Localization Algorithms Research in Wireless Sensor Network Based on Multilateration and Trilateration techniques

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***Abstract*—Recently there has been much focus on Wireless sensor networks (WSN). However Location information is one of the most important information in WSN. Many location estimation algorithms for WSNs have been used to determine the sensor nodes position. In this paper, two different localization algorithms using Trilateration and Multilateration mathematical techniques have studied and compared according to the number of anchor nodes. Some conclusions that are extracted verified that increasing the Number of anchor nodes could enhance the accuracy of the mean location error of location algorithm based on Multilateration technique.**

***Keywords*—WSN, localization algorithms, Trilateration; Multilateration, Energy consumption, Location error**

I. INTRODUCTION

The recent advances in micro-electronics and digital communication have allowed the development of micro components that integrate the mechanisms of captures and wireless communications in a single circuit, with a reduced size and a reasonable cost. These components called sensors promoted the idea of developing sensor networks based on collaborative effort of a large number of nodes operating autonomously and communicate with each other via short-range transmissions [1].

These types of networks should have a major impact on multiple areas such as monitoring, medical diagnostics, object tracking, environmental monitoring, etc...

Each network node is constituted by a miniaturized system, with capabilities of acquisition of data and treatment. Wireless technology allows them to communicate gradually, without a central hierarchy, dynamically and instantaneously reconfigurable depending on the evolution of the population of sensors.

Although this type of network shares similarities with the general concepts of ad-hoc networks, all its characteristics makes it different from conventional networks.

The problem of localization is essential in this type of network. It must taken into account the characteristics of sensors: each sensor has a unit of event detection, calculation and communication unit. All these components are powered by a battery.

Several solutions have been proposed to solve this problem. The easiest method to solve the localization problem is to equip all nodes with a GPS (Global Positioning System) receiver that would assign real coordinates to the nodes in the network. However, this solution is costly due to the cost of the GPS receiver [2]. Another solution is to assign virtual coordinates to nodes based on network connectivity; the relative coordinates of neighboring nodes are obtained by exchanging this information between neighbors. The main disadvantage of this solution is that the computational complexity and message overhead. In addition, it requires a memory space in the node already severely limited.

Many location estimation algorithms for WSNs have been proposed recently. The location estimation algorithms for WSNs can be categorized as range-based and range-free. Range-based methods use absolute point-to-point distance or angle information to calculate the location between neighbouring sensors. The second class of methods, range-free approach, employs to find the distances from the non-anchor nodes to the anchor nodes [3]. Several ranging techniques are possible for range measurement, such as angle- of-arrival (AOA), received signal strength indicator (RSSI) [4], time-of-arrival (TOA) [5] or time-difference-of-arrival (TDOA) [6].

Most of the existing works using different mathematical techniques such as triangulation, trilateration and multilateration. In these methods, information provided by every anchor node is used.

In this paper, two localization algorithms using trilateration and multilateration mathematical techniques have studied and compared.

The present paper is organized as follows: in section 2, we discuss related work, section 3 describes the techniques of location system, and section 4 shows simulation and analysing of results, and section 5 concludes our work.

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II. RELATED WORK

One of the fundamental challenges in wireless sensor network is node localization, although (GPSs) can provide location information, deployment of a GPS receiver in every sensor node is expensive and not useful for most WSN applications. Non-GPS localization algorithms are more practical for WSNs.

Most of the existing works using Localization algorithms to estimate sensor nodes position. On the other hand, localization algorithms can be classified into centralized and distributed categories. In the centralized algorithm, sensor nodes send control messages to a central node whose location is known. The advantage of centralized algorithms are that it eliminates the problem of computation in each node, at the same time the limitations lie in the communication cost of moving data back to the base station. In the distributed algorithm, each sensor node determines its own location independently [2]. The distributed localization can be further grouped into range-based and range-free algorithms. In the range-based approach, some range information, such as time of arrival, angle of arrival, or time difference of arrival is required. The range-free algorithms works as follows: Several anchor nodes are distributed in WSNs. Anchor nodes know their own locations, and they periodically broadcast a control message with their location information. Sensor nodes that receive these control messages can then estimate their own locations [7].

R.Nagpal, H.Shrobe[8], and J.Bachrach present an algorithm that exploits the characteristics of ad hoc wireless sensor networks to discover position information even when the elements have literally been sprinkled over the terrain. The algorithm is based on the fact that the position of a point on a two-dimensional plane can be uniquely described by its distance from at least three noncollinear reference points. The basic algorithm consists of two parts:

- Each seed produces a locally propagating gradient that allows other sensors to estimate their distance from the seed.
- Each sensor uses a multilateration procedure to combine the distance estimates fromall the seeds to produce its own position.

In this paper, two localization algorithms using triangulation and multilateration mathematical techniques have studied and compared.

