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On improving APIT algorithm for better localization in WSN

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Abstract
In Wireless Sensor Networks (WSNs), localization algorithms could be range-based or range-free. The Approximate Point in Triangle (APIT) is a range-free approach. We propose modification of the APIT algorithm and refer as modified-APIT. We select suitable triangles with appropriate distance between anchors to reduce PIT test errors (edge effect and non-uniform placement of neighbours) in APIT algorithm. To reduce the computational load and avoid useless anchors selection, we propose to segment the application area to four non-overlapping and four overlapping sub-regions. Our results show that the modified-APIT has better estimation's performance of localization for different sizes of network for both grid and random deployments in terms of average error and time requirement. For increasing the accuracy of localization and reduction of computation time, every sub-region should contain minimum 5 anchors. Variations of the size of a network and radio communication radius of anchors affect the value of average error and time requirement. To have more accurate location estimation, 5 to 10 anchors per sub-region are effective in modified-APIT.

Keywords: *WSN, Localization, APIT, Anchor, Coverage.*

1. Introduction

WSNs contain tiny and smart sensors nodes which are battery-operated (limited life-time) [1]. They have limited storage, processing, communication capacity to sense various physical phenomena in the environment. WSNs greatly extend our ability to track, monitor and control a physical phenomenon [2]. Applications include industrial process monitoring and control, military and civilian applications, healthcare, environment and habitat monitoring, home automation, traffic control, etc. [3]. The typical tasks of networked sensor nodes are to collaborate and aggregate huge amount of sensed data from the physical environment. Sensors are deployed either inside a phenomenon being monitored or very close to it. WSNs are highly distributed self-organized systems [4].

WSNs have attracted a lot of research attention in the recent years. It offers a rich area of research, in which a variety of multi-disciplinary tools and concepts are employed [5]. WSN protocols and algorithms must possess self-organizing capabilities. This allows random deployment in inaccessible terrains or hostile terrains.

Localization issue in WSN has attracted a lot of research effort in the recent years [6]. Estimation of the physical positions of the nodes is one of the fundamental and critical issues in Geographical Positional System (GPS) [7]. Accurate estimation of location is useful in sensor network services such as information processing, sensing coverage [8], location directory service [9], management and operation of the network [10], location-based routing protocols [11], etc.

The positional information is essential to many location-aware sensor network communication protocols, such as packet routing and sensing coverage [12]. When an abnormal event occurs, the sensor node detecting the event needs the positional information to locate the abnormal event and report to the special node called the Base Station (BS) or sink(s). BS has higher capability compared to an ordinary sensor node.

Many different protocols and algorithms were proposed for localization in WSN. It is a challenging task to design practical algorithms for node localization, given the constraints that are usually imposed on the sensors [13].

Sensors may be deployed in an application area manually or randomly. Manual sensor deployment is applicable when the size of network is not large. Generally, in the case of harsh or hostile environment large number of sensors is randomly deployed. Positions of sensors are unknown because of random distribution, while applications in this type of networks need to know the source of the received information.

The Approximate Point in Triangle (APIT) is a range-free approach [14]. The main idea of APIT is to consider overlapping triangles. Localization with APIT algorithm leads to PIT test problem and the issue of time. In this paper, to reduce the computational load and avoid useless anchors selection, and increase the location estimation accuracy in APIT algorithm, we propose modification of the APIT algorithm and refer as modified-APIT. The paper is organized as: section 2 deals with localization algorithms, section 3 deals with APIT algorithm, section 4 deals with results and discussion, and section 5 concludes the paper.

2. Localization algorithms

The proposed localization protocols may be divided into two categories: range-based and range-free [15]. The range information can be acquired by using different protocols. These protocols use absolute point-to-point distance estimates (range) or angle estimates for calculating location [16]. The simplest possible localization solution is to attach a GPS. Time of Arrival (TOA) technique is used to estimate distance based on measurement of signal propagation time between two communicating nodes. It uses GPS as the basic localization system [17]. The Time Difference of Arrival (TDOA) measurement uses ultrasound signals to make the distance information estimation possible for nodes [18]. Measurements that are based on signal propagation time can be affected by multipath fading and noise interference; therefore, TOA and TDOA are impractical solutions for WSN localization. To augment and complement TDOA and TOA technologies, an Arrival of Angle (AOA) technique has been proposed that allows nodes to estimate and map relative angles between neighbours. It needs additional expensive hardware like a directional antenna or a digital compass [19]. So, AOA is not a good choice for resource limited networks. Received Signal Strength Indicator (RSSI) technology has been proposed for hardware-constrained systems. It is another method based on signal strength and distance relation [20]. All range-based localization algorithms are relatively precise, but present a costly solution (expensive and energy consuming) for localization in large scale WSN [21].

