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Wireless Sensor Network Localization Techniques Performance

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ABSTRACT: A large number of inexpensive, small sensors make up a wireless sensor network. The collection and transmission of data is one of the crucial functions of a sensor network. In the greater part of the applications, it is of much interest to figure out the area of the information. Localization methods can be used to obtain this kind of information. Therefore, node localization is very important when using localization algorithms to determine the position of a node. As a result, WSN node localization emerges as one of the primary obstacles. The localization schemes can be broadly divided into two groups based on range measurements, such as: range based and range free plans. Range-based localization techniques cannot be used due to the sensing node's hardware limitations and high cost. Since coarse accuracy is sufficient for most sensor network applications, range-free schemes are being considered an alternative. The performances and accuracy of the range-free algorithms were tested with the application of MATLAB 2017a. The results demonstrated that the amorphous algorithm has the lowest localization error in most cases in comparison to the performance of these four algorithms. Likewise, results demonstrated amorphous, and DV-hop algorithms have 100% coverage rate in every situation that were tested.

KEYWORDS: Wireless Sensor Networks; Localization Algorithms; Range Free Localization; and Range Accuracy.

INTRODUCTION

Sensing is a method that is applied in gathering of information of physical objects and series of events that occur, that is, changes that occur in such as pressure and temperature. The object that performs the task of sensing is term as a sensor. An example, human body are armed with sensors that can apprehend information about optics from acoustic devices (ears), environment (eyes) and so on[1]. In the 21st century, wireless micro-sensor networks were recognised among the most significant technologies that can developed the world [2]. The progress recorded in wireless communication and MEMS have led to the achievement/advancement of several function, less power, less cost, and smaller sensor nodes that can perceive the environment, then carryout data analysis and communicate with the outcome to the others within a minor remoteness.

There are very vast range of possible of uses of wireless sensor networks (WSN), such as object-tracking, scientific observation, traffic and environmental management, to mention but a few. In WSN comprises of one or more base stations/ sinks and thousands sensor nodes that communicates with each other wirelessly over a topographical location. The sensor node on their part they have their own numerous constraints that range from smaller memory, battery power duration and capacity of signal processing [3-5]. It is now possible to deploy large-scale wireless sensor networks with hundreds or even thousands of wirelessly connected sensor and actuator nodes, thanks to the miniaturization of small devices that can sense and communicate with one another[6]. The positioning of sensor nodes was normally done at random locations in WSN to be able to collect information and handover the data or information to other nodes. Localization otherwise termed as location estimation ability is crucial in the applications of WSN. The estimation of the location of sensors is normally carried out with prior knowledge of the location of some few sensors based on some parameters like time difference of arrival, distance, connectivity and angle of arrival[7]. the location estimation approaches nearly comprise of measurement-based, anchor-based, centralized-based, hop-based and distributed-based. There is a common problem in WSNs localization, which lessen the non-line-of-sight (NLOS) error that occurs in numerous cases. Therefore, nearly associated approaches are identified to proffer solution to localization error such as real-time performance and strong robustness[8].

There is various WSN simulation software which tend to have different features, strengths, and weaknesses. In this context, it is, therefore, necessary to evaluate various WSN localisation algorithms and the localisation software to obtain their optimum performance. It is against this backdrop; this research will present the state-of-the art on WSN localisation techniques and localisation software packages. Localization is one of the major problems faced by WSNs, because the data collected by the sensor nodes will be worthless until the location from where the data have been taken is discovered. In WSNs, large number of nodes are placed at random sites whose locations cannot be predetermined. The objective of

localization problem is to discover the positions of each sensor node in WSNs [9].
The essence of this research study is to carry out a wide range of research on the range-free localization methods for the wireless sensor network and ascertain their strength and weakness. And an experimental simulation with the help of MATLAB will be used to determine their performances. Researchers are looking for new ways to improve estimation accuracy as the demand for location estimation that is more accurate while requiring the least amount of complexity grows. Utilizing all available information to its fullest potential is one method for enhancing performance. One of these techniques is collaborative localization. Target sensor (TS) cooperation is now a crucial tool for better system performance [10].

2.0 RELATED REVIEWS

A WSN is a network with little infrastructure. It is composed of a large number of sensor nodes that work together to track events in a certain area. Both structured and unstructured WSN exist. In a structured WSN, the sensor nodes are configured in advance. The advantage of structured WSNs is their small number of nodes and cheap management and maintenance costs. In contrast, the unstructured WSN has a larger number of sensor nodes. Once deployed, these sensor nodes are not monitored. Because there are so many nodes, it is extremely difficult to discover network issues and malfunctions. Additional sensors, memory, CPU, an actuator, power source, and radio are all components of sensor nodes. The sensor nodes are typically installed in inaccessible areas, therefore the radio acts as a way of wireless communication. It facilitates information transmission to the base station [11]. Time synchronization, compression, coverage, data aggregation, security, and localization are just a few of the network services found in WSNs [12].
To address the issue of WSN node localization, a number of researchers have employed various optimization algorithms. Consequently, localizing the WSN's nodes with BOA variants 1 and 2 improves WSN accuracy. The proposed BOA variants 1 and 2 don't require any additional hardware, so the WSN won't be more expensive. In addition, BOA variants 1 and 2 converge more quickly and take less time to compute than the previous algorithms [9]. Figure 1 displays a common Simple WSN. The sensor area is made up of a target, numerous sensor nodes, and is connected to the user by a sink node

