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Location Detection in Wireless Sensor Network using Classical Optimization Methodology

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Abstract

Wireless Sensor Networks (WSN) is used for hunting down targets, environmental supervising, and data collection for factors such as humidity, temperature, and pressure. While these networks are widely used in many applications, their success highly depends on the sensor node positions known as network deployment. Determining the position of sensor nodes is the main objective of deployment network which directly depends on the coverage of the concerned region. To locate sensors, Global Positioning System (GPS) is also used by which sensors know their position. But, this method is not feasible due to economic issues. So, only a small part of the network can affordably be equipped with GPS, and an automatic localization process is required for the rest of the nodes in the network. We estimate random solutions and then apply some technique to find the best feasible solution among all. Classical approach techniques are very efficient in cases where assumptions are fulfilled. In this paper, we have developed the Classical Approach for finding the location of any node which is in the network. We describe a three stage optimization technique is proposed to minimize the estimated error and finding the location of a node in a network.

Keywords

Wireless Sensor Network (WSN), Location Discovery (LD), Multilateration, Classical Optimization Approach (COA)

I. Introduction

In recent years, optimization and wireless sensor networks become a latest topic in research. Classical Optimization Technique is very efficient in cases where the assumptions are fulfilled correctly. For example, the production of a chemical reaction is a function of several variables, and physical characteristics like temperature. The relationship between these variables and the response function is unidentified, but it can be sampled by performing experiments [1]. The conditions in these experiments can be cautiously selected by using knowledge and, depending on the outcome, new experiments may be performed. WSN generally have capabilities for monitoring hefty area, fire fighting, transportation tracking etc. One of the applications of WSN is location discovery [2]. To know the exact location of an object we use sensors. We can give GPS to each node. But, it may not be suitable for movable users due to its high power consumptions. Therefore, we can give GPS to a petite subset of nodes known as beacon nodes and evaluate the distance of other nodes with reference to beacon nodes. Many localization techniques are used to measure the distance between sensor nodes [3]. Firstly, nodes are localized using measurements like distance, Time of Arrival (ToA), Time Difference of Arrival (TDoA), Angle of Arrival (AoA), direction of arrival [4]. Then, position computation techniques like multilateration are used to compute position of a node. Lastly, some localization algorithms are used to locate WSN nodes.

However, the distance estimated contains error which ranges from slight to larger ones [5-6]. The main aim of LD is to minimize the distance estimated error. In this paper, we propose a location discovery technique for Wireless Sensor Networks using classical optimization approach which finds the best solution among all feasible solution [7]. We explain a three stage optimization technique: Error Norm Function, Probability Function and Fitness Function.

The rest of the paper is organized as follows: In Section II, the location discovery problem is explained and formulated. Section III, gives a complete description of wireless sensor networks. Existing work on the field is commented in Section IV, SectionV, focuses on Classical Optimization Technique. SectionVI, presents the proposed optimization technique and its functional diagram. Finally, Section VII, draws some conclusion.

II. Location Discovery

The task of determining the node locations using distances between two nodes which combined with a set of known node locations is referred to as location discovery (LD) [8]. The main drawback found in LD is the presence of distance estimation errors, which result in node positioning errors. Location Discovery problem is the type of optimization problem where we have to find a set of solutions in such a way so that location error is minimized [9]. Here, we consider a multilateration technique given in [10], which is used to find the location of a node with respect to two or three beacon nodes as shown in Fig 1. We have 3 beacon nodes A, B and C who knows there position coordinates and two nodes N1 and N2 whose locations are unknown. Then both node N1 and N2 are able to measure its distance separating them from A, B and C. Now, if node C moves in another location then it again finds its position coordinates with the help of GPS and then again unknown nodes M1, M2 and M3 measure its distance separating itself from node C [6].

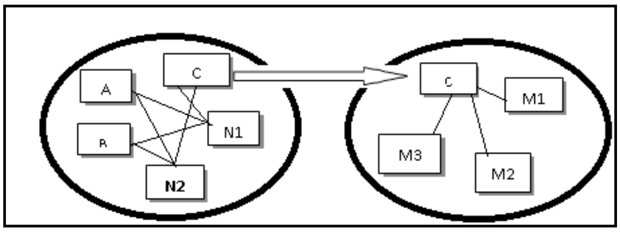

Fig. 1: Multilateration System: Nodes A, B and C Have Knowledge of their Positioning Coordinates. Node N1, N2 can then Calculates its Position by Measuring the Distance to Nodes A, B and C.

