A Novel Weighted Centroid Localization Algorithm Based on RSSI for an Outdoor Environment

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Abstract—Location information is one of the most important services in the field of wireless sensor networks (WSNs). Compared to other proposed non-interactive localization algorithms, the weighted centroid localization scheme only uses the received signal strength indication (RSSI), which makes it simple to implement and robust to variations in the propagation environment. In this paper, we propose a weight-compensated weighted centroid localization algorithm based on RSSI for an outdoor environment. By theoretically analyzing, the proposed algorithm has the advantage of lower complexity, little prior information and lower power consumption. The simulation results show that the proposed algorithm is better than AMWCL-RSSI (Anchor_optimized Modified Weighted Centroid Localization based on RSSI) and WCL (Weighted Centroid Localization) in terms of the localization accuracy. Our real experimental results also show that WCWCL-RSSI (Weight-Compensated Weighted Centroid Localization Based on RSSI) is better than WCL in terms of the localization accuracy.

Index Terms—Localization, received signal strength indicator, weight, wireless sensor networks

I. Introduction

Recent advancements in the wireless communications and hardware technology field have facilitated the development of wireless sensor networks (WSNs) for a wide variety of real-world applications, including environmental monitoring, disaster relief, site security, medical diagnostics, battlefield surveillance, home automation, assisted living, and so on [1]-[6].

Localization is very important for WSN applications, e.g, forest fire detection system based on WSNs. A large number of sensor nodes are needed to be deployed in the forest in order to detect environmental changes. Hence, we must determine the location of each sensor node. Indeed, the global positioning system (GPS) solves many localization problems outdoor, where the devices can receive the signals coming from satellites, but it will take a considerable cost if each sensor node is equipped with GPS module.

There exist several algorithms that can be used to determine the position of a target through received-signal-strength (RSS) measurements. Some of them are geometric methods, such as lateration or a minimum–maximum method, whereas some others are based on statistical approaches, such as maximum likelihood [7]-[8].

Most of the proposed localization algorithms rely on RSS measurements. In fact, RSS can be used to estimate the distance between an unknown node (called a target node) and a number of anchor nodes with known coordinates. The location of the target node is then determined by multilateration [9]-[11].

Unfortunately, due to the degrading effects of reflections, shadowing, and fading of radio waves, some studies have shown the large variability of RSS [12]-[15]. As a result, localization methods using RSS are affected by large errors and lack of accuracy. However, RSS-based techniques remain an appealing approach [16]. This is mainly due to the fact that RSS measurements can be obtained with minimal effort and do not require extra circuitry, with remarkable savings in cost and energy consumption of a sensor node. In fact, most of WSN transceiver chips have a built-in RSS indicator, which provides RSS measurement without any extra cost.

As aforementioned, the vast majority of studies on RSS-based localization have been performed in outdoor environments. But the accuracy of RSS-based outdoor localization has little improvement due to the effects of the disturbances and the path loss. Moreover, a small number of published papers are based on experimental results obtained from real outdoor test environments [15].

In [18], an intelligent outdoor positioning scheme is proposed. The scheme uses the estimated distance to determine the position of the unknown node. Moreover, this scheme is based on the received-signal-strength and does not need any location fingerprinting process in advance or location database. Experimental results show that the average localization error of the scheme is less than 3 m, which is much smaller than the typical GPS localization error.

C. Alippi and G. Vanini have tested an RSS-based outdoor localization methodology exploiting a minimum least square (LS) algorithm, after modeling a propagation channel [19]. The deployment of anchors has a density of one node over 25 m^2 on an area of 500 m^2. In their experiments, the average distance error obtained is 3 m.

