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Wireless Sensor Localization Technique Based On Hybrid PSO-ANN Algorithm

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Abstract: In wireless sensor network technology one major problem is localization problem. In most of the applications, without localization the data collected by the network that information does not useful. Location information has an significant role in both networking and application domains of wireless sensor network. Traditional received signal strength based localizations using propagation-loss model are often incorrect for the low cost WSN devices. The reason is that the wireless channel is unsafe to so many factors that deriving the appropriate propagation-loss model for the low cost WSN devices is not possible. Localization plays a critical role in various applications like tracking, battlefield, intrusion detection, medical surveillance etc. TDOA helps in finding out the distance between anchor nodes and sensor nodes and compares result on the basis of Root Mean Square Error (RMSE).This paper aims to measure the distance between the mobile node and sensor node by using the PSO-ANN algorithm.

Keywords: Wireless sensor network, Artificial neural network, Particle swarm optimization, received signal strength indicator, localization algorithms, TDOA.

1. INTRODUCTION

Wireless Sensor Networks (WSNs) consist of a large number of sensor nodes which are connected over wireless links. These sensor nodes are used for sensing, processing and communication process. WSNs have many applications such as target tracking, surveillance, pollution control, environmental monitoring, habitat monitoring, intrusion detection, fleet monitoring and rescue operations in battlefield etc. Basically all applications of WSNs need information about the physical location of the sensor nodes because without correct location information the collected/transmitted data by the sensor node could become meaningless and also this information is important for routing efficiency. One method to find the location of a device is through manual configuration, which may not be feasible for large scale deployment or mobile systems. Another method is Global Positioning System (GPS). But GPS system is not suitable for indoor environments and having high hardware cost and power constraints if we deploy them on every node. In general, only a small number of nodes' positions are measured by global positioning system (GPS) or manual configuration. These nodes whose positions are known in advance are called anchor nodes or beacon nodes. A number of techniques (more than 50) have been proposed for WSN node location estimation. All these techniques can be divided into two broad categories- (1) Range based and (2) Range free

Range based technique based on distance measurements between nodes. There are many techniques for the estimation of distance or angle between the nodes. Some general techniques are - (1) Received Signal Strength (RSS) (2) Time of Arrival (TOA) and (3) Time Difference of Arrival (TDOA) (4) Frequency difference of arrival (FDOA) (5) Angle of Arrival (AOA) is required to estimate the direction of node.

2. LOCALIZATION IN WIRELESS SENSOR NETWORK

Localization is one of the main application areas in wireless sensor networks. Localization can be used in various applications such as identifying the coverage area of WSN, monitoring location changes, geographical area-based routing, and location directory services. Wireless sensor networks may contain hundreds of nodes; where it may cause a high cost to use the global positioning system (GPS) for each node. In addition, as GPS receivers require relatively high energy, it is not suitable for the fundamental idea of energy-efficient WSNs.

In applications where only local location information is sufficient, there is no need for GPS. In this case, sensor nodes with known locations, called anchors, are used to determine the local coordinates of other nodes. In applications requiring global localization information, anchor nodes along with GPS can be used, or anchor nodes can be located at known coordinates.

Several studies suggest different measurement techniques and localization algorithms. WSN localization techniques can be classified into several categories. The localization process is generally comprised of three phases. These are distance estimation; position computation; and localization algorithm.

Distance Estimation: In the distance estimation phase, the relative distances between the nodes are estimated by using the measurement techniques. The four common measurement techniques can be classified as the angle of arrival (AoA), time of arrival (ToA), time difference of arrival (TDoA), and received signal strength indicator (RSSI). These are also known as range-based localization techniques.

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Position computation: The coordinates of a node are calculated via the range or connectivity information. The main techniques used in localization are lateration, multilateration, and angulation. The lateration technique is used to compute the location of a node with the distance measurements obtained by three anchor nodes. With the range information obtained by four anchors, it is also possible to realize three-dimensional localization. Trilateration is the process of lateration realized with three anchors. Lateration with more than three anchors is called multilateration. In angulation or triangulation method, the localization is computed based on the angle information obtained at least via three anchor nodes. In this method, the computation is realized by the node itself with the AoA information using trigonometric solutions.

Localization algorithms: WSN localization algorithms can be classified into several categories such as: single-hop or multi-hop based on the node connectivity and topology; range-based or range-free based on the dependency of the range measurement; distributed or centralized position computation. Determining the distance between two communicating nodes is essential for localization in wireless sensor networks. In range-based algorithms, localization is realized with the distance information between two nodes obtained via several techniques such as angle of signal arrival, time difference of signal arrival, and received signal strength. Since range-based algorithms require measurement at least via one anchor node, these techniques are also known as one-hop technique.