Considering the hardware limitations of WSN devices, solutions using range-free localization are being pursued as a cost-effective alternative to the more expensive range-based approaches [22]. Generally, the positions of sensor nodes are not to be engineered or predetermined. The range-free protocols make no assumption about the availability or validity of such information as are required in the range-based estimates.

The centroid algorithm is simple and economic. It requires a lot of anchor nodes broadcasting their positions (via GPS) to compute position as the center of the connected anchor nodes. All the sensor nodes should be connected to the anchor node for good localization results [23]. However, it results in large errors in the case of low anchor ratio or distribution of them is not even, since the nodes are not uniformly distributed and the relationship between hop counts and geographic distances is very weak [24]; therefore, estimated locations tend to be inaccurate.

Distance Vector-Hop (DV-Hop) algorithm has been proposed based on distance vector routing concept [25]. It assumes a heterogeneous network consisting of sensing nodes and anchors. Instead of single-hop broadcasts, anchors flood and broadcast their location information throughout the network maintaining a running hop-count at each node along the way [26]. Consequently, other anchors can obtain minimum hop count to other anchors.

3. APIT algorithm and its modification

The APIT algorithm requires a small percentage of anchors and employs a novel area-based approach to perform location estimation by segmentation of the field. Moreover, these nodes can be equipped with high-powered radio transmitter.

The main idea of APIT for localization of nodes is to consider overlapping triangles. The vertices of these triangles are anchors. Bounding triangles are obtained using any group of three reference nodes, rather than the coverage area of a single node. In the APIT algorithm, the sensor nodes receive location information from the nearby anchors initially.

Second, the Point in Triangulation (PIT) test checks whether a sensor node is in a virtual triangle that is formed by connecting the three anchors from which signals are received. After the PIT test is done, the APIT algorithm aggregates the results through a grid SCAN algorithm [27]. The APIT algorithm calculates the Centre of Gravity (COG) of the intersections of all the overlapped triangles in which the node resides to determine its location.

Localization with APIT algorithm leads to two major issues: (i) PIT test problem, and (ii) anchor selection problem leading to increased time requirement. To solve these issues, we modify the APIT algorithm and call it the modified-APIT algorithm. By selecting suitable triangles with appropriate distance (discussed later) between anchors, we reduce PIT test errors (edge effect and non-uniform placement of neighbours) in APIT algorithm. To reduce the computational load and avoid selection of useless anchors, we propose to segment the application area to four non-overlapping and four overlapping sub-regions.

3.1. PIT test

The purpose of PIT test is to check whether a node is inside a triangle that is formed by three anchors. Every time, the node selects three possible anchors and apply the PIT test. When a node M is inside ΔABC, if M is shifted in any direction, the new position must be nearer to (or further from) at least one of the anchors A, B or C. Also, when a node M is outside of ΔABC and M is shifted, there must exist a direction in which the position of M is closer to (or further from) all the three anchors A, B and C. When there is a direction such that a point adjacent to node M is closer to (or further from) anchors A, B and C simultaneously, then M is outside of ΔABC. Otherwise, M is inside ΔABC. This is named Perfect PIT test (PPIT). It can correctly determine whether node M is inside ΔABC or not.

To perform PIT algorithm in WSN without the need of node movement, approximate PIT test method has been proposed that takes advantage of high node density in WSNs. To emulate the movement of a node in the PPIT, node uses neighbor information, exchanged via beaconing. If no neighbor of node M is closer to (or further from) all the three anchors A, B and C simultaneously, it is assumed that M is inside ΔABC. Otherwise, M is outside this triangle. APIT can only check a few directions (neighbors).

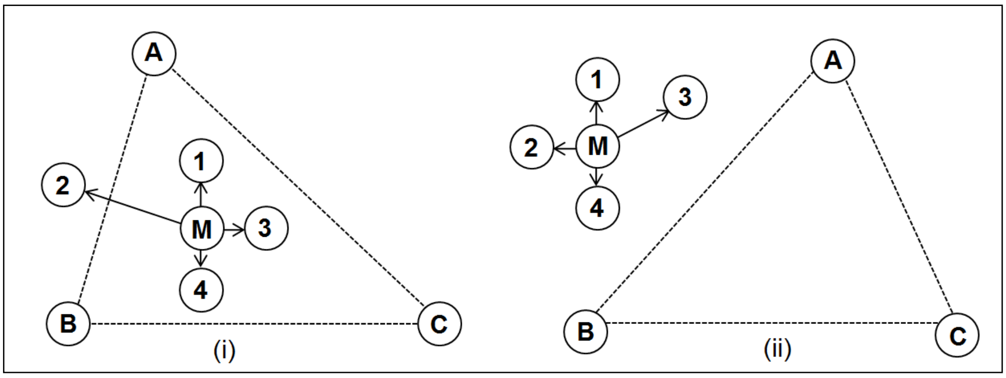


Figure1. In-to-out and out-to-in error situations.

