An Efficient Anchor Nodes Distribution for Accurate Localization (EDAL) in Mobile Wireless Sensor Networks

توزيع نقاط الربط (المرساة) في شبكات الاستشعار اللاسلكية المتنقلة من أجل توطين دقيق (EDAL)

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Received: 4/ 5/ 2019, **Accepted:** 20/ 8/ 2019
DOI: 10.33977/2106-000-003-002
http://journals.qou.edu/index.php/PJTAS

تاريخ الاستلام: 4/ 5/ 2019م، **تاريخ القبول:** 20/ 8/ 2019م.
E - ISSN: 2307 - 4655
P - ISSN: 2307 - 4647

Abstract:

The velocity parameter in mobile Wireless Sensor Networks (WSNs) is a critical factor in anchor nodes distribution. However, most of the previous schemes use the random velocity to transmit anchor nodes as in the waypoint mobility model, which produces a considerable overlap between anchor nodes without improving the localization accuracy. In this paper, we improve such model by controlling the anchor node velocity. In the proposed scheme (EDAL), the anchor node velocity is a function of the overlap degree between anchor nodes and number of anchor node in the neighbor. Thus, EDAL can distribute the anchor nodes efficiently to improve the localization accuracy and expand the coverage area simultaneously. We evaluate the EDAL performance through extensive simulation experiments.

Keywords: Wireless Sensor Networks, Waypoint Model.

ملخص:

تعد معلمة السرعة في شبكات الاستشعار اللاسلكية المتنقلة (WSNs) عاملاً هامًا في توزيع نقاط الربط (المرساة)، معظم المخططات السابقة تستخدم السرعة العشوائية لإرسال نقاط الربط كما هو الحال في نموذج التنقل بنقطة الطريق (Waypoint)، والذي ينتج تداخلًا كبيرًا بين عقد الربط دون تحسين دقة التعريب. في هذه الورقة، نقوم بتحسين هذا النموذج من خلال التحكم في سرعة عقد الربط، في المخطط المقترح (EDAL)، تعد سرعة عقد الربط مهمة لحساب درجة التداخل بين عقد الربط وعدد العقد في الجوار، وبالتالي، يمكن لـ(EDAL)توزيع نقاط الربط بكفاءة لتحسين دقة التموضع وتوسيع مساحة التغطية في وقت واحد. نقيم أداء(EDAL)من خلال تجار بمحاكاة واسعة النطاق.

الكلمات المفتاحية: شبكات الاستشعار اللاسلكية المتنقلة، نموذج التنقل بنقطة الطريق.

1. Introduction

Mobile Wireless Sensor Networks (WSNs) consist of a large collection of small and low-cost devices [1]. These devices can communicate and collaborate with each other to collect and broadcast data. Mobile WSNs have been used in various applications, such as in disaster monitoring, tracking animals in wildlife sanctuaries, creates automatic mapping[2] and monitoring patients in hospital[3]. In tracking and monitoring applications[4-6], the location information of the collected data is crucial in estimating the precise location of the data origins[7].

In the literature, localization schemes of mobile WSNs can be classified into two categories, namely range-based and range-free[8]. The range-based category operates additional hardware, such as an array of antennas and acoustic devices to localize the sensor node [9],whereas the range-free scheme estimates the location of blind node (a node without location) via the network connectivity information without additional hardware.

In the range-free schemes, the anchor nodes broadcast its location information to aid in estimation of blind node location. However, the distribution of anchor nodes (a node with location information using GPS) over the operation area is highly affecting the network connectivity, coverage area and localization accuracy. Thus, it is important to design an efficient anchor node distribution method that able to expand anchor nodes throughout the coverage area which would lead to a better localization accuracy. The blind node requires at least three anchor nodes in the neighbor to estimate its location [10].

Most range-free localization schemes utilized the random waypoint mobility model to transmit the sensor node. Though the waypoint model has the advantage of being simple, it produces a large overlap between anchor nodes. The large overlap shows that the waypoint model is not efficient in distributing the anchor node since additional anchor nodes were used to cover an area even though they are not needed. This would consume more energy, requires more devices (e.g. GPS) and increase the overall cost of the whole implementation. An efficient node distribution for accurate localization should be able to maximize the coverage area by utilizing the available anchor node. This can be achieved by reducing the overlapping between the anchor nodes.

