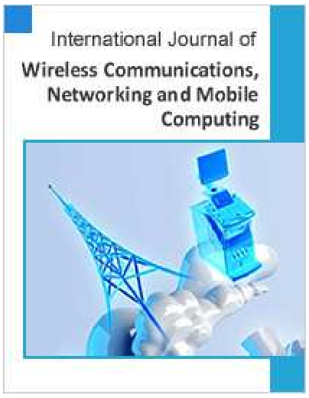
International Journal of Wireless Communications, Networking and Mobile Computing
2015; 2(4): 37-41
Published online November 27, 2015 (http://www.aascit.org/journal/wcnmc)
ISSN: 2381-1137 (Print); ISSN: 2381-1145 (Online)

American Association for Science and Technology



Determining the Optimum Number of Anchor Beacons while Localizing Wireless Sensor Network

Magy M. Kandil[1], May A. Salama[2]

[1]Nuclear and Radiological Regularity Authority, Cairo, Egypt
[2]Computer Engineering Dept., Faculty of Engineering at Shoubra, Benha University, Cairo, Egypt

Email address

Magy_kandil@yahoo.com (M. M. Kandil), msalama@megacom-int.com (M. A. Salama)

Citation

Magy M. Kandil, May A. Salama. Determining the Optimum Number of Anchor Beacons while Localizing Wireless Sensor Network. *International Journal of Wireless Communications, Networking and Mobile Computing*. Vol. 2, No. 4, 2015, pp. 37-41.

Keywords

Anchor Beacon,
Optimized Number,
DV-Hop,
WSNs

Received: September 1, 2015
Revised: October 8, 2015
Accepted: October 10, 2015

Abstract

Among the challenges that face wireless sensor network is minimizing the localization error and yet using minimum number of beacons. These two challenges are addressed in this pape by proposing a heuristic algorithm which is based on anchor based beacons and modified DV-Hop algorithm. The results give a recommended percentage of beacons that achieves a transmission accuracy of about 70%. The results are compared with similar algorithms and proven to be more general. The algorithm can be applied to detect the location of any anomalies inside the un-accessible rooms of the nuclear reactor which has high radiation levels, such as the mechanical control rods system room, while minimizing the power consumed.

1. Introduction

There are many challenges in the area of WSNs. Among these challenges are synchronization, coverage, security, energy consumption and localization. Localization is the process of determining the location of sensor nodes. A significant amount of localization algorithms [1] have been developed to localize sensor nodes by exchanging information with beacons. The remaining sensors determine their localization by distance measurements to their neighbors or using other methods such as the intensity of signal of communication between others. However, in some cases, just locating all nodes is not enough. It is also necessary to do that with minimum possible cost and power.

The Minimum Cost Localization Problem (MCLP) was defined in [2] where the goal is to locate all nodes with minimum number of beacon nodes. Although the authors show that the MCLP is NP-complete, it is important to make the number of beacon nodes as minimum as possible due to their high cost and power used. The use of other techniques as genetic algorithms [3] and particle swarm optimization [4] in WSN problems have been explored. However, most of these approaches do not consider minimizing the number of beacon nodes when solving a WSN localization problem.

There are two ways to deploy sensors. The first is to place the sensors in pre-determined locations, while the second way is to place the sensors in random locations. Localization algorithms are categorized into: anchor based and anchor free techniques. In the anchor based techniques, a small number of sensors, namely beacons, are placed in known locations. Anchor-based algorithms usually produce absolute node position. However, the accuracy of the estimated position is highly affected by the number of anchor nodes [5]. Also, anchor based approaches could have a scaling problem, since a large number of anchors may be required to configure an unbounded working area. [6]. Anchor-free algorithms do not make any assumptions regarding node positions. They use local distance information to attempt to determine node coordinates when no nodes have pre-configured positions. Beacons are considered as a reference for estimating the location of sensor nodes. Sensors, on receiving information from the beacons, can estimate their locations.

There are two approaches to determine distances locally; Trilateration and Multihop schemes. Trilateration uses distance measurements from an unknown sensor node to three non-linear beacons with known positions. Multilateration algorithms using more than three beacons reduce the effect of distance errors on the accuracy of localization. However, as mentioned above, dense placement of beacons is not desirable. In Multihop scheme, a range to a node is estimated to which no direct radio communication exists. It is either done by DV-Hop which counts the number of hops while assuming the length of one hop is known or by DV-Distance that uses range estimates between neighbors to improve total length of route estimation.

