics and to the same problem. Additionally this method provides straightforward method of estimating the MS location wherein it utilizes these feasible intersections of the circles and the line. However, not all the feasible intersections provide information of the same value for location estimation. But we want to change this concept using the location estimation by using the simple circle method.

Table.1 shows simulation for desired network

Simulation properties	Values
Antenna model	Omni Antenna
Dimension	750 X 550
Radio-propagation	Two Ray Ground
Channel Type	Wireless Channel
No of Mobile Nodes	20
Routing protocol	AODV
Time of simulation	10.0

After configuring the desired configuration and scenario of network system, we get the following given network. The simulation screen of NS2 Nam editor is given in the below diagram.

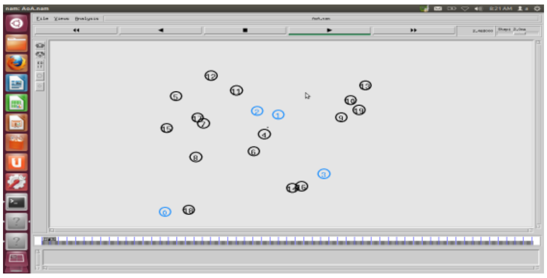


Fig.5 Simulation screen in simple conditions using above parameters

Simulation results are given by three different types for easy and graphical results analysis. In the first, we provide the real path that a mobile node follows during the simulation.

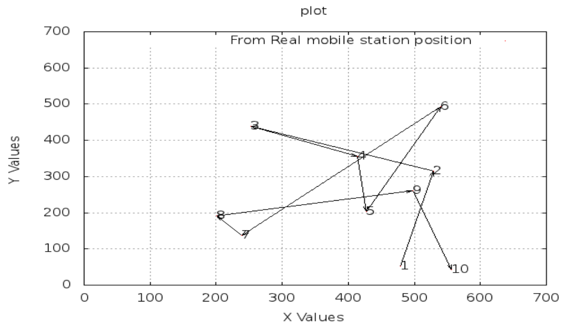


Fig.6 Real path of mobile station during simulation

In the above results we provide the actual mobile position which is extracted during simulation using their X and Y coordinates. After implementation of the desistance weighted method of AOA and TOA estimation, we found the below paths which is represented using Fig.7.

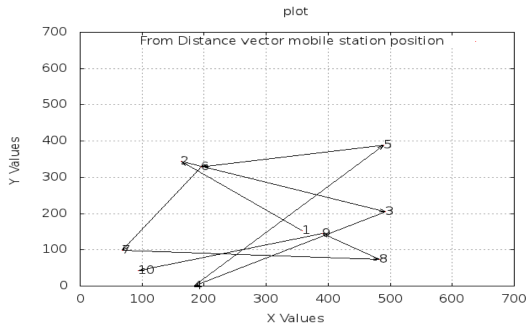


Fig.7 Distance weighted method for estimation

In addition after implementation of the proposed algorithm, the results are as given in Fig.8. This result finds that the proposed method is much accurate than previously proposed distance weighted method.

Fig.9 provides the combined results analysis using the graphs. This graph contains the time duration in X axis and Y axis which contains the positions of the node during the elapse time.

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After comparing them, we found that our proposed method estimates much closer value than distance weighted method.

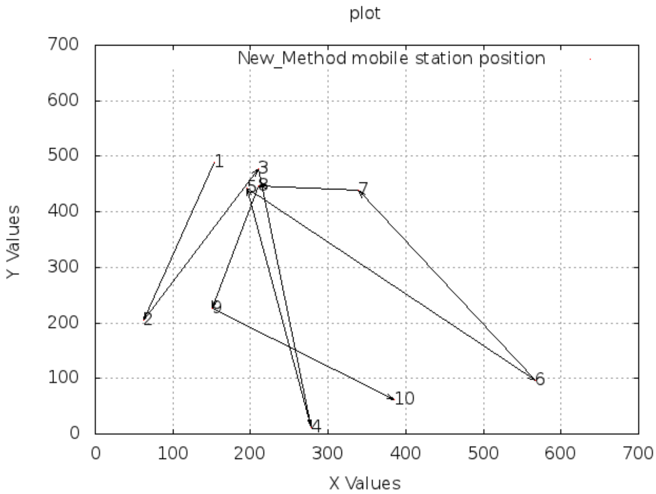

Fig.8 New proposed method position estimation

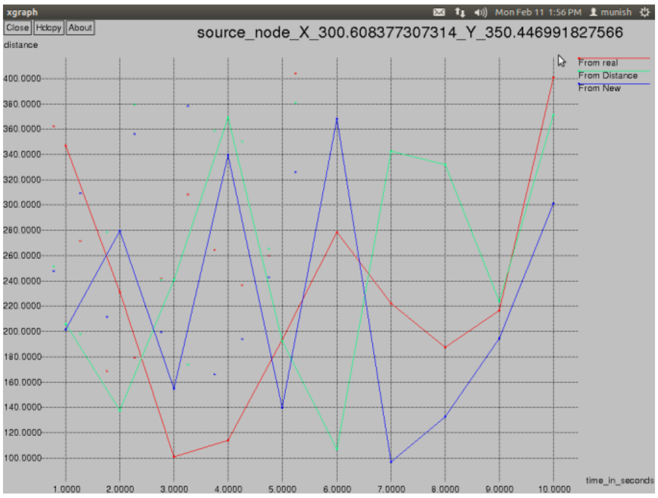

Fig.9 The combined position of the nodes with the time

Accuracy: To compare the % accuracy of the system we estimate the relative values by using the given below formula.

$$accuracy = \frac{Eveluated\ position}{acutal\ position} X100$$

The given below table provides the best results as is obtained by our simulation. The given position is based on the coordinates that are evaluated during simulation.