In this study, we develop a localization scheme to solve such problems by selecting the anchor node velocity as function of the overlap degree between anchor nodes and number of anchor nodes in the neighbor. The simulation results show that the proposed scheme can distribute anchor nodes efficiently, expand the anchor nodes coverage to 50% and improve the localization accuracy at the same time.

The rest of this manuscript is organized as follows: Section 2 presents the related work in localization scheme and mobility model. Section 3 explains the methodology of the EDAL scheme. The experimental protocol and its parameters are described and their results are presented in Section 4. Finally, Section 5 concludes the paper and outlines the future work.

2. Related Work

Compared to a static network, mobile WSNs have a higher coverage area with a limited number of sensor nodes. However, the mobility property of mobile sensors open a new challenge in estimating the location of blind node in WSNs. In this section, the related work is described in two sub-sections: localization scheme and mobility model.

2.1 Localization scheme

Localization schemes of mobile WSNs are categorized as range-based and range-free. The range-based scheme uses additional hardware to calculate the absolute distance between nodes. The deployment of additional hardware in WSNs is limited because of the restrictions in energy, size, cost and limited memory. Examples of hardware and their available methods are antenna which uses AoA[11], acoustic devices which measures the difference between light or sound signals via TDoA[12], and time synchronization between nodes in ToA. Another method in range-based scheme is received signal strength indicator (RSSI)that utilizes the relationship between signal strength and distance of the sensors. The localization accuracy of RSSI technology is affected by signal noise and weather conditions[13].

Range-free scheme estimates the location of blind nodes via network connectivity without additional hardware. In these schemes, three anchor nodes in the neighbor are required to estimate the blind node location in 2D space[10]. This estimation is based on the location information of the anchor nodes that broadcasted to the first and second hop neighbors in every time slot. Given the minimum dependency on anchor nodes, the range-free scheme is appropriate for indoor applications.

Location estimation of the mobile sensor node is a challenging task because the movement of mobile WSNs over time slot, in which affecting the localization accuracy. This challenge becomes more complicated for indoor localization applications since traditional solution such as GPS is highly affected by roofs, walls and other obstructions[14,15]. Additionally, the deployment of GPS in a sensor node is power-consuming and increases the costs and size of the sensor. Therefore, various localization schemes have been proposed to advance the location estimation of the mobile sensor in an indoor environment.

Mobile WSNs mainly use the SMC (Sequential Monte Carlo) technique to estimate the location of blind nodes in range-free schemes[16]. The SMC evaluates the posterior distribution function of the sample in the previous time slot to estimate the blind node location in current time. In each time slot, the normal node (node with location information in previous time slot) generates a new sample based on the sample from the previous time slot bounded by the maximum velocity (max-v). Anchor node constraints are then used to filter out the invalid samples. The processes are repeated until sufficient valid samples are generated. The average of weighted samples is later used for location estimation.

The Monte Carlo Localization (MCL) scheme[17] uses SMC technology to estimate the location of a blind node. Among the well-known techniques in WSNs localization which applies the SMC are MCL, MSL*, MCB and WMCL. In MCL, the location estimation of mobile sensor is simplified based on the following assumptions. First, the time is divided in an equal time slot, and second, the velocity of the sensor is limited to max-v. Moreover, the MCL estimates the location in three steps: initial, sample, and filter. The initial step involves the blind node generating samples randomly from the network bounded if it exists. This step is followed by the sample step, in which a new sample of the blind node is generated within a circle with a radius of max-v and is centered inside the area of previous time slot samples. In the filter step, anchor constraint is used to eliminate the weak samples and preserve the high weight samples. The anchor nodes constraints can be near or far and the near constraint is a region that is limited to radius R, whereas the far constraint is a region with a radius of R and 2R. The sample and filter steps should be repeated until sufficient valid samples are generated. The location estimation of the blind node is then calculated by averaging all valid samples.