3. RELATED WORK

Localization of sensor nodes is done in two phases. First distance between the unknown node and anchor node is estimated, then the coordinates of sensor nodes are calculated. On the base of technique used to estimate distance between the unknown nodes and anchor nodes, localization algorithms are classified as Range based and Range-free. Several Range-free localization algorithms are proposed in recent years. DV-hop , APIT and centroid are some typical Range-free localization algorithms. Basically Range-free algorithms are based on connectivity information between sensor nodes and no additional hardware is required for localization.

In Range based techniques distance between the sensor nodes is estimated using ranging technique like AOA (angle of arrival), TOA (Time of arrival), TDOA (Time difference of arrival) and RSS (Received signal strength) are used. These techniques use additional hardware like directional antenna, therefore these techniques are expensive and require additional energy for localization but give more accurate results as compared to Range-free techniques.

Some Hybrid localization algorithms are also proposed. Hybrid algorithms provide advantages of both the Range based and Range-free techniques. In [7] an anchor free localization algorithm is proposed. In anchor free technique, localization is done on the base of neighbourhood relation, distance, direction and connectivity between neighboring nodes. In this technique no extra infrastructure is required for localization. For optimizing the accuracy, several optimization algorithm based localization algorithms are proposed in literature. Presented an artificial neural network (ANN) approach to localization in wireless sensor network through the adjustment of the ANN structures using genetic algorithm. The population of ANNs containing their structure in a genetic code is evolved during twenty generations in order to select the best parameters for a particular simulated WSN. The method was tested in an indoor simulation environment of 26×26 meters with eight anchor nodes.In localization algorithm based on HPSO and BBO algorithms was presented for distributed Range based localization. H-Best Particle Swarm Optimization (HPSO) and Biogeography based Optimization (BBO) are nature inspired algorithm for optimization.

In presented a centralized localization algorithm based on genetic and simulating annealing. GA and SAA are both optimization algorithms. The proposed algorithm GSAA is optimized algorithm is optimized algorithm that integrates both GA and SAA. The proposed algorithm is implemented in centralized architecture. All the nodes send measurements to central station for localization. In localization technique based on fuzzy logic and genetic algorithm is presented. The author briefly described the RSS model. Then RSS values are divided into linguistic constructs. The Sinc membership function is used to assign values to the input values. Sinc membership function is selected because of best performance in most of the cases. Genetic algorithm is used to optimize the knowledge of fuzzy system.

4. PROPOSED ALGORITHM

Localization of sensor nodes is done in two phases. First the distance between the sensor nodes and anchor node is estimated than the position of the sensor nodes is estimated. Distance estimation is done using connectivity information or based on absolute distance between the sensor nodes. Than the position of sensor nodes is estimated by set of simultaneous equations by multilateration, angulation or optimization techniques. In the proposed algorithm Genetic algorithm is used for optimal position estimation of unknown nodes.

GENETIC ALGORITHM: Genetic algorithms are nature inspired algorithms based on genetics. GA are used for optimization of results. First of all, some population is initialized. Population is comprised of some individuals or chromosomes. The number of individuals or chromosomes in a population depends upon the problem to be solved. The chromosomes are evolved toward the better chromosomes using the iterative process like mutation and crossover. Each iteration process to evolve the chromosomes is called generation. In each generation fitness of each chromosome is evaluated using a fitness function for the selection process. Then the selected chromosomes participate in next generation. In the proposed algorithm a set of individuals or chromosomes are initialized and a fitness function is based on metrics, RSS and hop count is used for selection process.

RSS (Received signal strength): Received signal strength is the simplest and inexpensive metric to estimate the distance between the sensor nodes for the purpose of localization. Several localization algorithms based on RSS are proposed. The signal strength received at the sensor node is mapped into distances using some channel model. The most popular channel model is log normal shadowing model. The received power at sensor nodes using log normal shadowing model is expressed as:

$$L = L_0 - 10\alpha \log_{10}\left(\frac{d}{d0}\right) + n$$

Where Lis power in dB received at sensor node, a is path loss exponent, do is reference distance, Lo is received power at reference point and n is Gaussian random variable. Values of a and n depends on propagation environment. But the reliability of RSS is affected by the environmental factors such as noise, obstacles and multipath.