III. Wireless Sensor Network

Wireless Sensor Networks are an emerging technology that has been used in various applications. It monitors the physical world using small wireless devices known as sensor nodes. Wireless Sensor Network localization techniques are used to locate sensor nodes with the support of reference nodes and beacon nodes. Beacon Nodes are those who know their position coordinates [10]. Other nodes are localized using measurements like distance, Time of Arrival (ToA), Time Difference of Arrival (TDoA), Angle of Arrival (AoA), Direction of Arrival (DoA) [11]. Then, position computation techniques like multilateration are used to compute position of a node. Finally, some localization algorithms are used to locate WSN nodes. Several application scenarios of WSNs are

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present which include military, industrial, household, medical, natural disasters monitoring, and other emergency situations [12].

Let q and r be two points whose assumed unknown coordinates are (x_q, y_r) and (x_q, y_r) respectively, and (x'_q, y'_r) and (x'_q, y'_r) their estimated coordinates obtained through location discovery technique. We define the following:

Actual distance $A_{q,r} = ((x_q - x_r)^2 + (y_q - y_r)^2)^{1/2}$

Estimated distance $E_{q,r}$,

Measured distance error $ER_{q,r} = E_{q,r} - A_{q,r}$

Location errors $ER_q = ((x_q - x'_q)^2 + (y_q - y'_q)^2)^{1/2}$,

$ERr = ((x_r - x'_r)^2 + (y_r - y'_r)^2)^{1/2}$

We have to minimize ERq and ERr with our proposed optimization approach.

VI. Related Work

Location discovery is a very well-liked topic for study and has been solved for countless scenarios using a variety of technique. Therefore, a large body of information exists.

A. Localization Measurement using Measuring Parameters

In [3], Received Signal Strength (RSS) is used for localization. Based on the concept that the Radio Frequency signals will decompose when the distance between the source and destination increases, the RSSI can be used for object localization. Two key technologies are also applied for localization; first is Time of Arrival (ToA) and second is the Time Difference of Arrival (TDoA). By measuring the arrival time from recognized sources, the distances between the entity and the sound sources can be identified. This information can be used to calculate the location of the entity [13]. Also, by estimating the time differences between several known sound sources i.e., TDoA, the locations of the object can be identified.

B. Localization Algorithms

1. Trilateration Method

The trilateration is one of the popular methods that can be useful for localization. The main principle of this is use of three or more anchor nodes. The calculated distances from these points to the unknown entity are the radiuses of these circles [14]. The intersection of these three circles is the locations of the unknown entity. However, the intersection of these circles may not be a single point. Modification of trilateration method is needed.

2. Bee Optimization Algorithm

In [5], Bee Optimization Algorithm (BOA) for localizing the nodes of the wireless sensor networks is investigated. Different tests with different topologies are conducted based on normal allocation for Time of Arrival (TOA) measurements and received signal strength (RSS) measurements. It gives a comparison between the BOA algorithm performance and the Cramer-Rao Bound (CRB), which finds that the estimated location error is close to that of the CRB.

V. Classical Optimization Technique

Optimizations are typically performed in an iterative trend as shown in fig. 2.

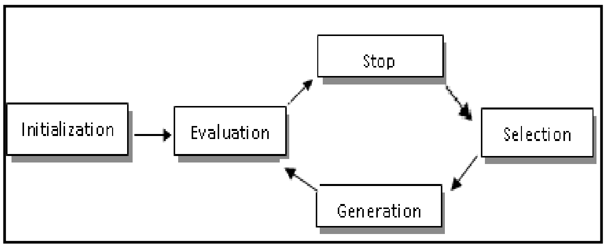

Fig. 2: The Iterative Optimization Steps

The search is started either from one or more random solutions picked according to some criterion. In the evaluation stage, the quality of the current locations (s) is calculated by experiments. Several criteria may be used to stop the optimization, the quality of the location found so far. If no stopping criterion applies, the next stage is to accept the location (s) as a starting point for new location (s), or to reject and to proceed from another location. This process is called selection [10]. Finally, the optimization method generates one or more new candidate solutions. These in turn are evaluated and the cycle enters its next iteration. There are many different optimization methods exist and they can be classified in a number of ways [11]. Classical methods are methods relying on a model of the response surface. Many assumptions about the relationship between problem parameters and response are made, but if they are correct then the performance of these methods is very good. These are strong methods. On the other hand, weak methods make almost no assumptions, but at a certain cost. In most of the cases they are not very effective, and they should only be used in very specific circumstances. Therefore, weak techniques sample the solution space in order to locate areas of good solutions. A strong random component is used in either selecting the sampling locations or defining the orientation of a group of samples.