In [18], MSL* was proposed to improve the localization accuracy of MCL. This technique uses the anchor and normal nodes location information in first and second hops. In each time slot, an anchor node and normal node broadcast their samples and sample weights to aid blind node location estimation. The sample weights of the anchor node are consistently high (one) and the normal node has a partial weight from zero to one. The weight of the normal node samples is calculated based on the distance between the samples of a normal node and the samples of another normal node in the neighbor. The use of normal nodes increases the localization accuracy substantially, but simultaneously increases the communication cost in WSNs. However, the communication cost is increased excessively in MSL* without improving the location accuracy. The communication cost of the MSL* is further improved in our previous research LCC [19] which emphasis on the selection of the closed normal nodes to the blind node based on the number of elements intersected between neighbors. This approach minimizes the communication cost while maintaining the localization accuracy as in MSL*. Nevertheless, the localization accuracy of MSL* decreases as the speed of the node increases. Thus, MSL* is more suitable for low-speed movement and static networks.

The MCB[20] scheme generates the sample from the bounded box method. The bounded box area is an intersection box between squares constructed by each anchor node over its center. This box minimizes the sample area and repetition in sample and filter steps. Thus, MCB scheme successfully improved the sampling efficiency but attained the same localization accuracy as in MCL. This is due to the fact that MCB used the same filtration strategy as in the MCL.

The sampling efficiency and localization accuracy of MCB are further improved in the Weighted Monte Carlo Localization scheme (WMCL) [21]. The WMCL improves the localization accuracy of MCB by using the location information of both normal and anchor nodes to generate and weight the candidate samples. The sampling efficiency is improved via location information of the blind node in the current time slot and its neighboring normal nodes location information in the previous time slot. The location information of the normal node comprises a sample set and maximum possible error of the estimated position in the x- and y- axes.

The WMCL is further improved in another method called the RMCB where it includes additional constraints of negative information to reduce the sample area, In this regard, RMCB uses both positive and negative anchor nodes constraints[22]. Contrarily, COMCL, PMCL, evaluates the distance and direction of the anchor node movement to decrease the scope of the sample area[23][39].

The Improved MCL (IMCL) scheme enhances the localization accuracy by introducing normal node location information [24]. This scheme consists of three steps: sampling, neighbor constraint, and refinement. In the sampling step, the blind node generates samples by exchanging messages with the anchor node as in the previous schemes. Then, the normal nodes will broadcast their location information, which contains position and length of eight sectors. Finally, the samples are filtered based on anchor node constraint and movement direction of normal nodes. Finding the length of eight sectors in this scheme require additional number of calculations and broadcasting the eight sectors length can increase the communication cost [41].

Typically, the blind node receives redundant messages from the normal nodes without further enhancing its localization accuracy. Therefore, distance from the normal nodes to the blind node and its maximum localization error has been proposed as a criterion to narrow the redundant messages[25]. Transmission of the location information is inhibited when the normal node exceeds the threshold value or has minimal localization error.

Orbit[26] improves the sampling efficiency by using a special graph theory known as star graph, which contains five edges in which the intersection of the edges present the bounded sample area. However, Orbit is more complex than the SMC scheme because Orbit increases the communication and computational costs. Moreover, finding five neighbors of a blind node is not consistently applicable all the time.

The EDAL scheme can improve the localization accuracy and maximize the anchor nodes coverage by controlling the anchor node velocity based on overlap degree between them. The velocity in EDAL is the function of the overlap degree between the anchor nodes whereas the previous schemes using random waypoint mobility model. Thus, the EDAL can maintain the number of anchor nodes in neighbors to improve accuracy and optimize the overlap degree between anchor nodes.

Table 1:
Comparison of SMC localization schemes

Studies	Mobility model	Accuracy	Communication Cost	Computation Cost	Dependent on anchors
MCL	Waypoint	Low	Low	High	Full
MCB	Waypoint	Low	Low	Medium	Full
MSL*	Waypoint	High	High	High	Partial
LCC	Waypoint	High	Medium	High	Partial
WMCL	Waypoint	Medium	High	Low	Partial
COMCL	Waypoint	High	High	Low	Partial
RMCB	Waypoint	High	Medium	Low	Partial
IMCL	Waypoint	High	Medium	Medium	Partial
Orbit	Waypoint	High	High	High	Partial
EDAL	EDAL	Medium	Low	Medium	Full

The localization accuracy in pervious schemes is improved by increasing the anchor node density and by utilizing normal node location information as presented in Table 1. However, increasing the anchor node density will increase the cost, size, power consumption and the connectivity of anchor node. Moreover, the location information of normal node is susceptible to present of error (its estimated location) and will maximize the communication cost in the network. Thus, the efficient distribution in EDAL can control the number of anchor nodes in the neighbors to increase the anchor node coverage and improve the localization accuracy.