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Centroid localization (CL) and weighted centroid localization [20]-[25], have attracted a lot of interest because of their simplicity and robustness to changes in wireless propagation properties such as path loss. This characteristic makes them suitable candidates for systems requiring coarse grained, but reliable and cost-effective techniques. Strictly speaking, weighted centroid localization is not an entirely range-free technique because it requires additional information aside from simple connectivity. Recently many proposed approaches on weighted centroid localization focused more on error control and management. Weighted centroid localization (WCL) is firstly proposed in [26]. In order to reduce localization error, X. H. Shen and J. Z. Yang propose a weighted centroid localization algorithm for outdoor localization [27]. This localization algorithm also achieves lower computation, lower hardware cost and fewer communication consumption, but it still needs to compute the path loss and the distances between the unknown node and anchor nodes. In [28], H. Y. Shi proposes an anchor_optimized modified weighted centroid localization algorithm based on RSSI. Other schemes have discussed inexact position problems [29], or analyzed the performance of WCL [30], or enhanced WCL's performance for specific scenarios [31]-[32].

All RSS-based localization algorithms mentioned above are range-based. Compared with the range-free localization algorithms, the range-based localization algorithms will consume a large amount of energy because of computing the path loss and the distances between nodes. Hence, the range-free localization algorithms have the advantage of lower power consumption.

In this paper, an improved weighted centroid localization algorithm based on RSSI is proposed. The proposed method is range-free and based on WCL in [26]. We compare our proposed scheme with some existing solutions via simulations and and experiments.

The rest of this paper is organized as follows. Section II presents proposed localization algorithm, followed by performance evaluation in Section III. We conclude the paper in Section IV.

II. Localization Algorithms

In this section, we will introduce WCL algorithm [26] and the proposed localization algorithm, respectively. WCL is the basis of the proposed localization algorithm.

A. WCL

The low accuracy in location estimation of CL has stimulated the development of WCL. WCL introduces the weights of the beacons depending on their distance towards the unknown node. The aim is to give more influence to those beacons which are nearer to the unknown node. As the RSSI also increases with a decreasing distance it is selected as an appropriate quantifier.

Notice that the CL approach assumes all the visible anchors equally near the unknown node. Since this assumption is most likely not satisfied in practice, in [26], Blumenthal *et al.* have proposed the basic idea of WCL, which assigns a greater weight to the anchor closest to the unknown node. Let $a_i = (x_i, y_i)$ denote the coordinate of anchor node. d_i is the measured distance between the unknown node and anchor node a_i . g is the degree which determines the contribution of each anchor node. w_i is the weight which depends on the distance between the anchor node i and the unknown node . w_i can be expressed as

$$w_i = d_i^{-g} \tag{1}$$

So, the WCL algorithm estimates the position of the unknown node as:

$$P = \frac{\sum_{i=1}^{n}\left(w_i \cdot a_i\right)}{\sum_{i=1}^{n} w_i} \tag{2}$$

From the above, we can know that we must compute the measured distance d_i if we want to get the position of the unknown node. In practice, we can get the measured distance d_i by computing the path loss exponent. But the path loss exponent has to be done with a mass of measured data, and the path loss exponent is not accurate by computing. To solve this problem, a simple method is proposed in this paper.

B. Weight-Compensated Weighted Centroid Localization Based on RSSI (WCWCL-RSSI)

In this section, we propose an improved weighted centroid localization algorithm based on RSSI. According to free space transmission, the detected signal strength can be expressed as

$$P_{RX_i} = P_{TX} \cdot G_{TX} \cdot G_{RX} \left(\frac{\lambda}{4\pi d_i}\right)^2 \tag{3}$$

where P_{RX_i} is the remaining power of wave at receiver from the ith anchor node. P_{TX} is the transmission power of sender. G_{TX} is the gain of transmitter. G_{RX} is the gain of receiver. λ is the wave length. d_i is the distance between the ith anchor node and the unknown node. From (2), we can obtain the relation between P_{RX_i} and d_i, which is shown in Fig. 1.