Hypothetically, the more beacons there are, the more accurate and easier a sensor can estimate its location. However, this would lead to more energy consumption, more complicated computations and could lead to self interference and network flooding. Langendoen et al. [7] showed that with anchor density of 20%, an accuracy of 25% of transmission range could be achieved, which fails to reach the standard inaccuracy in many applications. The Minimum Cost Localization Problem (MCLP), presented in [2], is an optimization problem that aims to locate all the nodes in a WSN using the minimum number of beacon nodes. Four different greedy algorithms based on trilateration were proposed, and follow two steps: (1) the nodes with less than three neighbors are marked as beacons – because these nodes cannot have their positions defined by other nodes; (2) at each iteration, the unlocated node for which its localization gives the best configuration to the network is selected and defined as a beacon. This best configuration is the one that allows the most number of nodes to be localized [2]. The work in [3] is based on the Greedy-Sweep2 of the [2]. It developed a genetic algorithm to determine the minimum set of beacon nodes enough to locate every sensor belonging to a network. A prior research using genetic algorithm was introduced in [8] where the objective was to define a set of Beacons that localizes every other node in a WSN spread across a 2D region in undefined positions. This approach solves the localization problem but it disregards minimizing the cost of the set B.

Another work for optimizing the number of beacons is presented in [[9] where it focused on the design of a beacon placement and introduced an integer linear programming (ILP) formulation and an algorithm for determining the optimal number of beacons for a given WSN. In [10], the network size was fixed to 100 nodes and it was concluded that the best result was achieved at 25 beacons. This number of beacons is restricted to the specific 100 nodes network.

The objective of this paper is finding an optimum number of beacons that would give the least error in estimating the sensors' locations.

2. The Proposed Algorithm

The problem addressed in this work is stated as follows:

Given a graph G = (V, E) that represents the WSN, determine the subset B of sensors to be beacons such that the remaining nodes can be localized and the number of beacons B is minimized.

The proposed algorithm is a localization algorithm based on DV-Hop to reduce the cost and complexity while improving the localization accuracy with the least number of beacons. It uses distance vector routing to propose modified DV-Hop localization algorithm. The pseudo code of the algorithm is as follows:

1. Start the algorithm with creating a WSN having a fixed number of sensors and predefined number of beacons. The sensors are randomly deployed in an area of 300x300.
2. Start with a number of beacons= 5% of the total WSNs leaving the network with 95% WSNs.
3. Place the beacons in positions where their x, y coordinates are known
4. Let every beacon broadcast its hop count relative to other beacons and hop distance.
5. Beacons then calculate the average single hop distance and broadcast its correction value
6. The unknown nodes will record the first received correction value, and forward it to neighbor nodes
7. The unknown nodes will calculate the total distance to beacons according to the recorded hop count and will calculate the error and accuracy for each node.
8. Record the error and number of beacons.
9. Increase the number of beacons by 5 percent and place it in known location.
10. Repeat steps 3-7
11. If new error is less than recorded error, replace the old number of beacons with the new number, otherwise go to step 8.

Stop when the error doesn't change.

Firstly, assume a known number of beacon nodes. Every node in the network obtained the hop count from all beacons. After calculating hop distances, beacons calculated the average single hop distance and gave it a survival period after which beacons broadcast their correction values. The unknown nodes recorded the first received correction value, and forwarded it to neighbor nodes. This strategy ensured that most nodes could receive the average single hop distance from closest beacons. Secondly, the unknown nodes calculated the total distance to beacons according to the recorded hop count and calculated the error and accuracy for each node. The average error and diverse accuracy were calculated and saved. Next step was increasing the number of beacons by one and repeating all steps again. The new average error and accuracy were compared to the saved ones. This continued until error stopped increasing.

The localization error was chosen to evaluate the performance of the proposed algorithm.

$$error = \sum_{i=1}^{n} \frac{\sqrt{(x' - x)^2 + (y' - y)^2}}{n \times range} \times 100\%$$

range: communicate radius of the network, *n*: the total number of the nodes inside the *range* .