2.2 Mobility Model

A mobility model is a design that models the changes ofsensor node location, velocity, direction and acceleration over time. This changes will rapidly modifies the topology in mobile WSNs[7] that in a period of time will affect network coverage and connectivity [16]. Generally, mobility models can be categorized as random, predictable, and controlled. The detailed comparisons, strengths, and challenges of the mobility models in the literature are discussed in[27-29].

An adequate investigation with at least one sensor node is essential in WSNs. This issue is mainly because of the movement of sensors can affect the coverage area in two ways. The optimistic way is to transfer the mobile sensor to more discovered areas, communicates with the isolated sensor, and extends network life[30]. However, nodes in static networks use the same routing path all the time to communicate with the sink, which consumes more power of sink neighbors and causes a split between the network and isolated sink node. The negative approach of the movement originates from the data lost in the handover process when the network disjoints into two parts. Moreover, sensors with high-speed movement can frequently disconnect and decrease network performance and stability.

The waypoint model permits the mobile sensor to move forward independently from its neighbors and its previous position. Hence, the movable sensor chooses its direction and velocity randomly without any correlation to its neighbors [8]. Such movement flexibility may not be the cases for certain applications such as speed of vehicles, disaster relief, battlefield, and other applications. The fact is that there are applications that movement can be controlled and a level of dependencyoccurs between the velocity of the nodes in the neighbors[31,32]. Another drawback of the waypoint model is the convergence of nodes close to the center of the simulation area[33], which decays the velocity of the respective nodes [34,35].

In the previous literature, the waypoint model was typically used in range-free localization schemes [16]. The main properties of waypoint model is the sensor node only retainedthe maximum and minimum velocities due to a small memory capacity, and this simplicity has led to its usage in most of the previous studies. Pause time is an important parameter in the waypoint model [36]. In the waypoint model, the pause time is set to zero, in which the sensor nodes move continuously without pausing time.

The movement of sensor node is highly dependent on the reference point or leader in the reference point group mobility model (RPGM). However, the election of the leader requires a long process, and the loss of the leader will affect the robustness and stability of the networks. Another issue in the RPGM is that each sensor node must request the leader for direction and velocity of movement in each time slot [8], which increase the communication cost in the networks and overhead for the leader. Therefore, RPGM is only suitable for specific application, such as museum visitors and conference members[37].

The inefficient distribution in the random waypoint and high dependency in RPGM mobility models maximizes the overlap between anchor nodes without improving localization accuracy. Based on this observation, we proposed localization scheme EDAL to control the movement of the anchor nodes based on the number of anchors in the neighbors and the degree of overlap between the anchor nodes.

3. Proposed scheme EDAL

Generally, mobile anchor nodes are used in the range-free schemes to aid location estimation of the blind node. Thus, the anchor nodes distribution is a critical issue in the localization process. An efficient distribution can increase the coverage of anchor nodes and network connectivity with minimum number of anchor nodes, while a weak distribution will leads to an excessive anchor nodes that will increase cost and energy consumption[33].

The overlap between sensor nodes is a critical issue in WSNs connectivity. The minimum overlap is important in maintaining connectivity and conserving the robustness of the networks. In contrast, a large overlap produces redundant messages and consumes extra energy without improving localization accuracy. Another critical issue in the localization process is a number of anchor nodes in the neighbors. A typical localization process in 2D space requires three anchor nodes in the neighbors to estimate a blind node location[10][40].

Based on these observations, we implement an efficient localization scheme to distribute the anchor nodes with an optimal overlap degree. The main challenge when the anchor node has the flexibility to move randomly is that the blind node can find more than three anchor nodes in the neighbor or two anchor nodes with large overlap degree as depicted in Fig. 1[10,38]. The EDAL scheme can effectively resolve this problem by correlating the velocity of the anchor nodes and the anchor node number in the neighbors with its overlap degree. The optimum value of velocity can maintain the robustness of the WSNs and increase the coverage areas.

