Multi-Objective Nature-Inspired Algorithms for Sensor Node Localization in Wireless Sensor Networks

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***Abstract* —Localization of sensor nodes in WSN in many different scenarios is becoming an important issue due to widespread application. Localization process is necessary to report the origin of events, routing and to answer questions on the network coverage, assist group querying of sensors. Small and inexpensive tools with low energy consumption and limited processing resources are increasingly being used in various scenarios of application including search, rescue, disaster relief, target tracking, biomedical health monitoring and number of tasks in day to day life. In general, localization schemes are classified into two broad categories range-based and range-free. However, it is difficult to classify hybrid solutions as range-based or range-free. We make this classification simple in this paper, where range-based schemes and range-free schemes are divided into two categories, complete schemes and hybrid schemes. In this study are taken in consideration the simulation of the approaches of Hybrid algorithm. Based on simulations, we understood the influence of dimensioning, so the localization efficiency will increase from 1D to 3D because at 3D the reference nodes will interact in more directions, but because of the complexity of the network, the convergence time will also increase. Node localization is one of the fundamental problems of the wireless sensor network. This paper reviews different approaches of node localization discovery in wireless sensor networks. Also presented is the summary of the schemes suggested by various scholars for localization improvement in wireless sensor networks. Moreover, compare the existing localization algorithms and analyze the future research directions for the localization algorithms in WSNs.**

Keywords — localization, Node, range-based, range-free

I. Introduction

The automatic location detection of sensors, namely localization is an important issue for WSN applications, especially in cases, when the sensors are deployed randomly, or when they move about after deployment. One explanation is that in order to be relevant, the position of a sensor must be known for its results. The location itself is often the only data to be sensed in most situations. For many location-aware network communication protocols such as packet routing and sensing coverage, position information is essential [2].

Using the same transmission medium as wireless local area networks (WLANs) to communicate properly with nodes in a local area network. But, this and the other protocols cannot be directly applied to WSNs. The major difference is that, unlike devices participating in local area networks, sensors are equipped with a very small source of energy, which drains out very fast. Therefore need arises to design new protocols for MAC (Media Access Control) [1] that are energy aware. Obviously, as the latter has limited resources, there is some gap between a normal WLAN and a WSN(Wireless Sensor Networks).

WSN localization is an important, key enabling technology that attracts considerable interest in research. With the constrained resources of network sensors, as well as their high failure rate, many challenges exist in the automatic determination of the sensor's location. Different application requirements such as: scalability, energy efficiency, cost, accuracy, responsiveness and privacy affect sensor localization systems research and development [3].

Many different application scenarios can be built on the basis of nodes with sensing and actuation capabilities. The major application scenarios include; Proceedings of the 2009 13th International Conference on Computer Supported Cooperative Work in Design disaster relief applications [4], environment control, intelligent buildings [5], facility management, preventive maintenance of machines, medicine and health care.

II. Objetives

Algorithms inspired by a new nature are used to test their effectiveness in solving problems. Therefor the main objective of this research is to be as follows,

- To develop a multi object nature inspired algorithm use to localize sensor nodes in wireless sensor network.
- Find the most suitable nature inspired algorithm for wireless sensor network localization and define more accuracy, scalability algorithm and Overcome existing problem in defined algorithms.

III. Methodology

The TBL (Trilateration-based Localization) & MBL (Multilateration-Based Localization) techniques are among the most common and used methods of localization based on trilateration and multilateration [6]. This chapter discusses different aspects of the performance of the TBL algorithm through the application of single and multi-target PSO (Particle Swarm Optimization) variants. Number of localized nodes, trade-offs between multiple objectives, the number of transmitted messages, the time needed to localize as many nodes as possible and power consumption are studied.

Multiple output levels can be used by wireless transceivers [7]. Three separate PSO models have been developed to observe the effect of multi-output power levels. The first two are single and multi-target, binary PSOs, designed to vary the power output only between three distinct stages. The other one is continuous multi-objective version with multiple objectives which shows the extreme case in which the power output is infinite. The continuous version shows that the full optimization can actually be achieved, while modern transceivers cannot do so. Then comprehensive power consumption measurements are carried out during nodes in transmission mode using discrete or continuous power levels.

Discrete Levels has been believed to have three different power levels and then the length of the wave can be determined on the basis of the required output power. The permitted levels were computed in (1) and (2) where R is the range in meters, Po is the sender power, Pr is the sensitivity of the receiver, Fm is the faded margin in dB, f is the frequency of the signal in MHz and n is the exponent of the loss. Po and Pr measured in dBm.

$R = 10x$ (1)

$x = (P0 – Fm - Pr + 30 * n – 32.44 – (10 * n * \log [10]f))/(10 * n)$ (2)

In Continuous Levels ZigBee transceiver is capable maximum range of 132 meters and the minimum 60 meters is assumed in this process. In this method, transmission range varies continuously, as in (3) and (4), instead of previously in power range. As in previous discreet methods, energy consumption is measured using [8]. In the end (4) power consumption Po is converted from dBm to mW.

$P0 = (10 * n * \log10 R) + (10 * n * \log10 f) – (30 * n) + Fm + Pr +32.44$ (3)

$\hat{P}_0 = 10^{(\frac{P_0}{10})}$ (4)

The proposed approach includes using a single and multi-objective PSO for each wireless sensor node to select a suitable, discrete or continuous output power level. PSO was used to optimize different targets, including the position time, the messages transmitted while localizing and power consumed, for various combinations. The method would only optimize the transmitter mode to reduce the average power output level used by all nodes to make the procedures as protocol independent as possible as well as allow the methods to be used for any protocol of localizing.