It may be incorrect in the selection of its decisions (Figure 1) to determine the node's position. Although, node M is inside the triangle but APIT decides that it is outside.

The node is near to the edges and some of its neighbors are outside the triangle and further from all anchors in relation to node M. Consequently, node M mistakenly considers it is outside the triangle due to edge effect (In-to-out error, Figure 1 (node A). Although, node M is outside the triangle but since none of its neighbors are closer to (or further from) all anchors simultaneously, node M assumes it is inside the triangle (Out-to-in error, Figure 1 (node B).

3.2. Removing anomalies in PIT test

Selecting suitable triangles of anchors in PIT test is an important issue. In-to-out and out-to-in errors in PIT test is caused by edge effect and non-uniform placement of neighbors. When the triangles formed do not have appropriate sides and areas, these errors mostly occur (Figure 2).

The triangles of anchors should satisfy two conditions. These are: (i) sides of triangles should be comparable within a range. Narrow triangles should be eliminated from the considered set of triangles, because few number of nodes reside inside a very narrow triangle (one of its sides is short and the other two are very long)

Most of the neighbors of a node are located outside the triangle. Sides (x, y, z) of a triangle are to satisfy (1), where α and β are scalars.

$$(\alpha \times z \le x + y \le \beta \times z \text{ and } \alpha \times y \le x + z \le \beta \times y)$$

$$\text{where } \alpha = 0.7 \text{ and } \beta = 1.4. \qquad (1)$$

(ii) Because of random deployment of anchors in the environment, short distances among anchors are possible. In such a situation, they may form triangles with very small areas where a few nodes only can reside inside these triangles. They do not have utility in node localization process. Consequently, triangles with area less than a threshold are eliminated from the considered set of triangles. The area size should satisfy (2), where λ and γ are scalars.

$$\lambda \times A_{\text{Application}} \le A_{\text{Triangle}} \le \gamma \times A_{\text{Application}}$$

$$\text{where } \lambda = 1/16 \text{ and } \gamma = 1/4 \qquad (2)$$

$A_{\text{Application}}$ is the area of the field of interest and A_{Triangle} is the area of the selected triangle.

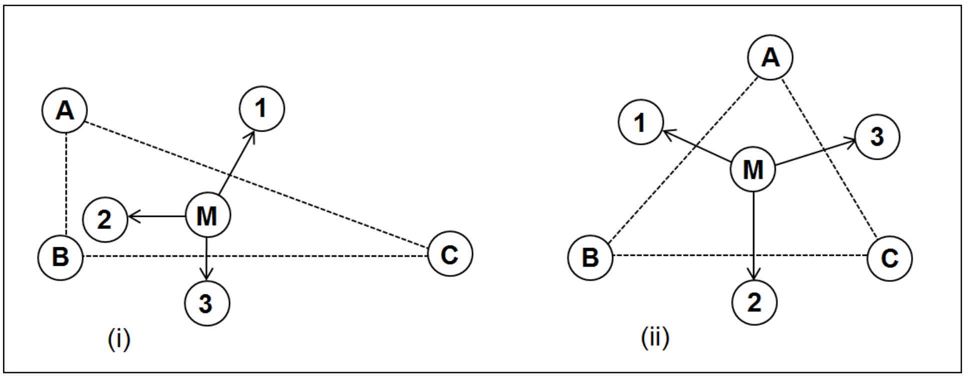


Figure 2. Two instances of inappropriate triangles.

3.3. Appropriate anchor selection problem

Extension of covering area can lead to discontinuity of coverage, computational overload, and increase in localization errors. In APIT algorithm, anchors advertise their locations by using maximum power of radio communication. In addition to consumption of energy, it wastes the sensor nodes resources as well. Possibility of useless anchors selection is one of the major problems that may occur while using APIT algorithm in large area increasing the system cost. Receiving of signal by a sensor node from an anchor is not adequate for selection in localization. To reduce computational load and useless anchors selection, we propose that a new device named Super Anchors (SA) should be used in the environment. SAs are high-powered equipment with wide radio communication range and it broadcasts signal in the whole environment. They help other sensors to conserve energy and prevent wastage of resources. Segmenting the application area to four sub-regions, four SAs are located in the four corners.