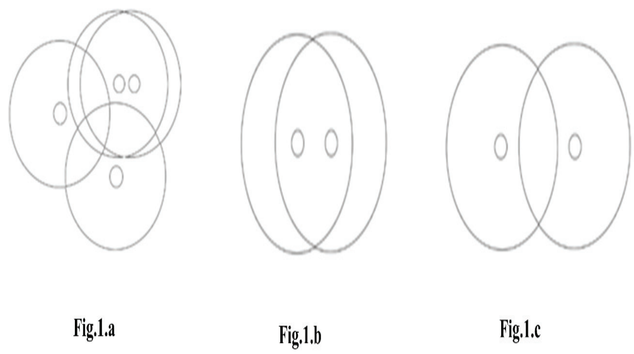

Fig.1.a

More than three anchor nodes in the neighbor

Fig.1.b

Two anchor nodes with extra overlap

Fig.1.c

Two anchor nodes with optimal overlap.

The velocity of the anchor node in EDAL scheme is set to maximum velocity (max-v) if a large overlap exist or more than three anchor nodes occur in the neighbors, whereas the minimum velocity (min-v) is chosen if small overlap occur, another velocity choose according to overlap degree (distance between anchor node) as presented in Algorithm 1. A small distance between two anchors nodes indicates a large overlap exist, whereas a large distance indicates a low overlap occur. Based on our simulation results, the distances between anchor nodes in the neighbors are divided into five periods and the velocity is associated with it, as in Algorithm 1. In this study, we used the minimum overlap of 1.73R as in[10].

Algorithm 1. A framework of EDAL localization algorithms.

Initial phase:

1. Find the number of anchor node in the neighbor (NA)

2. Calculate the distance between anchor nodes in the neighbors (The overlap degree (OD))

Velocity calculation phase:

If NA >= 3 or OD<=0.25R then velocity= max_v;

Else if OD> 0.25R and OD<= 0.50R then velocity= max_v * 0.75;

Else if OD> 0.50R and OD<= 0.75 R then velocity= max_v * 0. 50;

Else if OD> 0.75R and OD<= R then velocity= max_v* 0.25;

Else if OD> R and od< =1.75 R then velocity= min_v;

If OD < 1.75R then velocity= selected randomly;

Where R is the communication range, max_ is maximum velocity and min_v is minimum velocity.

4. Experimental setup and results

We tested the performance of EDAL scheme using various simulation parameters to verify its efficiency and compared it with previous localization schemes: MCL, MCB, MSL*, WMCL, and WMCLB schemes. The Java-based simulator code of MCL, MCB, and MSL* are received from the original authors, whereas WMCL, WMCLB and EDAL are implemented in the same simulator code provided by MCB authors[20].

4.1 Experimental setup

The normal nodes were set to move randomly based on the waypoint model and the anchor nodes were set to move based on the EDAL assumption. Anchor node density (Ad) is the number of anchor nodes in the first and second hops, whereas normal node density (Nd) is the number of anchor and normal nodes in the first hop.

In this experiment, the MCB scheme was selected to measure the performance of EDAL because it uses only anchor nodes observation in the localization process while other schemes use both anchor and normal nodes to improve localization accuracy. The use of normal nodes can increase communication costs and the overhead in the networks, moreover the location information of normal node is estimated location that impeded with the present of error. For these reasons, MCB was selected to measure the coverage of EDAL. Moreover, the MCB scheme also has an advantage over MCL in sample efficiency.

The EDAL scheme includes three important parameters: the degree of overlap between anchor nodes, the density of anchor nodes, and the velocity of the anchor node. The effect of each parameter is measured by several simulation tests and compared with MCB scheme over two different mobility models: waypoint and RPGM. The appropriate parameter values are selected and applied in the simulation.

The value of each parameter is calculated by executing 30 networks randomly. We simulated 1,000time units in each network, and then the time unit was averaged between 600 and 1,000 to assess each value. Each data point presented in this study was averaged by 30 independent experiment results. Other important parameters used during the simulation were the boundary of simulation area, which was set as 500 unit*500 unit, and the communication range (R) for anchor and normal nodes at 50 units. Time is a discrete time unit. In the initial setup, all sensors were distributed randomly over the simulation area. The pause time is set to zero, max-v is 0.2R, the number of samples is 50, Ad = 1and Nd =10, and the minimum overlap is 1.73R.

4.2 Experimental Results

The experimental results are described in two sub-sections. The first sub-section describes the coverage of the EDAL scheme in different overlap degrees and different anchor node densities. The second sub-section explains the measurement value of location accuracy in different velocity values, anchor nodes, normal nodes densities, and degrees of irregularity. Note: the MRPGM and M Waypoint means MCB scheme using RPGM and waypoint mobility model, respectively.