HOP COUNT: In a wireless network Hop count metric between source node S and destination node D can be defined as number of intermediate nodes between source node S and destination node D including the source node. Localization techniques which are based on hop count information need less number of anchor nodes because the position of anchor node is propagated in the network by packet forwarding. Algorithms are based on hop count metric.

5.ARTIFICIAL NEURAL NETWORK

A Wireless Sensor Network is an interconnected network of multiple sensor nodes, which communicate with each other to create a smart sensor network which performs various functions[1]. The role of sensor nodes is to convert the physical conditions (e.g. temperature, atmospheric pressure, humidity etc.) surrounding them to electric signals. These signals are then transmitted in the entire network in a fashion that each sensor node co-operates and communicates with each other. The data being so transmitted through signals is centrally collated and analysed by few special nodes (often known as base station nodes).

These anchor nodes provide the useful information about the area covered by WSN. These WSNs are now increasingly being used to provide critical and sometimes lifesaving information about the environment e.g. providing early warning of floods, cyclones, Tsunami etc. Apart from these, such networks also have practical usage in other areas like industrial, commercial, military operations etc. Many of these applications require the precise information about the location of sensor node in the network for tasks such as network routing, communication and to state geographical source of events such as fire detection, earthquake detection, flood detection, temperature monitoring etc. This phenomenon is achieved by a process called Localization, wherein the node placed in a network determines its own location in relation to the anchor nodes. The general approach used to facilitate the localization is to deploy certain nodes which are aware of their location in the overall network and are called anchor nodes (or Beacon nodes). The other nodes in the system calculate the distance between their location and the anchor nodes.

There are quite a few techniques to enable the process of localization which can be broadly classified into a) range based; and b) range free techniques [4]. In a range based technique, absolute distance or absolute angle is measured between the two nodes using methodologies like ToA (Time of Arrival), TDoA (Time-Difference of Arrival),AoA (Angle of arrival), and RSS (Received signal strength).On the contrary, range free techniques rely on the connectivity and proximity of nodes viz-a-viz the anchor nodes to estimate the distance between them.

These estimates are based on certain parameters like amount of packets transferred during routing etc. Range based techniques are more precise and accurate than range free techniques however the latter are more simple and cost effective. These days, the range-free techniques are gaining more popularity than the range-based methods. Application of Artificial neural network (ANN) as a range free technique is one of the forthcoming methods that can be used for localization in WSNs.

a. Introduction to ANN

Artificial Neural Network (ANN) is a computational tool modeled on the structure and interconnection of the neurons in the nervous system of the human brain. These are massive parallel computing systems consisting of an extremely large number of simple processors with many interconnections. The basic processing unit of ANN is artificial neuron. The model of an artificial neuron was propounded by McCulloch and Pitts in 1943 which consists of a) input weights, b) processing element; and c) output function as shown in the following figure:

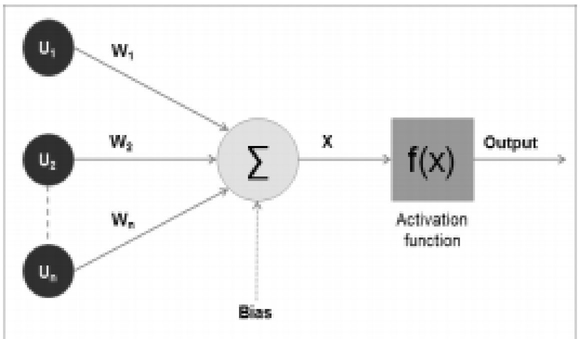

Fig. 1: Mathematical model of artificial neuron

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In the above figure, U1, U2… Un are the inputs to the neuron ;
W1, W2, …..,Wn are weights of the inputs and $X = Ui * Wi \; n \; i=1$. The processing element in the neuron is represented by ∑ in the figure, which processes the weighted inputs along with the bias element resulting in X. The output is then generated through the activation function by limiting the amplitude of the output within a specific range.