The power usage is estimated from the adjusted transmission range of each node in the proposed implementation. In order to help solve localization problems the transmission ranges are modified with the SOPSO (Single-objective Particle Swarm Optimization) and MOPSO (Multi-objective Particle Swarm Optimization) algorithms.

To configure the different discreet power ranges or the continuous range of transfer of each sensor node intelligently, the SOPSO and MOPSO algorithms are used. Therefore, an N-dimensional representation is used to represent each sensor used in the field. In addition, objective functions for messages sent, time needed for localization, power consumption and localized node numbers (A.K.A. locizability) are determined.

As discussed above, the issue in this study is the number of messages sent, the total energy consumption, localization time and localizability. In order to achieve those goals a PSO approach was introduced to manage Multi-objective Problems, with the intention of seeking a balance between conflicting targets and offering a range of optimal solutions, instead of just one objective solution in which the main objective is to maximize the number of localized nodes without unnecessary power or more time to localize the nodes.

The pseudo code of the two MOPSO Versions implemented is shown in Fig 1.

```
procedure MOPSO(nodesList)Saac
    initialize swarm;
    initialize leaders archive;
    measure crowding distances;
    for i ← 0 → numberIterations do
        for j ← 0 → numberP articles do
            procedure calculateNewVelocities
                choose random leader as global best;
                update velocities;
            end procedure
            calculate new positions;
            run MOPSO mutation;
            evaluate the solution;
            update particle memory;
            update leaders archive;
            measure crowding distances;
        end for
    end for
end procedure
```

Fig 1 - MOPSO Algorithm

IV. Results and Discussion

The tool used in this research based on Java SE 7. The network topology has been saved in a file (topology file) via the tool, to allow the examination of the same localization scenario, using different power levels or methods. The file contains the X and Y coordinates of each node in addition to the type of the node, if it’s a normal or anchor node.

The simulation process flow chart is shown in Figure 2 Notice that, in step 2, in addition to the X and Y anchor coordinates, the Java code used reads the location of the node in the saved topology file. A random file of 240 nodes, 40 of which anchor nodes, is spread around an area of 1000 x 1000 meters for this research. One PSO versions proposed is used in Step 3. Step 4 and Step 5 are part of the fitness function in the analysis of particle solutions through the flooding and TBL localization process.

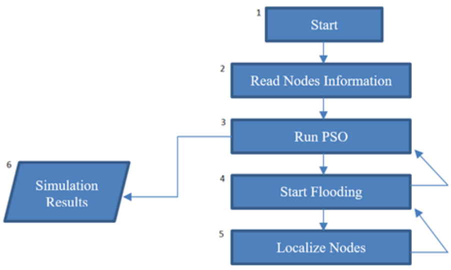

Fig 2 - Simulation Flow Chart

; with statically selected power ranges as Minimum, Medium, Maximum.

As shown in Table 1, the first run was for all 240 nodes only using minimal power ranges, allowing each of the nodes to transmit up to 63.28 meters over the distance. The localization procedure has consumed 20, 55 mW. This reflects 41 messages from the 40 anchors, and the only identified node from the anchors has been over 480 units. The second time used only medium range transmission, which allowed the transmission up to 91.47 meters of each node at a distance. Following flooding, the 40 anchor nodes and localized nodes were used to identify 96 nodes over a period of 1,200 units by results of 136 messages consuming 171.21 mW. Both 200 nodes were localized in the last run where the maximum power range for all nodes during 960 units of time was used. When using the maximum range of power each node could transmit up to a distance of 132.22 meters, the localizing procedure consumed 758.95 mW of electricity.

Table 1 - Baseline results using multiple discrete output power levels.

	Run_1	**Run_2**	**Run_3**
Power Ranges	Minimum	Medium	Maximum
Transmission Ranges	63.28	91.47	132.22
Time	480	1200	960
Energy Consumption	20.55	171.21	758.95
Localized Nodes	41	136	240

BMOPSO was used to overcome the poor quality of BSOPSO's solutions by reducing localization time and energy consumption and increasing the number of localized nodes. The BMOPSO parameter values are shown in Table 2.

Parameter	value
# Particles	100
# Iterations	200
Min Tran Range	64
Max Tran Range	132
Mutation Percentage	15%
Mutation Value	Min Tran Range
C1 and C2	1.49445
Inertia Weight (ω)	0.1

Table 2 - BMOPSO Parameters' values

This method has managed to find a balance between all the competing objectives and to provide solutions which exceed the BSOPSO (Binary Single-objective Particle Swarm Optimization) approach, which shows the results from 50 tests. In some cases the two previous methods were better implemented at all stages, which was to localize all the nodes in the shortest possible time with less energy than all other solutions previously used in the methods.

In the 50 experiments, 77 solutions were found, but not optimal. Of these, the baseline was 28 above power consumption and the same time and number of localized nodes were retained. The overall energy consumption rated between 4% and 21% below the baseline. The best approach is to achieve a 29 percent energy consumption improvement by the BMOPSO (Binary Multi-objective Particle Swarm Optimization) process, but to localize only 145 nodes.

V. CONCLUSION

By simultaneously optimizing the different objective functions, the general performance of the TBL algorithm has been calculated and improved. The results show clearly that SOPSO and MOPSO are used effectively to optimize the TBL algorithm with regard to energy consumption, which can be improved by up to 32% on the Transmit mode of transceivers. In addition, PSO has been found, as shown in the study, that it is less stable to use single global output power in location of the nodes than to use multiple levels and that using the maximum possible output level is not a cost-efficient solution to localization stability, In particular, PSO was found to overcome this problem without advertising the TBL work. However, in addition to many other techniques, our analysis can be mapped to actual test beds using component based localization.

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