In embedded systems, the received signal strength is converted to a received signal strength indicator (RSSI). RSSI can be expressed as:

$$RSSI_i = 10 \cdot \log \frac{P_{RX_i}}{P_{Ref}} \tag{4}$$

where, P_{RX_i} is the received signal strength from the ith anchor node, P_{Ref} is the reference power. From Fig. 2, we can also know the relation between $RSSI_i$ and P_{RX_i}.

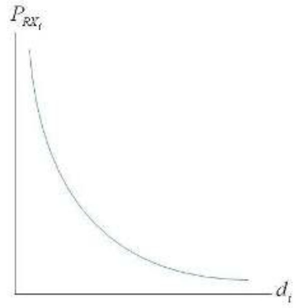

Fig. 1. Received power P_{RX_i} versus d_i

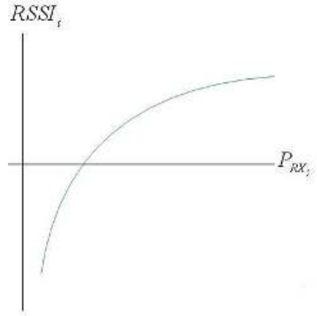

Fig. 2. $RSSI_i$ versus P_{RX_i}

From (3), d_i can be expressed as

$$d_i = \lambda \sqrt{\frac{P_{TX} \cdot G_{TX} \cdot G_{RX}}{4\pi P_{RX_i}}} \tag{5}$$

According to (4), P_{RX_i} can be expressed as

$$P_{RX_i} = P_{Ref} \cdot 10^{\frac{RSSI_i}{10}} \tag{6}$$

So, the weight w_i can be expressed as

$$w_i = \frac{1}{d_i^{\,g}} = \frac{1}{\left(\lambda \sqrt{\frac{P_{TX} \cdot G_{TX} \cdot G_{RX}}{4\pi P_{Ref} \cdot 10^{\frac{RSSI_i}{10}}}} \right)^g} \tag{7}$$

After w_i normalization, the weight can be expressed as

$$W_i = \frac{w_i}{\sum_{j=1}^{n} w_j} = \frac{\sqrt{\left(10^{\frac{RSSI_i}{10}}\right)^g}}{\sum_{j=1}^{n} \sqrt{\left(10^{\frac{RSSI_j}{10}}\right)^g}} \tag{8}$$

So, the position of the unknown node can be expressed by

$$P = \sum_{i=1}^{n} W_i a_i \tag{9}$$

where W_i is as the weight of anchor node a_i ($i = 1, 2, \cdots, n$), but W_i can not fully reflect the binding on the estimated position of the unknown node due to the interference of external environment. We solve the problem through the method of compensating the weights of anchor nodes, and propose a novel weight model. In the novel weight model, we increase the weight of anchor node closer to the unknown node. Because the closer anchor node gets to the unknown node, the greater weight anchor node has [26].

We choose $W_i \cdot n^{2 \cdot W_i}$ as the improved weight because $W_i \cdot n^{2 \cdot W_i} > W_i$ (n is the number of anchor nodes, and $n > 1$).

After $W_i \cdot n^{2 \cdot W_i}$ normalization, the novel weight can be expressed as:

$$Wn_i = \frac{W_i \cdot n^{2 \cdot W_i}}{\sum_{j=1}^{n} (W_j \cdot n^{2 \cdot W_j})} \tag{10}$$

So, the position of the unknown node can be expressed as

$$P = \sum_{i=1}^{n} (Wn_i \cdot a_i) \tag{11}$$

From (10) and (11), it can be seen that we can get the estimated position of an unknown node by just knowing $RSSI_i$ and the coordinates of anchor nodes. And the unknown node does not need to compute the path loss exponent and obtains other prior information. Additionally, the proposed localization algorithm has the advantage of lower complexity. Some parameters must be consistent in all nodes, including P_{TX}, G_{TX}, G_{RX} and λ.