4.2.1 Coverage of EDAL scheme

The degree of overlap is measured by Euclidean distance, in which the small value of this similarity measure implies a large overlap between the anchor nodes and vice versa[10]. For example, a distance value lower than 0.1R indicates a substantial overlap, whereas a distance value near than1.73R indicates the optimal overlaps. The threshold value of the overlap degree is essential in ensuring the network stability. In this study, the threshold value of the overlap was set at1.73R as in [10].

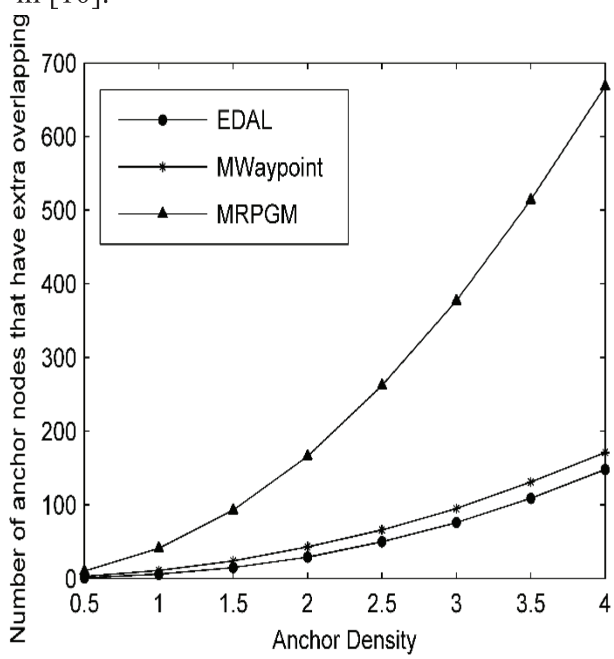

Fig. 2.

The relationship between anchor density and a number of anchor nodes with extra overlap.

The possibility of large overlap occurrence between the anchor nodes or finding more than three anchor nodes in the neighbors increase when the density of anchor nodes increases, as shown in Fig. 2. However, EDAL uses control velocity with the overlapping degree to optimize these overlaps and maximizes the coverage area with the same number of anchor nodes when compared with localization scheme using waypoint model. The inefficient distribution of anchor nodes in the waypoint and RPGM models increase the number of anchor nodes that have extra overlap. The group coherent almost requires minimum distance between neighbors that can produce huge overlap, as in RPGM. In the RPGM model, the increased of anchor node density can enormously increase the overlap degree because the localization parameters: velocity and direction of the anchor nodes are maintained based on the group leader decision.

Table 2:

Number of anchor nodes with extra overlap.

Mobility Model	Localization scheme				
	MCL	MCB	MSL*	WMCL	WMCLB
RPGM	41	41	42	42	41
Waypoint	10	11	10	10	10
EDAL	6	6	6	5	6

Different localization schemes (MCL, MCB, MSL*, WMCL, WMCLB) are used to examine the efficiency of the EDAL. The performances of these schemes are listed in Table 2 and 3. Table 2 presents the number of anchor node with extra overlap degree in different localization scheme based on RPGM, waypoint mobility models and EDAL assumption and Table 3 presents the localization accuracy. The number of anchor node with large overlap is highly affected by mobility model type and slightly affected by variation of the localization scheme. These results showed the importance of controlling anchor node velocity in its distribution. EDAL can optimize the number of anchor node with extra overlap degree in each localization scheme with 50% while maximizing the coverage area as compared to the waypoint model. The RPGM model has the highest number of extra overlap degree in all schemes.

Table 3:

Localization accuracy in different schemes.

Mobility Model	Localization scheme				
	MCL	MCB	MSL*	WMCL	WMCLB
RPGM	0.55	0.54	0.42	0.48	0.39
Waypoint	0.56	0.56	0.31	0.38	0.40
EDAL	0.51	0.51	0.28	0.34	0.35

Similarly, the results in Table 3 showed that the localization accuracy can be improved by controlling the anchor nodes velocity. The performance of the EDAL attained the highest localization accuracy among the tested schemes.