The most important property of an artificial neural network is its ability to learn by examples and generalize itself. To make ANN learn, it is trained to perform the desired function by inputting a particular input data which leads to a specific output data. Once the network is so trained, it can predict the output of any new dataset. The training techniques are broadly categorized into two:

i) Supervised learning techniques–These techniques use both input and target output dataset. The target output dataset is used as a milestone which the network is supposed to achieve by processing the input data; and

ii) Unsupervised learning -These techniques uses only input data set. The network is not provided with the target data set.

b. Multilayer Perceptron

There are various categories of neural networks and most commonly used is the Multilayer Perceptron (MLP). It is an enhancement of single layer perceptron consisting of only input and output layer, as explained above. In MLP, apart from the input and output layers, there are multiple layers of the hidden neurons. These hidden layers are not visible to the users and are used to provide high level of processing power combined with flexibility to the system. A diagrammatical representation of MLP is shown in Fig. 2:

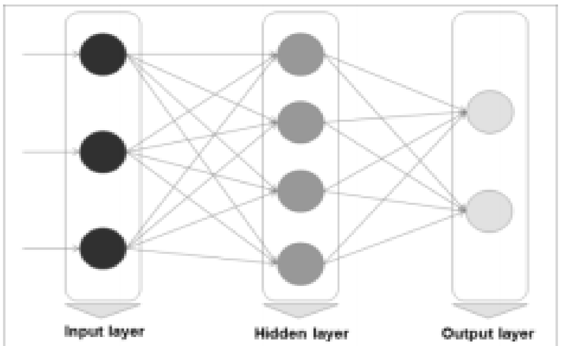

Fig. 2: Model of Multilayer Perceptron

Given the complexity involved in the MLP, their training is generally performed in a supervised manner. The training is normally based on the minimization of errors between the output generated by the network and the desired output. This is achieved by backward propagating the errors calculated in the previous iterations through the network hence this training algorithm is known as Error Back propagation. The idea of the back propagation algorithm is to reduce the error until the ANN learns the training data. The training begins with random weights, and the goal is to adjust them so that the error will be minimal. The performance function used for BPN is mean square error (MSE) where, MSE is the difference between desired output and estimated output.

The objective of BPN is to minimize MSE till the required goal is met. In the next sections of the paper, application of ANN in localization process is explained, using BPN training algorithm for providing supervised training to MLP. The trained network is then tested to determine the effectiveness of the proposed model.

c. Neural Network Architecture

Neural networks are modeled resembling the biological neuron system. It is the network of interconnected nodes, termed 'Neurons', with linear or nonlinear active functions. Various types of networks can be created by varying the activation functions of the neurons and the structure of the weighted interconnections among them. MLP is a widely used NN class. Adjusting the weights requires a learning strategy that starts from a set of labeled examples to construct a model that will then be generalized in an appropriate manner when confronted with new data, not present in the training set.

The architecture of the multi-layer perceptron is shown in Fig.3. The signal flows sequentially through the different layers (input, hidden, and output) from the input to the output layer. Each layer contains one or more neurons and every neuron contains a transfer function. Each neuron calculates a scalar product between a vector of parameters (weights) and the vector given by the outputs of the previous layer. The result is then applied to the transfer function to produce the input for the next layer. Normally, the hidden layers contain sigmoid transfer function while the output layer contains linear function, so that output is not bound. It has been shown that a network of a single hidden layer having adequately large number of neurons is sufficient to approximate any continuous function with the desired accuracy.

In our study, we have investigated several network configurations and activation functions. After a series of tests, it is seen that MLP network with 2 hidden layers (10 neurons in the first hidden layer and 4 neurons in the second hidden layer) and tan-sigmoid transfer function gives better estimation in the present study.

d. Network Training

To approximate a function, the MLP network is trained by repeatedly passing forward the input through the network. The weights are updated based on the difference between the desired output and the actual output of the network. Final weights of the MLP network completely depend on the initial weights. Finding the sets of weights to get the best performance is a great challenge and it ultimately turns into trial and error procedure.

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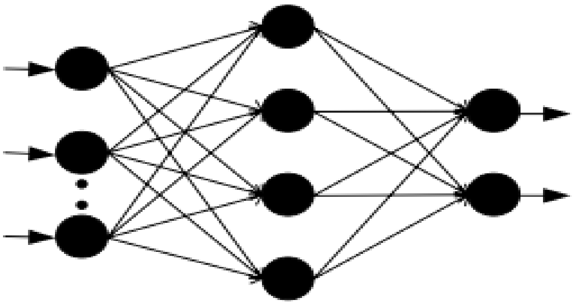

Fig.3: Multi-layer Perceptron neural network architecture. Inputs are the received signal strength values from a particular sensor and measured by different access points. Output is the location.

It is essential to note that the objective of the training algorithm is to build a model with good generalization capabilities when confronted with new input values, values not present in the training set. Among all simulated data sets, 60% are randomly extracted for training purpose, 20% for validation purpose and the remaining 20% for test purpose. There are many variations of error back propagation algorithms for training the network. In our present study, we apply Levenberg-Marquardt training algorithm.