C. *The Algorithm Process*

The algorithm process of WCWCL-RSSI is as follows:

Step1: After an unknown node receives signals, it records RSSI values and the coordinates of anchor nodes $a_i = (x_i, y_i)$ which come from anchor nodes;

Step2: Compute the weight $Wn_i = \frac{W_i \cdot n^{2 \cdot W_i}}{\sum_{j=1}^{n} (W_j \cdot n^{2 \cdot W_j})}$;

Step3: Compute the estimated position $P = \sum_{i=1}^{n} W_i a_i$.

D. *Theoretical Performance Analysis*

In theory, the proposed algorithm is obtained on the basis of WCL. Compared with WCL, WCWCL-RSSI reduces the number of parameters (e.g., the path loss exponent) which need to be measured or computed, and WCWCL-RSSI reduces the algorithm complexity. Furthermore, WCWCL-RSSI decreases energy consumption of nodes and prolongs the network lifetime because it is range-free.

From (1) and (2), the distance between the unknown node and anchor node a_i must be estimated if we want to know the location of the unknown node. In order to estimate the distance between the unknown node and anchor node a_i, some parameters have to be measured or computed, including the path loss exponent and the received signal strength at reference distance d_0 ($d_0 = 1$ m). However, the calculation of these parameters will increase the algorithm complexity and energy consumption of nodes.

In this paper, the proposed algorithm does not need to compute the path loss exponent, the received signal strength at reference distance d_0 ($d_0 = 1$ m) and the distance between two nodes. And (10) demonstrates the result of the proposed algorithm.

From the above analysis, the proposed algorithm reduces the number of parameters which need to be measured or computed as compared with that of WCL. According to partII.C, WCWCL-RSSI outperforms WCL in localization accuracy because WCWCL-RSSI compensates the weights. It can also be shown that the proposed algorithm has the advantage of fewer parameters and lower complexity.

III. Performance Evaluation

A. RSSI Model

RSSI model can be expressed as

$$RSSI = PL0 - 10\beta\log_{10}(d/d_0) + N_\alpha \quad (12)$$

where d is the real distance, $PL0$ is the received signal strength at reference distance d_0 ($d_0 = 1$ m), β is the path loss exponent, and N_α is a zero-mean Gaussian noise with standard deviation α.

B. Simulation

In this section, we analyse the performance of the studied localization scheme through simulations, using Matlab as simulation tool. We compare the proposed weighted centroid localization algorithm with WCL [26] and AMWCL-RSSI [28]. Equation (12) is RSSI model for our experiments. We set the degree $g = 1$ in all experiments.

1) Localization error versus the number of anchor nodes

In this experiment, we evaluate the performance of the proposed WCWCL-RSSI algorithm with the changing the number of anchors. Fig. 3, Fig. 4 and Fig. 5 depict the effect on localization error when varying the number of anchors. All nodes are deployed in a $100\text{ m} \times 100\text{ m}$ area. Anchor nodes are uniformly deployed around this area, 10000 sensor nodes are uniformly placed in the region. We assume that $PL0 = -60$ db and $\beta = 3.5$.