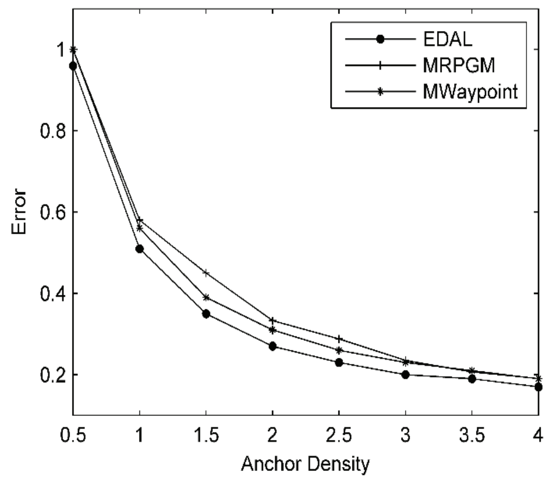

Fig. 3.

Anchor node density and localization error.

The increase of anchor node density can improve the localization accuracy in all schemes, as shown in the figure 3. EDAL is capable of improving the localization accuracy faster in all cases with optimal number of anchor nodes. In the MRPGM, the localization accuracy is less improved because the blind node requires to ask the group leader for location information per each time slot. The localization accuracy in the Waypoint also improved less when compared with EDAL.

From this results, we can show the important of anchor node distribution and how much the random movement can produce large overlap without improving the localization accuracy.

4.2.2 Localization Accuracy

Accuracy is the most important parameter in the localization process. For this, the accuracy of EDAL scheme measured based on the effective parameters: anchor node density, normal node density, velocity, and degree of irregularity.

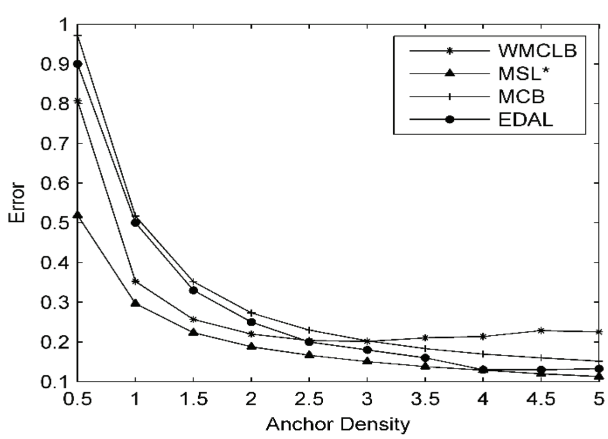

Fig .4.

Accuracy and anchor node density.

Anchor node density: In Fig. 4, the localization accuracy of EDAL and MCB rapidly improved with the increasing of anchor nodes density because they draw observations primarily from the anchor nodes. Other schemes that draw observations from the anchor and normal nodes, such as MSL* and WMCLB, are less affected by the increment of anchor node density. Nevertheless, the increment of anchor node density can be reflected negatively in the power consumption and dependency on hardware such as GPS. EDAL has a capability to improve the localization accuracy comparable with other schemes in the case of large anchor nodes density, results in Fig.4 show that at the anchor node density equal to 4, EDAL can improve the localization accuracy more than other schemes even it use normal node location information like MSL* and WMCLB.

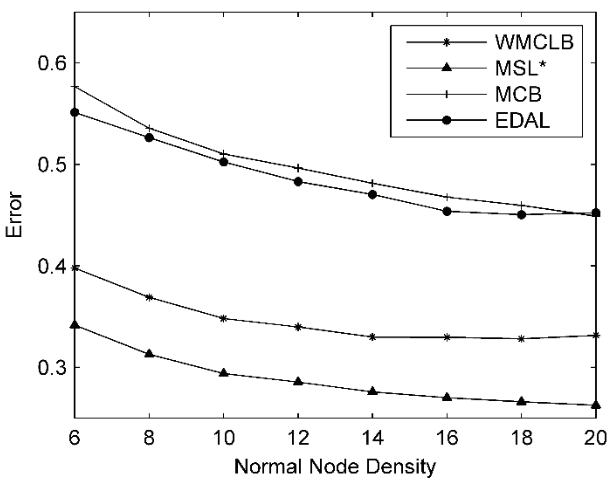

Fig. 5.

Accuracy and normal node density.