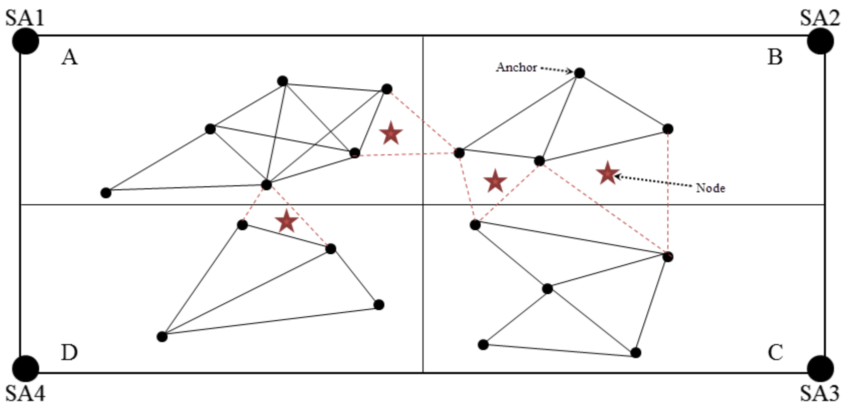


Figure 3. Non-formation of triangles because of residence of anchors in different sub-regions.

By comparing received signal strength of SAs, every node can determine its location in the sub-regions. Sensor nodes select only close by anchors co-located in the sub-region to estimate their location. With wide radio communications range, an anchor broadcasts its location information over a long distance.

Sometimes, more than one triangle may be formed in APIT algorithm for the specified nodes which are located near the external borders, but the nodes maybe outside of all of these triangles.

Whole of the covering area except the formed triangle could be determined as a possible node location and COG (Centre of Gravity) is calculated for a large but wrong region. After the environment is equipped with SAs, the effect of location miscalculation error is decreased. The maximum error may be equal to the distance of the sub-region corners from its center (Figure 3). After addition of the SAs, same miscalculation error may happen for the nodes located near to the internal sub-region borders and it has negative effect on localization algorithm. The maximum error may be equal to the distance of the sub-region corner and its center. Triangles with dashed lines (Figure 3) can be used to localize the specified node.

To solve miscalculation of the nodes located near the internal sub-region borders, we propose to segment the environment to four non-overlapping and four overlapping regions. Each overlapping region covers about 30% of regions. Based on the received signals from the SAs, every node is able to determine its location in a sub-region through comparison of the received signal strengths. A node is co-located with a SA from which it has received signal of highest strength. After determination of the nearest SA, every node can estimate its sub-region (including overlapping and non-overlapping sub-region) location in the application area through comparison of the strengths of received signals. If the received signal strength from SA ‘A’ is greater than 70% of the signal strength received from SA ‘B’ and if the signal strength of SA ‘B’ be greater than 70% of the signal strength of SA ‘A’ then the node is located in the overlapping region. Otherwise, it is located in the sub-region corresponding to the greater signal strength of the SAs. Through the same rule, a node determines the left or the right half of the environment. Based on the proposed method, every node may be located in a sub-region or an overlapping region. The anchors which are least common in one region are selected for triangle formation. Figure 4 shows non-localized nodes (□ and □) in the domain with four sub- regions, because they are located near the internal borders of the sub-regions (no triangles are formed). The nodes □ and □ have been successfully localized after segmenting the environment to four overlapping sub-regions in addition to considering four sub-regions (Figure 4).

The anchors #1, #2 and #3 have been used to localize the node □. Figure 4 shows that the anchor #1 is located in regions 4 and 8, and anchor #2 is located in regions 4, 7 and 8, and anchor #3 is located in regions 1, 5 and 8. These anchors are common in region 8, so they can be used to form triangles. Anchors #4, #5 and #6 have participated in node ★ localization. Anchor #4 is placed in regions 3, 6 and 7, and anchors #5 is placed in regions 3 and 7, and anchor #6 is placed in regions 2, 5 and 6. The common region of these anchors in region 6, they can be used to localize the node★.