III. TECHNIQUES OF LOCATION SYSTEM

Location systems consist of three major components [9]:

- **Distance/angle estimation:** This component is responsible for determining the physical relationship between two nodes. Different techniques can be used for this purpose, such as RSS, ToA, and time difference of arrival.
- **Position computation:** This component is responsible for computing the position of a node based on available information about the distance estimated from the previous component and position of references. Recognised techniques used in this component include triangulation, trilateration, and multilateration.
- **Localization algorithm**: This is the main component of a localisation system. It determines how the available information will be manipulated in order to enable most or all of the nodes of the WSN to estimate their position.

A. Trilateration, Multilateration and Triangulation techniques

Trilateration [10]: This method determine the position of a node from the intersection of 3 circles of 3 anchor nodes that are formed based on distance measurements between its neighbours. The radius of the circle is equal to the distance measurement as shown in Fig. 1. However, in a real environment, the distance measurement is not perfect; hence, more than three nodes are required for localization.

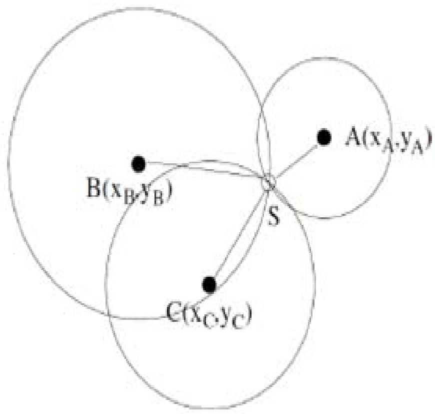

Fig. 1. Trilateration technique

Multilateration[11]: Trilateration technique cannot accurately estimate the position of a node if the distance measurements are noisy. A possible solution is to use the Maximum Likelihood (ML) estimation, which includes distance measurements from multiple neighbour nodes as shown in Fig. 2. This method intends to minimize the differences between the measured distances and estimated distances.

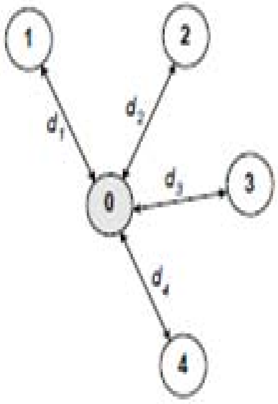

Fig. 2. Multilateration technique

Triangulation: This method is used when the direction of the node instead of the distance is estimated, as in AoA systems. The node positions are calculated in this case by using the trigonometry laws of sines and cosines (shown in Fig. 3).

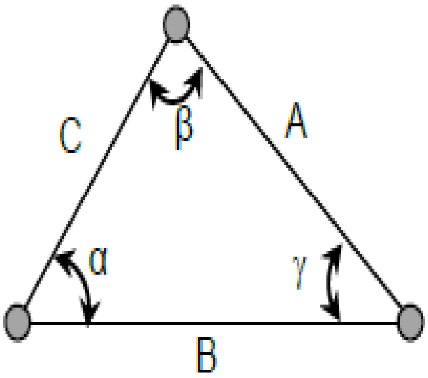

Fig. 3. Traingulation technique

B. *Characteristics of M_refine and Nearest algorithms*

The performance of any localization algorithm depends on a number of factors, such as number of anchor nodes [12], node density, computation and communication costs, and accuracy of the scheme and so on.

Moreover some schemes perform well in high anchor density while some need only few anchors. Multilateration has low computation and communication cost and performs well when there are many anchors.

Two localization algorithms (M_refine[13] and Nearest[14] algorithms) have been implemented for the performance comparison. The characteristics of these algorithms are summarized in Table 1.

TABLE I. CHARACTERISTICS OF M_REFINE AND NEAREST

	Distance/ angle estimation	Trilatiration and Multilateration	coordination	Anchor node numbers
M_refine	RSSI	Multilateration	2D	>=3 anchors
Nearest	RSSI	trilatiration	2D	3anchors

IV. SIMULATION AND ANALYZING

A. *Simulation*

In this section, simulation results are presented and analyzed. We simulated the M-refine and Nearest algorithms to evaluate location performance. The simulations were done in ns2 and 60 sensor nodes are randomly deployed in a square grid of 200x200 area (Fig.4) (red nodes present the unknown nodes and the bleu nodes present anchor nodes).