Normal node density: Localization accuracy can be improved with the increment of normal node density, as shown in Fig.5.The observation on EDAL and MCB only shows small percentage of improvement when the normal nodes increases. This is because both methods broadcast the location of anchor nodes to the first and second hop sensors in the neighbor. However, MSL* and WMCLB shows the opposite reaction because they draw observations from both anchor and normal nodes in the neighbors. MSL* is more effective than WMCLB because it uses all normal nodes samples in the first and second hops to draw observations with high communication costs. WMCLB uses bounded box over normal nodes to improve sampling efficiency and filter out the invalid samples. Thus, it is more sensitive to changes in normal node density.

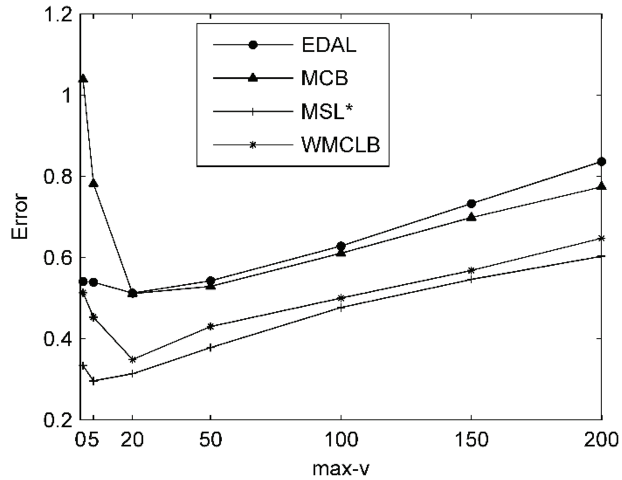

Fig. 6.

Accuracy and velocity of sensor nodes.

The velocity of nodes: Fig.6 shows that the movement of sensor nodes can improve the localization accuracy by receiving new anchor nodes and finding more observations. Movement with limited velocity can further improve the localization accuracy because the blind node can use some previous location information in the last time slot. A thigh-velocity, sensor can move to a farther distance from the previous location, thus the location information in previous time slot cannot improve the localization accuracy. Fig.6 shows that all schemes have high accuracy at velocity equal to 20.This value is used throughout this study as default value for velocity.

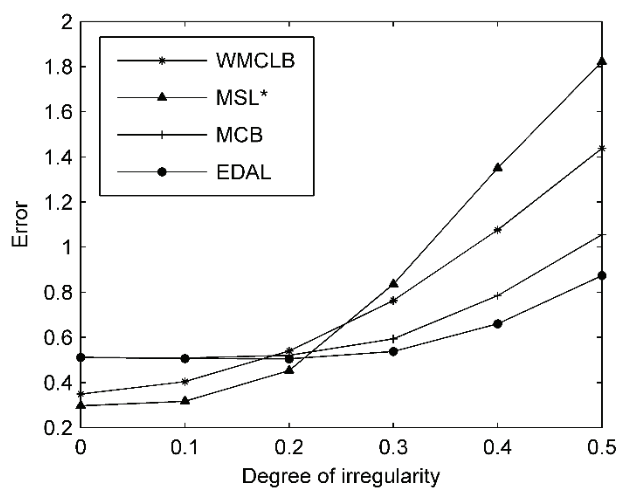

Fig. 7.

Accuracy and degree of irregularity.

The degree of Irregularity (DOI): Fig.7 shows the effects of DOI on localization accuracy wherein the increase of DOI minimized the localization accuracy in all schemes. However, in real-world applications, the signals can be interrupted by noise and affected by antenna direction and natural phenomena such as humidity and walls. In some cases, the distance between two sensor nodes is nearly half the radio range; in this case, they cannot communicate because they share a large variation of radio range. A full circle in EDAL was used during the experiments to present the communication range of the sensor nodes.

5. Conclusions and future work

The random velocity used in previous schemes based on waypoint mobility model has a large overlap between the anchor nodes that consumed more power and reduced the coverage area without improving the location accuracy. However, the EDAL can distribute the anchor nodes efficiently using the adaptive velocity with overlapping degree between the anchor nodes in the neighbors. Nevertheless, the patterns of movement remains an open research area in mobile WSNs. In future, we intend to extract the features of the mobile node movement from the real experiment and implement EDAL in real experiments to measure its efficiency.

Acknowledgments

The authors thank the University of Malaya for the financial support (UMRG Grant RP036A-15AET) and facilities to carry out the work. Also, deepest appreciation to Hu, Evans, Rudafshani, Datta, and the management and staff of al-Quds Open University.

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