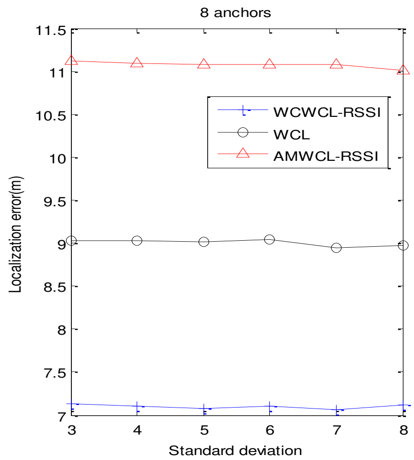

Fig. 3. Localization error versus standard deviation

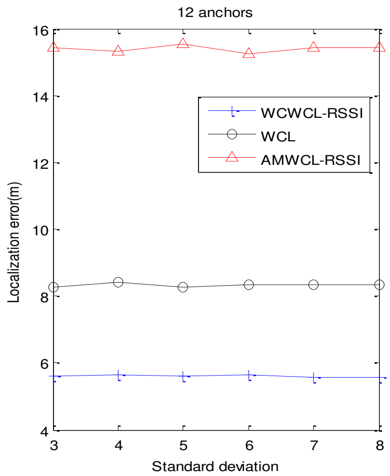

Fig. 4. Localization error versus standard deviation

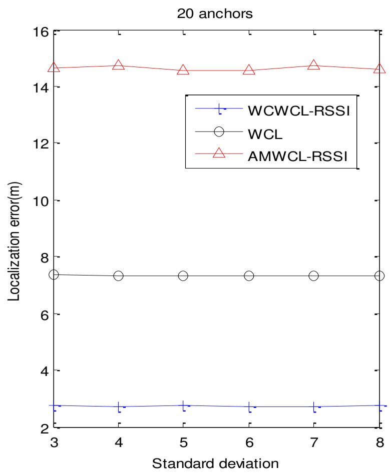

Fig. 5. Localization error versus standard deviation

The plots in Fig. 3, Fig. 4 and Fig. 5 show the results of simulations running three localization algorithms with 8, 12, and 20 anchors positioned as described in Sections II and choosing $g = 1$. As shown, passing from 8 to 20 anchors, the localization error globally decreases. From Fig. 3, Fig. 4 and Fig. 5, it can be observed that WCWCL-RSSI algorithm outperforms WCL and

AMWCL-RSSI algorithm in localization accuracy. This is because WCWCL-RSSI algorithm compensates the weights of anchor nodes.

2) Localization error versus the path loss exponent

Fig. 6 depicts the effect on localization error when varying the path loss exponent. All nodes are deployed in a $100\ \text{m} \times 100\ \text{m}$ area. 20 anchors are uniformly deployed around this area, 10000 sensor nodes are uniformly placed in the region. We assume that $PL0 = -60$ db and the zero-mean Gaussian noise N_α in (10) has a standard deviation of 3 db.

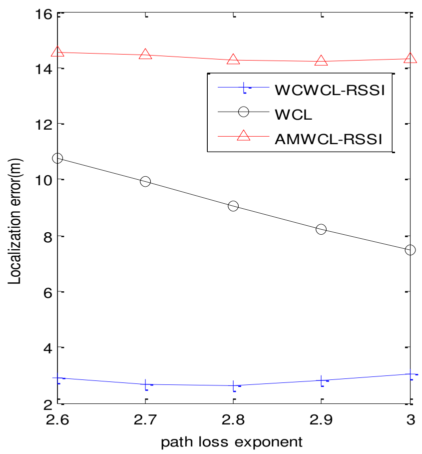

Fig. 6. Localization error versus the path loss exponent

From Fig. 6, it can be observed that as the path loss exponent increases, the error in location estimation increases for WCWCL-RSSI algorithm. However, the path loss exponent has a little effect on localization error for WCWCL-RSSI algorithm as the path loss exponent increases. From Fig. 6, obviously, WCWCL-RSSI is better than AMWCL-RSSI and WCL in the localization accuracy. Using WCWCL-RSSI algorithm, we do not need to compute the path loss exponent. Furthermore, compared with WCL, WCWCL-RSSI reduces energy consumption of nodes.

3) Localization error versus the standard deviation

Fig. 3, Fig. 4 and Fig. 5 also depict the effect on localization error when varying the standard deviation.

From Fig. 3, Fig. 4 and Fig. 5, it can be observed that as the standard deviation increases, the error in location estimation increases for all three localization algorithms. But Gaussian noise has a little effect on localization errors of all three localization algorithms. WCWCL-RSSI obviously outperforms WCL and AMWCL-RSSI in localization accuracy. This is because WCWCL-RSSI compensates the weights.