VI. Proposed Methodology

The target of the proposed approach is to estimate the position of nodes in a wireless environment with minimum error. First of all we calculate the distance using parameters like Time of arrival, Time difference of arrival, Received signal strength which is the calculated distance of nodes. Then, using multiletration estimate the distance of unknown nodes. Comparing both distances with the real values and find distance error. Then apply the optimization functions given below.

A. Algorithm for Calculating Location Using Classical Optimization Technique

Step 1: Find out distance using parameters like Time of Arrival (ToA), Angle of Arrival (AoA), Received Signal Strength (RSS), Time Difference of Arrival (TDoA).

Step 2: Using multilateration each node compute its own distance and get estimated random solution.

Step 3: Compare those random solutions with the real values and if solution is close to the real solutions then those values are considered as approximation values.

Step 4: In first stage of optimization approach, that is the error norm function we obtain approximated solutions without considering the previous knowledge. We calculate how much error a given candidate solution incurs. For example, P_q and P_r be two possible values for a given node. Initialize (P_q), evaluate (P_q), initialize (P_r), evaluate (P_r).

Step 5: In probability optimization function, we develop a measurement error model. This finds a probability for the estimated distance above. In this we assume the measurement error follows some probability distribution and adjust the parameters to best fit the data we have.

Step 6: We applying third stage for finding consistency among approximated values and decide which one is best. It depends on location error (LR)

If location-error (P_q) ≤ location-error (P_r) then P_q is better solution, otherwise P_r is selected as a final solution.

B. Functional Diagram

It describes the complete process diagrammatically.

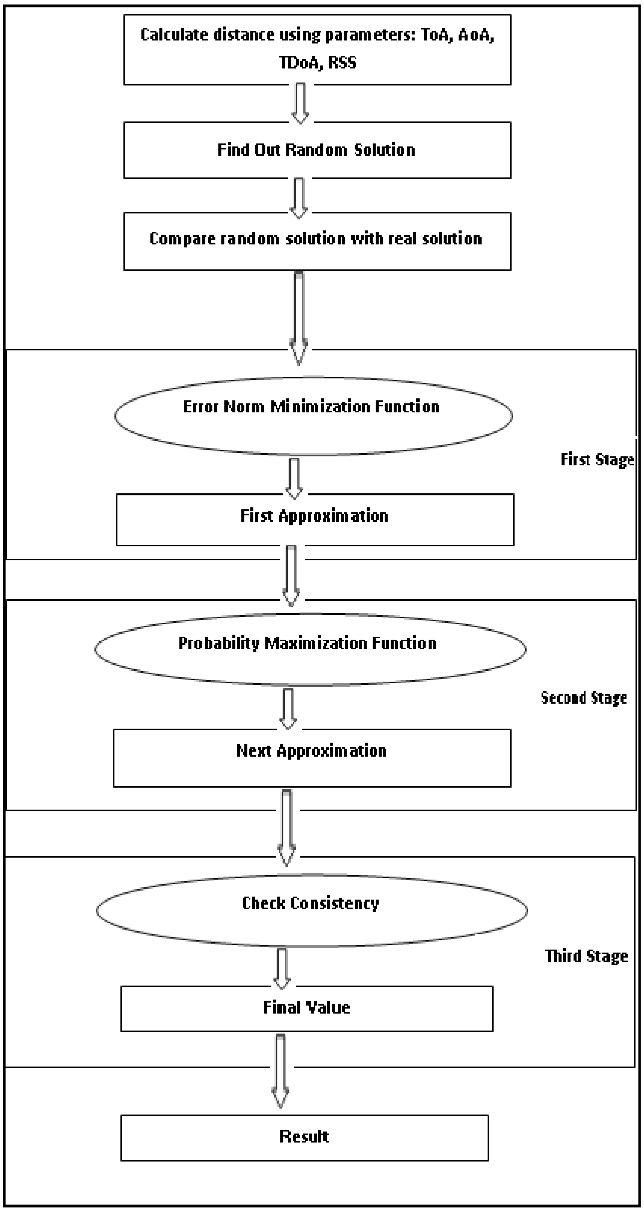

Fig. 3: Functional Diagram for Classical Technique

VII. Conclusion and Future Research Direction

Sensor location is vital for many critical applications like battlefield surveillance, target tracking, environmental monitoring, wildfire detection, and traffic regulation. Location discovery is still an active area of research, both in terms of proposing and validating specific applications and in terms of developing a theoretical framework. Localization has two important metrics: efficiency and accuracy. In this, we have discussed the unique operational challenges faced by WSNs, presented a comprehensive overview of the localization process, and discussed the three optimization techniques: error norm function, probability function and a consistency function is described. Future work will lead towards an implementation of the proposed work, the use of new search technique and improvements in the estimated values.

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