Average error =sum (error)/ unknown nodes

Average diverse Accuracy= Average error /r

3. Results

The simulation of the algorithm was carried out using Matlab. For each random generated number of WSNs, several fixed numbers of beacons were tested. The locations of the beacons were known. The simulation was run 5 times for each of these tests. In each run, the nodes were randomly created. The average error was then calculated from these runs. Table 1 shows, as an example, the simulation results for 6 networks based on 200, 500, 700, 1000, 1500 and 2000 WSNs. For each of these, the number of anchor beacons that were tested was 5%, 10%, 15%, 20%, 25%, 30% of the total WSNs.

Table 1. *Average Error vs. Percentage of Beacons.*

Anchor Beacons	Average error for WSN of 200	Average error for WSN of 500	Average error for WSN of 700	Average error for WSN of 1000	Average error for WSN of 1500	Average error for WSN of 2000
5%	34.1097	30.2453	30.6766	29.3348	31.0044	32.0372
10%	30.9276	30.0405	30.3468	29.7580	30.1149	30.9912
15%	31.8435	29.3132	29.3412	29.8002	30.9801	31.4134
20%	27.6753	30.0970	29.3079	30.3939	31.0526	31.2683
25%	29.1926	29.5872	30.4321	29.1720	30.6406	30.4656
30%	*28.9460*	28.5094	28.7059	*29.4818*	*30.4500*	30.4652

4. Discussion

From the table, minimum error resulted from 30% beacons for networks of sizes 500, 700, 2000 that which are shown in bold. For networks of sizes 1000 and 1500, the minimum error reached at 25% and 10%. However, the difference between that minimum error and 30% error is 1% in both cases. This is typical for randomly generated networks of various sizes starting from 500 sensors. Also 25% and 30% gave very close error values.

In the network of size 200, the minimum error was reached at 20% beacons with a difference 4% in error from the 30% beacons. This could be due to the small number of sensors (200) that are scattered around. However, this should be further investigated.

Figure 1 shows the transmission accuracy for the various networks used. The transmission accuracy, in general, ranged from 69% to 74%. This is much better result than that resulting from the algorithm in [7].

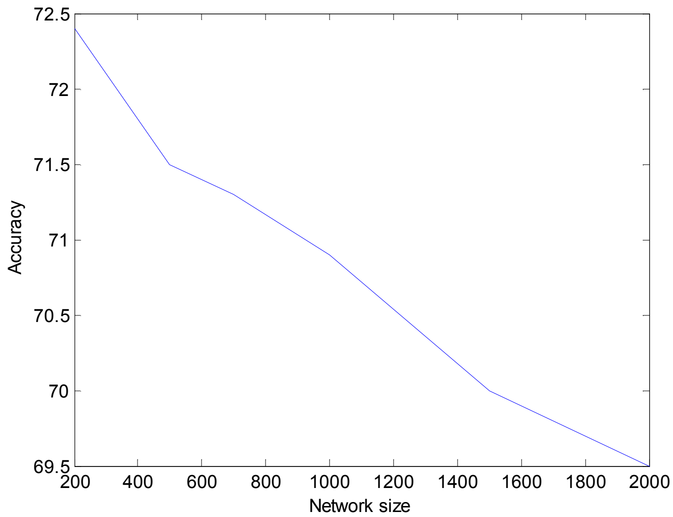


Figure 1. *Transmission accuracy.*

From the results of the simulations, it is concluded that

1. Transmission accuracy has an average of 70% which is much higher compared to the work done in [7] that achieved a transmission accuracy of 25%.
2. Heuristically, it could be stated that having (25-30%) of the total WSNs anchor beacons is the optimum number of to give a good transmission accuracy and least error. Although in some cases this percentage doesn't apply, the difference between the proposed (30%) and the actual reached from the simulation is very small such that it could be ignored.

The work done in [11] showed the results for a network of size 100 nodes where the error was calculated. The authors concluded that regardless of how beacons are placed, randomly or regularly, localization average error tends to decrease with the increase in beacon nodes. The authors tested their algorithm with 4, 9, 16, 25 beacons. With regular placement of beacons, the average error declines faster than with random placement.

Table 2 summarizes a comparison between the proposed algorithm and others with respect to the method used, network size tested with the corresponding algorithm, the optimum number of beacons and whether the algorithm could be scaled to any network size.