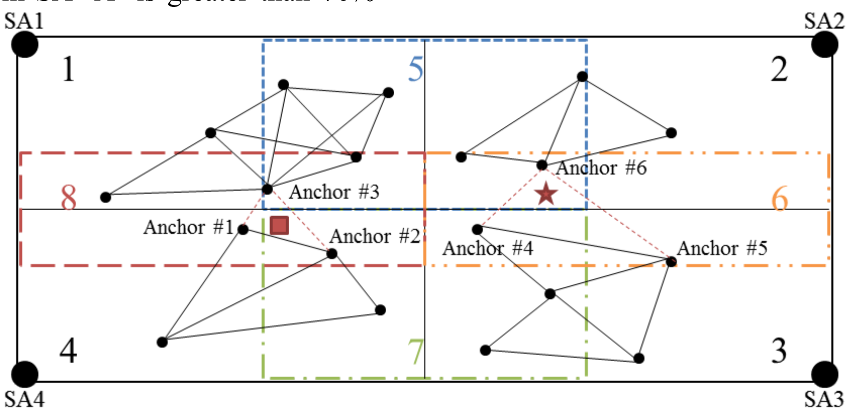
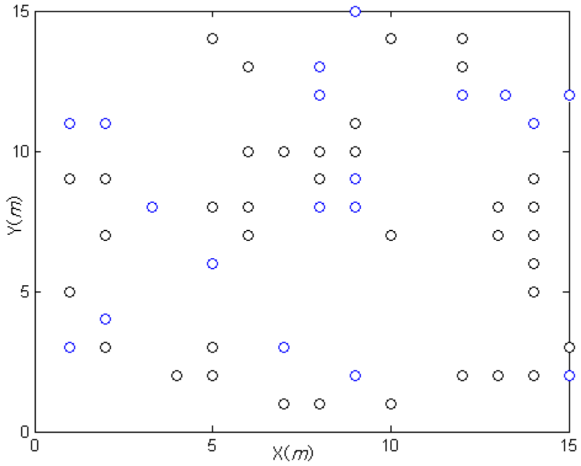


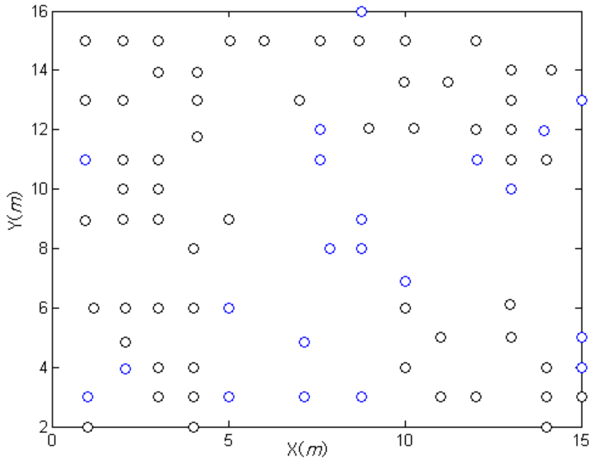
Figure 4. Localization of nodes ★ and ■ after segmentation of field to four non-overlapping and four overlapping sub-regions.

4. Results and discussion

In our study we applied APIT and modified-APIT algorithms on three different network sizes (100, 225, and 400) in a square shaped application area. Figures 5(a) and (b) show the localized sensors with APIT and modified-APIT respectively for a WSN with 100 sensors (the blue sensors determine locations of localized anchors sensors and black sensors determine locations of localized ordinary sensors).

The algorithms are coded in MATLAB version 7 on Intel(R) core *i*5 CPU 650 3.2 GHz running Windows 7 professional. In APIT algorithm every sensor node is able to receive all anchors’ signals to estimate its location. We assume limited percentage of sensor nodes (almost 10%) is equipped with GPS (anchors) to find and advertise its location. When the size of network is low, modified-APIT algorithm is not useful. For example, in a network with 100 sensor nodes, 10 sensors are used as anchors (10%). Therefore, in every sub-region 2.5 anchors probably are deployed but to form a triangle three anchors are required. Also, for estimation accuracy we need more than one triangle for every sensor node.





(a) APIT **(b) Modified-APIT**

Figure 5. Localized sensors with APIT and modified-APIT.

We define a threshold for the number of anchors in every sub-region and we use minimum 5 anchors in every sub-region. Based on this, we assume that in a network of size 100, 20% of the sensor nodes are anchors. In addition to estimation accuracy, to conserve the energy, we find the threshold value for anchors' radio communication radius based on the number of localized sensors. We compare the APIT and modified-APIT algorithms based on average error and computational time. Average error is calculated by (3).

$$\text{Average error} = \frac{\sum_{i=1}^{n} |\,\text{Exact Location}_i - \text{Estimated Location}_i\,|}{n} \quad (3)$$

In the first part of this study, we apply APIT algorithm for three different sizes of network (100, 225, and 400) with grid and random deployments. Table 1 shows that the APIT algorithm has better performance for all sizes of network with random deployment in terms of average error and time requirement.