C. *Experiment*

In this section, we analyse the performance of the studied localization scheme through the real experiment. A wireless node is based on a MSP430 microprocessor and equipped with an IEEE 802.15.4 compliant Chipcon CC1100 radio module. The antenna is a 2.4 GHz planar inverted-F antenna. All nodes are deployed in a $100\ \text{m} \times 100\ \text{m}$ area of the lawn of our university. 20 anchor nodes are uniformly distributed around this area. 25 sensor nodes are uniformly deployed in the experimental region, corresponding to the deployment map in Fig. 7. We set the degree $g = 1$ in all experiments.

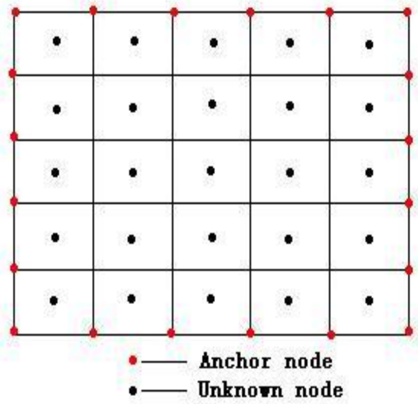

Fig. 7. The deployment map of nodes

TABLE I: AVERAGE LOCALIZATION ERROR

Localization Algorithms	Average localization error (meters)
WCL	7.42
WCWCL-RSSI	2.81

Table I shows the average localization error of two localization algorithms. From Table I, we can clearly know that the average localization error of WCWCL-RSSI is 2.81 m, the average localization error of WCL is 7.42 m. Obviously, the average localization error of WCWCL-RSSI is lower than the average localization error of WCL. In our experiment, WCWCL-RSSI is faster than WCL in the speed of getting the position of unknown node because the algorithm complexity of WCWCL-RSSI is lower than the algorithm complexity of WCL. It can also be seen that the proposed algorithm has the advantage of lower power consumption and lower complexity because the proposed algorithm reduces the number of the parameters which need to be calculated, e.g. the path loss exponent and $PL0$ (the received signal strength at reference distance).

IV. CONCLUSIONS

Many weighted centroid localization schemes have been widely used for WSNs. However, these schemes do not help, since the errors are high in practical deployments. For an outdoor environment, in this paper we have researched and analyzed many weighted centroid localization algorithms and RSS-based localization algorithms, and proposed a novel localization scheme, called weight-compensated weighted centroid localization algorithm based on RSSI. In the proposed localization algorithm, we can get the estimated position of the unknown node by just knowing RSSI and the coordinates of anchor nodes. And we do not need to obtain the path loss exponent and other prior information.

Luckily, RSSI is easy to get directly from embedded systems, and the information of the coordinates of anchor nodes is from RSSI. In the meantime, we compensate the weights which can reduce the localization error.

In this paper, we analyzed the performance of WCWCL-RSSI algorithm through the number of anchor nodes, the standard deviation and the path loss exponent. The results show that the proposed algorithm achieves a reduced localization error than WCL and AMWCL-RSSI. From real experimental results, it can be seen that WCWCL-RSSI is better than WCL in terms of the localization accuracy. It also has been shown that WCWCL-RSSI has the advantage of lower complexity, little prior information and lower power consumption. Hence, the proposed localization algorithm can be applied to the occasion of lower complexity and lower power consumption. Although we have got some progress in power consumption and algorithm complexity, the improvement of the localization accuracy is not big. In the case of fewer anchor nodes, we plan to work on improvement of the localization accuracy in the future work.

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REFERENCES

[1] C. Y. Chang, C. Y. Lin, and C. T. Chang, "Tone-based localization for distinguishing relative locations in wireless sensor networks," *IEEE Sensors Journal*, vol. 12, no. 5, pp. 1058-1070, 2012.

[2] H. A. Nguyen, H. Guo, and K. S. Low, "Real-time estimation of sensor node's position using particle swarm optimization with log-barrier constraint," *IEEE Transactions on Instrumentation and Measurement*, vol. 60, no. 11, pp. 3619-3628, 2011.