Table 2. *Comparison between proposed algorithm and others.*

Algorithm Ref #	Optimization method used	Network size tested	No of recommended beacons	Scalable
[2]	Greedy algorithm	400-1000	variable	Yes
[3]	Genetic algorithm	500-3000	variable	Yes
[5]	Empirical incremental	100	25% of sensors	No
[7]	3 various algorithms	225	5% of sensors	No
[9]	Integer linear programming	Based on sensor density	Placement oriented	Yes
[10]	DV distance	100	25 sensors	No
[11]	DV Hop	100	Not Available	No
Proposed	DV Hop	200-2000	25-30% of sensors	Yes

5. Application in Nuclear Power Plant (NPP)

For the design of the reactor control system in NPPs, it is necessary that the primary parameters of the nuclear reactor be maintained within the suitable operating range regardless of possible changes of the operating conditions, load and disturbance. It is also essential to maintain the reactivity change while taking into consideration the combined effect of three elements: the control rod, rod drive system and recirculation flow control system. The reactivity change could be the result of load fluctuation of the reactor, change of xenon concentration, change of temperature from high to low, and fission.

In addition, it is vital for the reactor control system to punctually and easily detect any power fluctuation of the reactor. The room which contains the three elements is the control rods mechanical system room. Its role is very important as it controls the thermal power inside the reactor essentially in the emergency shutdown. Due to the high radiation inside that room, no one can enter that room. Thus, a wireless sensor network is required to real time recognize any abnormal process such as fire or water leakage and locate the abnormality. The required wireless network must be of low electric power consumption, which is the major problem in most wireless network.

Accordingly, the proposed algorithm would be highly recommended to be applied in such a room.

6. Conclusion

In this paper, a heuristic localization algorithm is presented for WSN network with the objective of finding the minimum number of anchor beacons that could achieve least average error. Minimum number of beacons is essential to avoid high power consumption in the WSN which leads to longer lifetime of the network. This feature is essential to detect any abnormalities in Nuclear Power Plant. The algorithm is based on DV Hop. The results were compared to other algorithms and showed that the transmission accuracy of the proposed algorithm is much higher. Also, a recommended percentage of anchor beacons is achieved for networks with different numbers of WSNs. Future work will be further done on 3D localization, i.e. finding z dimension besides the x and y of the sensors while minimizing the number of anchor beacons.

References

[1] Kuriakose J, Amruth V, Nandhini S., A Survey on Localization of Wireless Sensor Nodes. ICICES, 2014.

[2] Huang M, Chen S, Wang Y. Minimum cost localization problem in wireless sensor networks. Ad Hoc Networks, May 2011; vol 9; 387-399.

[3] Assis A F, Vieira L F M,Rodrigues M T R, Pappa G P. A Genetic Algorithm for the Minimum Cost Localization Problem in Wireless Sensor Networks. IEEE Congress on Evolutionary Computation, 2013.

[4] Kulkarni R V, Venayagamoorthy G K. Particle Swarm Optimization in Wireless Sensor Networks: A Brief Survey. IEEE Transactions on Systems, Man, and Cybernetics, Part C: Applications and Reviews 2011. Volume:41; Issue: 2.

[5] Bulusu N, Heidemann J, Bychkovskiy V, Estrin D. Density-adaptive beacon placement algorithms for localization in ad hoc wireless networks. IEEE Infocom June 2002.

[6] Priyantha N B, Balakrishnan H, Demain E, Teller S. Poster Abstract: Anchor-Free Distributed Localization in Sensor Networks. Proc. 1st International Conference on Embedded Networked Sensor Systems (SenSys 2003); 340-341.

[7] Langendoen K, Reijers N. Distributed Localization in Wireless Sensor Networks: A Quantitative Comparison. Computer Networks (Elsevier), special issue on Wireless Sensor Networks August 2003: 499-513.

[8] Gao Y, Zhuang Y, Ni T, Yin K, Xue T. An improved genetic algorithm for wireless sensor networks localization. BIC-TA. IEEE 2010: 439-443.

[9] Roy S, Mukherjee N. Integer linear programming formulation of optimal beacon placement problem in WSN. Applications and innovations in mobile computing 2014.

[10] Yin M, Shu J, Liu L, Zhang H. The Influence of Beacon on DV-hop in Wireless Sensor Networks. Proceedings of the Fifth International Conference on Grid and Cooperative Computing Workshops (GCCW'06).

[11] Zhang Y, Ben W. An improved DV-Distance Algorithm with Assistant Anchor for nodes Localization in WSNs. 11th interneaional Loint conference on Computer science and software Engineering 2014.