Table 1. Result of APIT algorithm.

WSN Size	Grid Deployment			Random Deployment		
	Time (*s*)	Avg. Error	No. of Sen.	Time (*s*)	Avg. Error	No. of Sen.
100	62.96	3.12	80	52.07	2.97	80
225	1245.48	3.83	202	1246.36	4.67	202
400	110039.1	6.82	360	109949.36	6.11	360

By increasing the size of the network, average error increases linearly and the time requirement increases non-linearly. In a large size network, sensors localization needs lots of time to calculate their location through the APIT algorithm. In the second part of this study we apply the modified-APIT algorithm on three different sizes of network (100, 225, and 400) with grid and random deployments (Table 2).

APIT consumes more time for sensors localization with more average error compared with modified-APIT algorithm. Also, anchors have to consume more energy for location advertisement. In modified-APIT algorithm, by varying radio communication radius of anchors between 6m and 9m, all sensor nodes are localized. In the modified-APIT algorithm, the average value of this radius is 8m for grid and random deployments. Variation of the size of a network and the value of radio communication radius of anchors affect value of average error and localization time. Increasing the size of the network, the average error increased linearly but the amount of time required increased non-linearly. When the size of a network is increased, the number of anchor nodes in every sub-region is also increased. For example in a network with 225 sensors, every sub-region has 5 anchors and every sensor node can use 10 triangles for location estimation. When the size of the network is 400, every sub-region contains 10 anchors and sensors can use at least 120 triangles for localization. The results illustrate that with increment of anchors in every sub-region, the average error and time requirement are also increased. Therefore, for having more location estimation accuracy, we propose that 5 to 10 anchors per sub-region be used.

Table 2. Result of modified-APIT algorithm.

WSN Size	Grid Deployment				Random Deployment			
	R(*m*)	Time (*s*)	Avg. Error	No. of Sen.	R(*m*)	Time (*s*)	Avg. Error	No. of Sen.
	5	1.18	1.81	78	6	2.43	1.75	66
100	**6**	**2.05**	**1.83**	**80**	**7**	**3.57**	**1.83**	**80**
	7	2.51	1.87	80	8	3.67	1.85	80
	7.5	19.63	2.8	201.4	7.5	25.33	2.84	195
225	**8.5**	**24.05**	**2.83**	**202**	**8.5**	**27.73**	**2.93**	**202**
	9.5	34.42	2.96	202	9.5	30.64	2.72	202
	8	66.83	3.53	358	7	70.19	2.74	348
400	**9**	**92.46**	**3.63**	**360**	**8**	**105.41**	**3.12**	**360**
	10	103.27	3.73	360	9	18622	3.83	360

5. Conclusion

We proposed modification of the APIT algorithm and studied efficacy of the modified algorithm in terms of average error and computational time and compare with those of APIT with segmentation of the application area to four non-overlapping and four overlapping sub-regions. Our results show that the modified-APIT algorithm has better performance in terms of average error and time requirement for all sizes of network with random and grid deployments. To increasing accuracy of localization and prevention of localization complexity, every sub-region should contain minimum 5 anchors. Variations in the size of a network and radio communication radius of anchors affect average error and time requirement. Localization in a large size network using APIT algorithm needs lots of time compared to modified-APIT algorithm. APIT algorithm localizes sensor nodes with more average error compared with the modified-APIT algorithm. Also, in APIT algorithm, anchors consume more energy to advertise their locations. It reduces anchors' lifetime. For more accurate location estimation, 5 to 10 anchors per sub-region are effective in modified-APIT. Sensors localization based on the modified-APIT algorithm through clustering approach is our future plan of study.

References

[1] Akyildiz, I. F., Su, W., Sankarasubramaniam, Y. & Cayirci, E. (2002). Wireless sensor networks: a survey. Journal of Computer Networks, vol. 38, pp. 393-422, DOI: 10.1016/S1389-1286(01)00302-4.

[2] Anastasi, G., Conti, M., Di Francesco, M. & Passarella, A. (2009). Energy conservation in wireless sensor networks: A survey. Journal of Ad Hoc Networks, vol. 7, no. 3, pp. 537–568, DOI: 10.1016/j.adhoc.2008.06.003.