Table 2 Shows the relative % accuracy of the system

	Distance weighted method	Proposed method
1	80.53	59.27
2	34.24	42.83
3	54.28	100
4	100	83.51
5	28.19	92.34
6	49.63	73.64
7	62.41	30.22

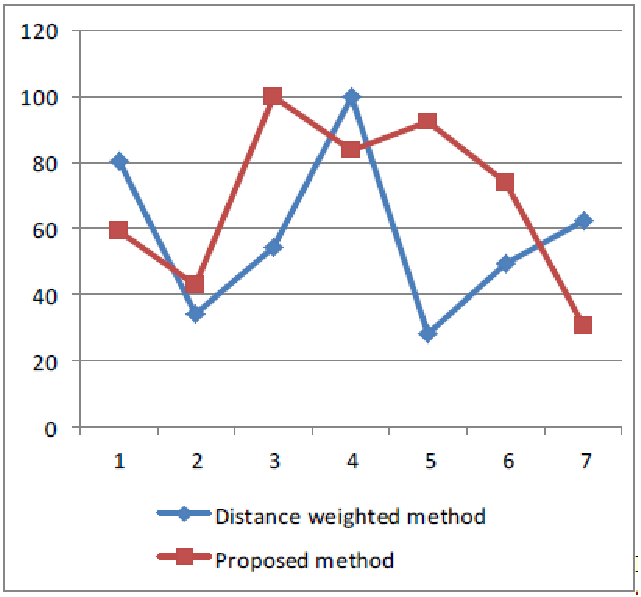

Fig.10 Shows the relative accuracy of the system.

Error rate: These performance parameters provide the values indicating how much difference actually exists in estimation of the accurate values which is calculated as
Error in % = 100 – accuracy %

Table.3 Shows the % error for the system

	Distance weighted method	Proposed method
1	19.47	40.73
2	65.76	59.17
3	45.75	0
4	0	16.49
5	71.81	7.66
6	50.37	26.36
7	37.59	69.78

For the above accuracy and error rate calculation, the actual accuracy gap between actual value and the estimated values were found from the system. After analysis of the results we found that our proposed model produces much accurate results than distance weighted method of location estimation.

Theoretically both the methods are suitable for implementation and are low cost, and both these methods use the mathematical location estimation technique. Additionally we found that these methods are based on the previous position analysis mobile nodes and we measure the new positions of the mobile stations. But during study we found that more or additional parameters are required to be added for the proper and accurate position estimation of the location by both these methods.

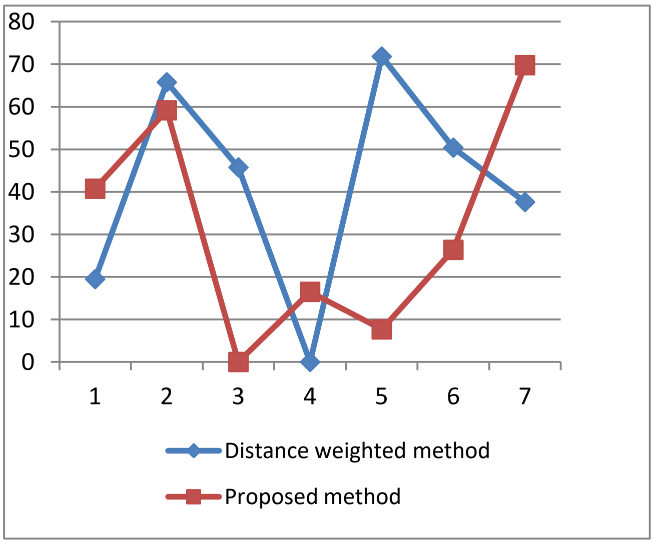

Fig.11 Shows the % error for the system

IV. CONCLUSION

In this paper, the aim was to study different localization scheme and finding an adoptable efficient and accurate method for AOA and TOA estimation. In search of accurate estimation method, we studied different previously proposed and implemented methods and we found that the distance weighted method promises to estimate the most accurate values than other algorithms.

Thus here we implement the distance weighted method for estimating the AOA and TOA, Thereafter, we proposed a new technique which is trigonometric calculation based method for estimation using NS2 discrete event simulator. For estimating the accuracy of old and newly proposed algorithm, we traced the actual path of traversing and in addition we evaluated the calculated positions during simulation time.

As the results are derived and compared, we completed our desired goal to design a new method of AOA and TOA estimation. However, it is found that at times it is comparatively inefficient from the real values, but it is much accurate than distance weighted method.

Location in wireless networks is of increasing importance for safety, gaming, and commercial services. There are plenty of methods which are available today, ranging from signal arrival times to maps of received power. We have demonstrated how important the FIM for each measurement is to assess possible location presentation.

In the last few years, WSNs have been drawing the significant interest, and will continue for years to come. In spite of rapid evolution, we are still facing new difficulties and severe challenges. Here our implementation of the proposed and old technique required some more analysis and improvements for measuring more accurate results. This could be enhanced due to the introduction of linear regression and error improvement methods. In future we work with the similar model for AOA and TOA estimation scheme and apply error correction methods for accurate measurement.

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