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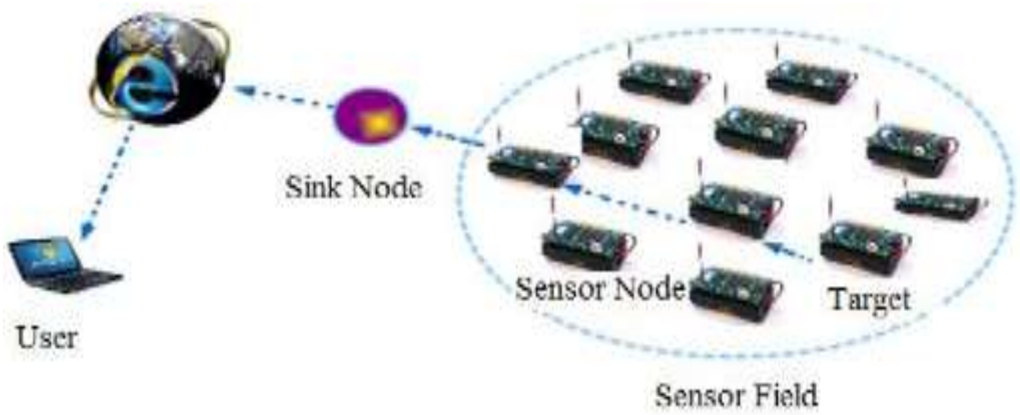


Figure 1. Wireless Sensor Network (Source: [13])

According to their computational paradigm, distributed and centralized localization systems or approaches are typically divided into two categories. 1. [5]

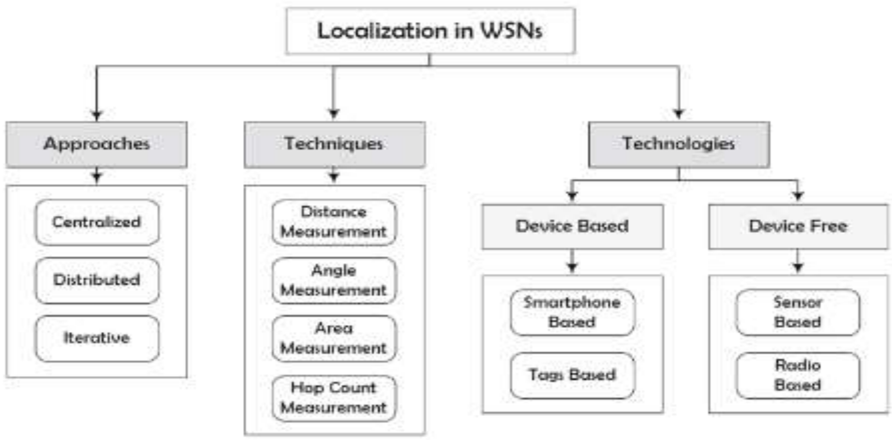


Figure 2. localization techniques[5]

WSN sensor networks are set up on land, in the ocean, and underground. WSN is faced with obstacles and restrictions. Mobile WSN, terrestrial WSN, underwater WSN, underground WSN, and multi-media WSN are the several types of sensor networks [10]. WSN are used in a variety of industries, including smart buildings, precision agriculture, vehicle tracking, environmental monitoring, health care monitoring, security, and surveillance.[14].Three elements make up the localization process: the localization algorithm, distance estimation, and position calculation. The relationship between two physical nodes that can be utilized to compute the nodes' positions is determined through distance estimation. Radio frequency (RF), directional antennas, fingerprint, distance bounds, and connectivity are the methods used. Along with received signal strength (RSS), angle of arrival (AoA) and time of arrival (ToA), they also provide round-trip time (RTT) and time difference of arrival (TDoA) [15].

The localization algorithm is crucial to the process of localization. It is used to figure out how to alter the data that estimates where each node in a wireless sensor network (WSN) is located. It may be dispersed or centralized [12]. According to [13], the hardware and software components of sensor nodes are divided into four categories: processors, radio transceivers, sensors, and power units. Tinyos, Nano Rk, and Contiki are the software components. Microprocessors, sometimes known as tiny CPUs, utilise a range of memory types to process information. The microprocessor's speed, power consumption, and voltage are its three key concerns. Sensors come in analog and digital varieties. The analog sensors continuously emit information, which is sent to the processing unit and then transformed for human consumption. Digital sensors, however, produce distinct data that is delivered for processing. [16].