[3] Arampatzis, T., Lygeros, J. & Manesis, S. (2005). A Survey of Applications of Wireless Sensors and Wireless Sensor Networks. In: the Proceeding of 13th Mediterranean Conference on Control and Automation Limassol, pp. 27-29, DOI:10.1109/.2005.1467103.

[4] Akyildiz, I. F. & Kasimoglu, I. H. (2004). Wireless Sensor and actor Networks: Research Challenges. Journal of Ad Hoc Networks, vol. 2, no. 4, pp. 351-367, DOI: 10.1016/j.adhoc.2004.04.003.

[5] Zheng J. & Jamalipour, A. (2009). Wireless Sensor Networks, a networking perspective. Wiley, New York.

[6] Pal, A. (2010). Localization Algorithms in Wireless Sensor Networks: Current Approaches and Future Challenges. Journal of Network Protocols and Algorithms (Macrothink Institute), vol. 2, no. 1, DOI: 10.5296/npa.v2i1.279.

[7] Hofmann-Wellenhof, B., Lichtenegger, H. & Collins, J. (1993). Global Positioning System: Theory and Practice. Springer, New York.

[8] Yan, T., He, T. & Stankovic, J. A. (2003). Differentiated Surveillance Service for Sensor Networks. Proceedings of the 1st international

conference on Embedded networked sensor systems, USA, pp. 51-62.

[9] Li, J., Jannotti, J., De Couto, D. S. J., Karger, D. R. & Morris, R. A. (2000). Scalable location service for geographic ad-hoc routing. In: the Proceeding of International Conference on Mobile Computing and Networking (MOBICOM), pp. 120-130, DOI: 10.1145/345910.345931.

[10] Gengzhong, Z. & Qiumei, L. (2010). A Survey on Topology Control in Wireless Sensor Networks. In: the Proceeding of Second International Conference on Future Networks (ICFN 2010), pp. 376-380, DOI: 10.1109/ICFN.2010.31.

[11] Ko, Y. B. & Vaidya, N. H. (1998). Location-Aided Routing (LAR) in Mobile Ad Hoc Networks. In: the Proceeding of International Conference on Mobile Computing and Networking (MOBICOM) (1998), DOI: 10.1145/288235.288252.

[12] Xu, Y., Heidemann, J. & Estrin, D. (2001). Geography-informed Energy Conservation for Ad Hoc Routing. In: the Proceeding of International Conference on Mobile Computing and Networking (MOBICOM), vol. 1, DOI: 10.1145/381677.381685.

[13] Yu, K., Hedley, M., Sharp, I. & Guo, Y. J. (2006). Node Positioning in Ad Hoc Wireless Sensor Networks. Journal of IEEE International Conference on Industrial Informatics (2006), pp. 641-646, DOI: 10.1109/INDIN.2006.275636.

[14] He, T., Huang, C., Blum, B. M., Stankovic, J. A. & Abdelzaher, T. (2005). Range-Free Localization and Its Impact on Large Scale Sensor Networks. ACM Transactions on Embedded Computing Systems, vol. 4, no. 4, pp. 877-906, DOI: 10.1145/1113830.1113837.

[15] Datta, S., Klinowski, C., Rudafshani, M. & Khaleque S. (2006). Distributed localization in static and mobile sensor networks. In: the Proceeding of IEEE International Conference on Wireless and Mobile Computing, Networking and Communications, (WiMob'2006), pp. 69-76, DOI: 10.1109/WIMOB.2006.1696397.

[16] Garcia-Morchon, O. & Baldus, H. (2009). The ANGEL WSN Security Architecture. In: the Proceeding of third International Conference on Sensor Technologies and Applications (SENSORCOMM), pp. 430-435, DOI: 10.1109/SENSORCOMM.2009.71.

[17] Patwari, N., Hero, A., Perkins, M., Correal, N. & Dea, R. (2003). Relative location estimation in Wireless Sensor Networks. Journal of IEEE Transactions on Signal Processing (2003), pp. 2137-2148, DOI: 10.1109/TSP.2003.814469.

[18] Doherty, L., Pister, K. S. J. & El Ghaoui, L. (2001). Convex Position Estimation in Wireless Sensor Networks. In: the Proceeding of twentieth Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM), vol. 3, pp. 1655-1663, DOI: 10.1109/INFCOM.2001.916662.