[3] W. Meng, W. D. Xiao, and L. H. Xie, "An efficient EM algorithm for energy-based multisource localization in wireless sensor networks," *IEEE Transactions on Instrumentation and Measurement*, vol. 60, no. 3, pp. 1017-1027, 2011

[4] L. Mo, Y. He, Y. Liu, J. Zhao, S. Tang, X. Li, and G. Dai, "Canopy closure estimates with GreenOrbs: Sustainable sensing in the forest," in *Proc. ACM SenSys*, 2009, pp. 99-112.

[5] I. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "A survey on sensor networks," *IEEE Commun. Mag*., vol. 40, no. 8, pp. 102-114, Aug 2002.

[6] F. Salvadori, M. D. Campos, P. Sausen, R. D. Camargo, C. Gehrke, *et al.*, "Monitoring in industrial systems using wireless sensor network with dynamic power management," *IEEE Trans. Instrum. Meas.*, vol. 58, no. 9, pp. 3104-3111, Sep 2009.

[7] D. P. Qiao and G. K. H. Pang, "An iteratively reweighted least square algorithm for RSS-based sensor network localization," in *Proc. International Conference on Mechatronics and Automation*, 2011, pp. 1085-1092.

[8] N. Patwari, A. O. Hero, M. Perkins, N. S. Correal, and R. J. O'Dea, "Relative location estimation in wireless sensor networks," *IEEE Trans. Signal Process*., vol. 51, pp. 2137-2148, Aug 2003.

[9] Y. b. Yao, R. Zeng, and Z. Q. Yi, "Bounding box based distributed search localization algorithm for WSN," *Tongxin Xuebao/Journal on Communications*, vol. 33, no. 2, pp. 135-140, November 2012.

[10] J. Zhao, W. Xi, Y. He, Y. Liu, L. Mo, and Z. Yang, "Localization of wireless sensor networks in the wild: Pursuit of ranging quality," *IEEE/ACM Transactions on Networking*, vol. 21, no. 1, pp. 311-323, 2013..

[11] W. Y. Chiu, B. S. Chen, and C. Y. Yang, "Robust relative location estimation in wireless sensor networks with inexact position problems," *IEEE Transactions on Mobile Computing*, vol. 11, no. 6, pp. 935-946, 2012.

[12] S. S. Kumar, M. N. Kumar, and V. S. Sheeba, "Obstacle based range-free localization-error estimation for WSN," *International Journal of Computer Science Issues*, vol. 8, no. 2, pp. 31-39, September 2011.

[13] E. Elnahrawy, X. Li, and R. Martin, "The limits of localization using signal strength: A comparative study," in *Proc. 1st Annu. IEEE Commun. Soc. Conf. SECON*, Oct 2004, pp. 406-414.

[14] D. Lymberopoulos, Q. Lindsey, and A. Savvides, "An empirical characterization of radio signal strength variability in 3-D IEEE 802.15.4 networks using monopole antennas," *Wireless Sensor Networks*, vol. 3868, pp. 326-341, 2006.

[15] K. Whitehouse, C. Karlof, and D. Culler, "A practical evaluation of radio signal strength for ranging-based localization," *SIGMOBILE Mobile Comput. Commun. Rev.*, vol. 11, no. 1, pp. 41-52, Jan 2007.

[16] G. Chandrasekaran, M. Ergin, J. Yang, S. Liu, *et al.*, "Empirical evaluation of the limits on localization using signal strength," in *Proc. 6th Annu. IEEE Commun. Soc. Conf. SECON*, Jun 2009, pp. 1-9.

[17] W. H. Kuo, Y. S. Chen, G. T. Jen, and T. W. Lu, "An intelligent positioning approach: RSSI-based indoor and outdoor localization scheme in Zigbee networks," in *Proc. International Conference on Machine Learning and Cybernetics*, vol. 6, 2010, pp. 2754-2759.