6. PARTICAL SWARM OPTIMIZATION

PSO is a population based stochastic optimization technique developed by J. Kennedy and R. Eberhart in year 1995 . Based on the problem of bird flocking, each bird defined a particle in the search space. The objective of the problem will be to find the food. For this case, the search space represents the area around the food and the birds represent the particles in the search space. Each particle has its own distance from the food and in this case it is defined as the cost function of the problem. Each particle has its own pbest (particle best) and among all the pbest obtained, there will be a bird whereby its location is the nearest to the food. We obtained the gbest (global best) among the pbest obtained which is the shortest distance between the bird and the food. Based on PSO, the entire particle (birds) will therefore move towards the direction of the bird where the gbest is obtained. In each iteration, the position and velocity of each particle are updated and the search for a new gbest will also be executed. This cycle continues until the condition of termination is met.
PSO is a population based search algorithm based on the simulation of the social behavior of birds, bees or a school of fishes.

It employs a set of feasible solutions called particles which explore the search place to find the global solution. The it particle occupies the current position Xi and velocity Vi in a D-dimension space. Each particle evaluates its fitness through an objective function, and it keeps track of its own best fitness pbest. All the particles have a global best fitness solution gbest. PSO repeats a process of updating Vi and X; using (2) and (3) until either an acceptable gbest is achieved or a fixed number of iterations is reached.

$$V_i^{k+1} = wV_i^{k+1} + c_1 r_1 \left(pbest - X_i^k \right) + c_2 r_2 \left(gbest - X_i^k \right)$$

$$X_i^{k+1} = X_i^k + V_i^{k+1}$$

where Cl and C2 are acceleration constants, rl and r2 are random numbers uniformly distributed in [0,1], and w is the inertia weight to control the scope of the search. Usually, w is set to linearly decrease with the evolution.

7. RECEIVED SIGNAL STRENGTH INDICATOR

The RSSI technique is used as the distance estimation method. The RSSI technique is based on the received signal strength indicator to estimate the distance between neighboring nodes. In free-space, the RSSI value is inversely proportional to the squared distance between the transmitter and the receiver. The radio signals attenuate with the increase of the distance. The propagation of the radio signals may be affected by reflection, diffraction, and scattering. Especially in indoor environments, such effects may impact the measurement accuracy. Therefore, this technique is more suitable for outdoor applications, rather than indoor applications. The advantage of this technique is that it do not require the additional hardware since the RSSI feature exists in most wireless devices, and there is no significant impact on the local power consumption.

RSSI is affected from some factors that cause localization errors and reduce accuracy. These errors can be classified into two groups as environmental and device errors. Environmental errors are caused due to wireless communication channel. The causes are usually multi path, shadowing effect, and interference from other RF sources. Device errors are usually caused due to calibration errors, and the important issue here is to keep constant transmit power even under the circumstances of device differences and depleting batteries.

Signal samples, even with the same transmit power, show some standard deviations due to atmospheric conditions. Temperature, for example, has a little effect on a signal. However, rain can affect the signal considerably. Especially, in localization based on the received signal strength method, this will cause less accuracy and reliability.

8. TIME DIFFERENCE OF ARRIVAL (TDOA)

Time Difference of Arrival (TDOA) is one of the widely used localization schemes, in which the signal emits by target (source) and a number of anchors (receivers) record the arriving time of the source signal. The time difference of different receivers is calculated, and then the location of the target is estimated. In such a scheme, receivers must be precisely time synchronized. But time synchronization adds computational cost, and brings errors which may lower localization accuracy. Previous studies have shown that existing time synchronization approaches using low-cost devices are insufficiently accurate, or even impossible under high requirement for accuracy. In our scheme (called Whistle), several asynchronous receivers record a target signal and a successive signal that is generated artificially. By two-signal sensing and sample counting techniques, time synchronization requirement can be removed, while high time resolution can be achieved. This design fundamentally changes TDOA in the sense of releasing the synchronization requirement and avoiding many sources of errors caused by time synchronization. We implement Whistle on commercial off-the-shelf (COTS) cell phones with acoustic signal and perform simulations with UWB signal. Especially we use Whistle to localize nodes of large-scale wireless networks, and also achieve desirable results.

9. CONCLUSION AND FUTURE WORK

In this paper, a review of Hybrid PSO-ANN algorithm for the localization in WSN has been discussed. A lot of research has been conducted to improve distance estimation accuracy of the mobile node. Because the location knowledge is important in WSN. If we have not any information about the target or event then the collected data is not useful. In future scope will focus on the accuracy for the localization in WSN.

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