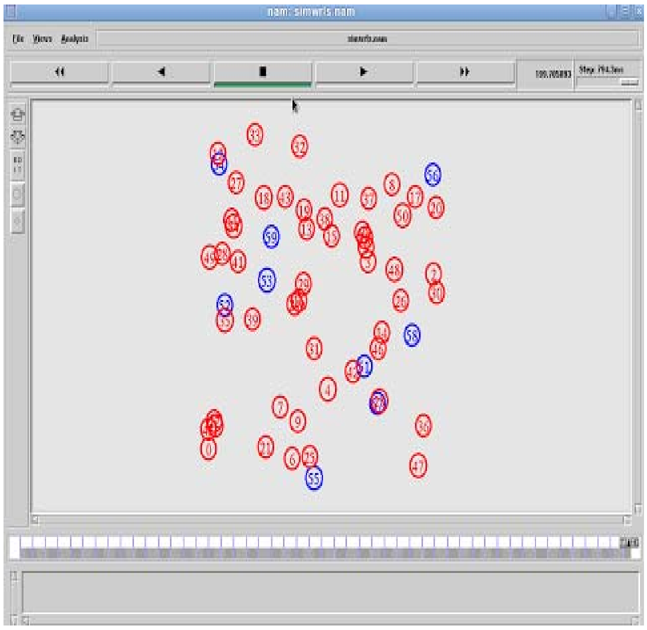

Fig. 4. Simulation network

The simulation results presented as flow figures:

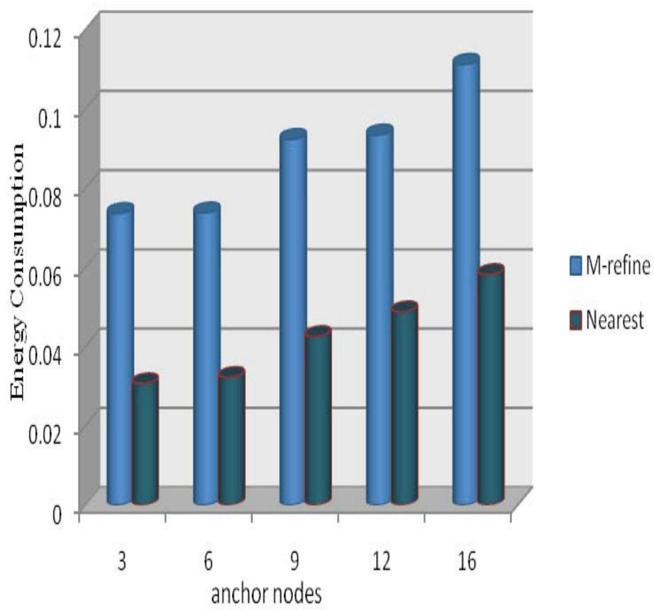

Fig. 5. The energy consumption

At the beginning of simulation each node has 2.0 joule. The figure5 shows the average consumption energy versus anchor nodes density. The comparison between two location algorithms was done considering only energy consumption. The result shows that M_refine algorithm consumes more energy than Nearest.

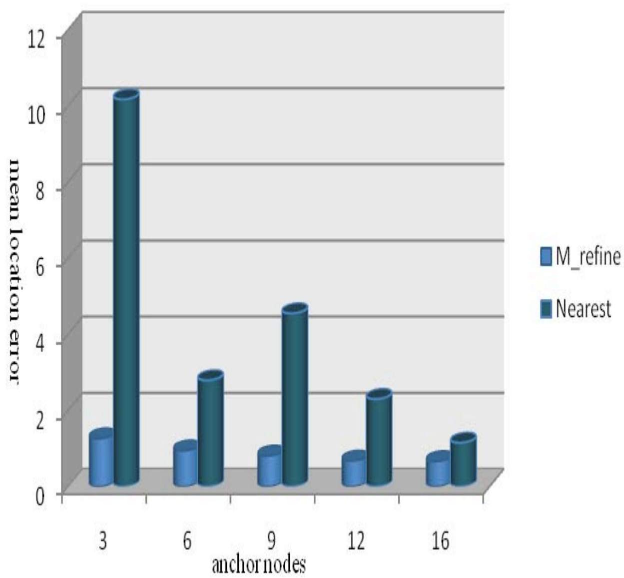

Fig. 6. The mean error location

The figure6 shows the average mean location error versus anchor nodes density. The compare between two location algorithms was done considering only mean location error. The result shows that M_refine algorithm has less mean location error than Nearest.

B. Analyzing

The simulation experiments indicate that the localization algorithms which studied in this paper, namely the M_refine based on Multilateration technique and NEAREST based on trilateration technique show a different result. We conclude that Nearest algorithm can effectively save the energy of wireless sensor node and lengthen the network life cycle. And M_refine algorithm reduces the location error and with the increasing of the anchor node M_refine gives a best performance of location error. The influences of anchor nodes on the M_refine algorithm are explored in the result.

V. CONCLUSION

In this paper we evaluated the localization algorithms namely the M_REFINE based on Multilateration technique and NEAREST based on trilateration technique performance measures i.e. mean location error and energy consumption.
The simulation result reported in section4 shows that the M_refine gives a better result compared with Nearest in term of mean location error, and Nearest algorithm shows best performance concerning energy consumption. The influences of anchor nodes on the M_refine algorithm are explored in this paper.

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