[19] Niculescu, D. & Nath, B. (2003). Ad Hoc Positioning System (APS) using AoA. In: Twenty-Second Annual Joint Conference of the IEEE Computer and Communications. IEEE Societies (INFOCOM), vol. 3, pp. 1734-1743, DOI: 10.1109/INFCOM.2003.1209196.

[20] Kumar, P., Reddy, L. & Varma, S. (2009). Distance measurement and error estimation scheme for RSSI based localization in Wireless Sensor Networks. In: the Proceeding of Fifth International Conference on Wireless Communication and Sensor Networks (WCSN), pp. 1-4, DOI: 10.1109/WCSN.2009.5434802.

[21] Liu, C., Wu, K. & He, T. (2004). Sensor Localization with Ring Overlapping Based on Comparison of Received Signal Strength Indicator. In: the Proceeding of IEEE International Conference on Mobile Ad-hoc and Sensor Systems (IEEE Cat. No.04EX975 2004), pp. 516-518, DOI: 10.1109/MAHSS.2004.1392193.

[22] Le, V. D., Dang, V. H., Lee, S. & Lee, S. H. (2008). Distributed localization in wireless sensor networks based on force-vectors. In: the Proceeding of International Conference on Intelligent Sensors, Sensor Networks and Information Processing (2008), pp. 31-36, DOI: 10.1109/ISSNIP.2008.4761958.

[23] Meguerdichian, S., Koushanfar, F., Potkonjak, M. & Srivastava, M. B. (2001). Coverage problems in wireless ad-hoc sensor networks. In: the Proceeding of twentieth Annual Joint Conference of the IEEE Computer and Communications Societies (INFOCOM), vol. 3, pp. 1380-1387, DOI: 10.1109/INFCOM.2001.916633.

[24] Sheu, J. P., Li, J. M. & Hsu, C. S. (2006). A distributed location estimating algorithm for wireless sensor networks. In: the Proceeding of IEEE International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing (SUTC). vol. 1, DOI: 10.1109/SUTC.2006.1636179.

[25] Rudafshani, M. & Datta, S. (2007). Localization in Wireless Sensor Networks. In: the Proceedings of the 6th international conference on Information processing in sensor networks (IPSN’07), pp. 51-60, DOI: 10.1145/1236360.1236368.

[26] Tian, S., Zhang, X., Liu, P., Sun, P. & Wang, X. (2007). A RSSI-based DV-hop Algorithm for Wireless Sensor Networks. In: the Proceeding of International Conference on Digital Object Identifier (WICOM 2007), pp. 2555-2558, DOI: 10.1109/WICOM.2007.636.

نشریه هوش مصنوعی و داده کاوی

بهبود الگوریتم APIT برای مکان‌یابی بهتر در شبکه‌های حسگر بیسیم

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چکیده:

درشبکه‌های حسگر بیسیم، الگوریتم‌های مکان‌یابی می‌توانند وابسته به مسافت و یا مستقل از مسافت باشند. الگوریتم تخمین نقاط در مثلث (APIT) بر اساس رویکرد مستقل از مسافت می‌باشد. ما اصلاحاتی برروی الگوریتم APIT پیشنهاد کرده و الگوریتم حاصل را APIT اصلاح شده می‌نامیم. ما میزان خطاهای PIT (خطای لبه و پراکندگی غیر یکنواخت همسایگان) را در الگوریتم APIT با انتخاب مثلث‌هایی با فاصله مناسب از گره‌های لنگر کاهش می‌دهیم. برای کاهش بار محاسباتی مکان‌یابی و جلوگیری از انتخاب لنگرهای نامناسب، ما ناحیه‌کاری را به چهار زیرناحیه غیر همپوشان و چهار زیرناحیه همپوشان تقسیم‌بندی می‌کنیم. نتایج بدست‌آمده نشان می‌دهد که الگوریتم APIT اصلاح‌شده دارای عملکرد بهتری در میزان میانگین خطای تخمین مکان‌یابی و زمان لازم برای آن در سایزهای مختلف شبکه با پراکندگی random و grid می‌باشد. برای افزایش میزان صحت مکان‌یابی، هر زیرناحیه باید حداقل شامل پنج لنگر باشد. تغییر سایز یک شبکه و شعاع رادیویی ارتباطی لنگرها، بر روی میزان خطا و زمان موردنیاز برای مکان‌یابی موثر است. برای افزایش بیشتر صحت تخمین مکان‌یابی، پنج تا ده لنگر برای هر زیرناحیه در الگوریتم APIT اصلاح شده ضروری است.

کلمات کلیدی: شبکه های حسگر بیسیم، مکان‌یابی، APIT، لنگر، پوشش.