[18] T. Stoyanova, F. Kerasiotis, K. Efstathiou, and G. Papadopoulos, "Modeling of the RSS uncertainty for RSS-Based outdoor localization and tracking applications in wireless sensor networks," in *Proc. Fourth International Conference on Sensor Technologies and Applications (SENSORCOMM)*, 2010, pp. 45-50.

[19] C. Alippi and G. Vanini, "A RSSI-based and calibrated centralized localization technique forWireless Sensor Networks," in *Proc. 4th Annu. IEEE Int. Conf. PERCOMW*, 2006, pp. 301-305.

[20] C. Zhao, M. Liu, Y. J. Jia, and T. Zhang, "Weighted centroid localization algorithm based on link quality," in *Proc. International Conference on Computer Distributed Control and Intelligent Environmental Monitoring (CDCIEM)*, 2012, pp. 840-843.

[21] H. Q. Cheng, H. Wang, and H. K. Wang, "An improved centroid localization algorithm based on weighted average in WSN," in *Proc. 3rd International Conference on Electronics Computer Technology (ICECT)*, vol. 4, 2011, pp. 258-262.

[22] X. Q. Su and Z. M. Lei, "Node localization in WSN based on weighted vectors centroid algorithm," in *Proc. 4th International Conference on Intelligent Networks and Intelligent Systems (ICINIS)*, 2011, pp. 109-112.

[23] X. Q. Su and Z. M. Lei, "Improved centroid algorithm localization for WSN based on particle swarm optimization," in *Proc. 2011 Fourth International Symposium on Computational Intelligence and Design*, vol. 1, 2011, pp. 139-142.

[24] W. K. Chen, W. F. Li, S. Heng, and Y. Bing, "Weighted centriod localization algorithm based on RSSI for wireless sensor

networks," *Journal of Wuhan University of Technology (Transportation Science & Engineering)*, 2006, pp. 30-32.

[25] R. Behnke and D. Timmermann, "AWCL: Adaptive weighted centroid localization as an efficient improvement of coarse grained localization," in *Proc. 5th Workshop on Positioning, Navigation and Communication*, 2008, pp. 243-250.

[26] J. Blumenthal, R. Grossmann, F. Golatowski, and D. Timmermann, "Weighted centroid localization in zigbee-based sensor networks," in *Proc. IEEE International Symposium on Intelligent Signal Processing*, October 2007, pp. 1-6.

[27] X. H. Shen and J. Z. Yang, "Node self-localization algorithm based on rssi in wireless sensor networks outdoor," in *Proc. International Conference on Intelligent System Design and Engineering Application*, vol. 1, 2010, pp. 1010-1012.

[28] H. Y. Shi, "A new weighted centroid localization algorithm based on RSSI," in *Proc. International Conference on Information and Automation*, 2012, pp. 137-141.

[29] L. S. Xu, K. Wang, Y. Q. Jiang, F. F. Yang, Y. H. Du, and Q. C. Li, "A study on 2D and 3D weighted centroid localization algorithm in Wireless Sensor Networks," in *Proc. 3rd International Conference on Advanced Computer Control*, 2011, pp. 155-159.

[30] H. Q. Cheng, H. K. Wang, and H. Wang, "Research on centroid localization algorithm that uses modified weight in WSN," in *Proc. International Conference on Network Computing and Information Security*, vol. 2, 2011, pp. 287-291.

[31] M. Chen and H. Liu, "Enhance performance of centroid algorithm in wireless sensor networks." in *Proc. Fourth International Conference on Computational and Information Sciences*, 2012, pp. 1066-1068.

[32] J. Li and H. P. Liu, "A new weighted centroid localization algorithm in coal Mine wireless sensor networks," in *Proc. 3rd International Conference on Computer Research and Development*, vol. 3, 2011, pp. 106-109.

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