3.0. METHODOLOGY

The performance of localization algorithms is determined by a variety of elements and network parameters, such as the model and deployment method, which is further classified as random, regular, or square random. Some anchor nodes and radio ranges can be used to compare various algorithms. Algorithm analysis can also take into account node density and connectivity. Thus, for better contrast among the range free techniques, localization error estimation must be addressed for all parameters. In this study, MATLAB 2017a will be used for numerical test simulation. Several simulation tests will be carried out to analyse and assess the overall performance of range-free localization algorithms under various experimental settings. The term "location estimation error" will be used in this study to assess the accuracy and efficiency of the algorithms under consideration.

One of the most difficult parameters in the range free algorithm is the location estimation error, also known as positioning error. Because range free localization methods are built without distance information but rely on radio connectivity, they are vulnerable to the challenge of larger estimation error. As a result, it is desirable to evaluate and compare the location estimation inaccuracy of at least four distinct and frequently utilized range free algorithms under different scenarios. To that end, the centroid, amorphous, APIT, and DV hop localization techniques will be simulated. The simulation will be designed to examine the performance of these algorithms in both a small setting of 100m × 100m and a bigger setting of 1000m × 1000m.

In various settings, small range sensors with communication ranges of 5m to 30m and bigger range sensors with communication ranges of 150m to 350m will be used. Small node deployments of 100 nodes and large node deployments of 1000 nodes will both be used. The researcher will create four experiments for each of the algorithms. As such, this simulation will provide a more thorough and detailed comparison of the four selected algorithms under broad conditions.

To acquire the position of unlocalised nodes, range-free localization methods commonly calculate the approximate distance to the anchor nodes using the real location. This reduces design costs by eliminating the need for additional hardware measuring devices. However, because range-free methods are based on topological information, the accuracy of average non-anchor node location is greatly influenced by anchor ratio, communication radius, node density, or node deployment [17].

4.0 SIMULATION PARAMETERS

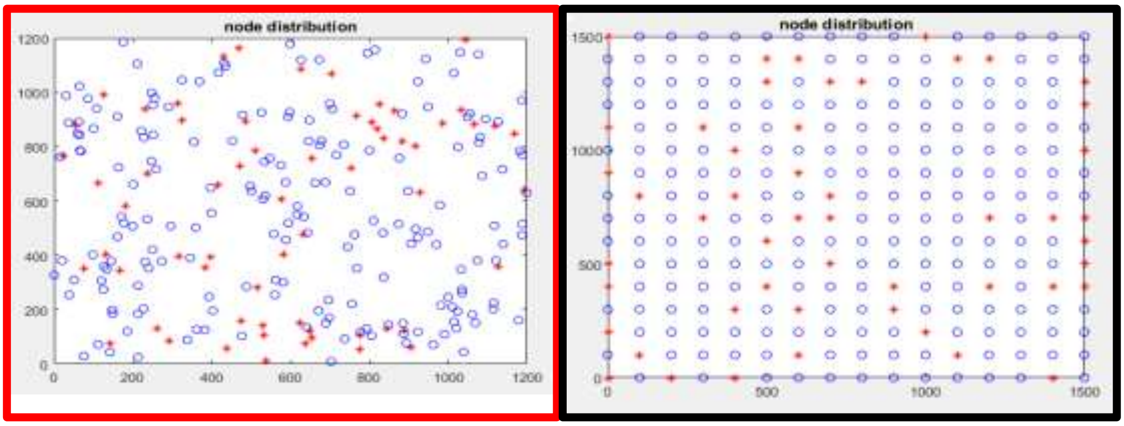
Several parameters that affect estimate error in range-free localization algorithms will be examined in the simulation experiments, and certain necessary assumptions on signal anisotropy will be described and made in accordance with those assumptions. The following is a description of these parameters:

a. Node Distribution

In the sensor field, this is referred to as Node Placement. There are two alternative ways to distribute or position nodes and anchors in a WSN. These are uniform and at random.

i. **Random Node Distribution:** As shown in the next graphics, fig 3, the simulation randomly places all nodes and anchors throughout the square landscape.

ii. **Uniform Node Distribution:** The space is divided into grids, nodes and anchors are evenly distributed throughout each grid.



(a) Random node distribution (b) Uniform node distribution

Figure 3. Sensor node distribution in WSN.

A distribution of nodes is shown in figure 3. This consists of 200 nodes spread out over 1200m x 1200m in Fig. 3(a) and 1500m x 1500m in Fig.3 (b), respectively, employing random and uniform node distribution. For each distribution, there are 50 anchor nodes. Anchor nodes are represented by the red 'x' and normal nodes by the blue circles represented with an 'o' in them.

4.1 Simulation Experiment

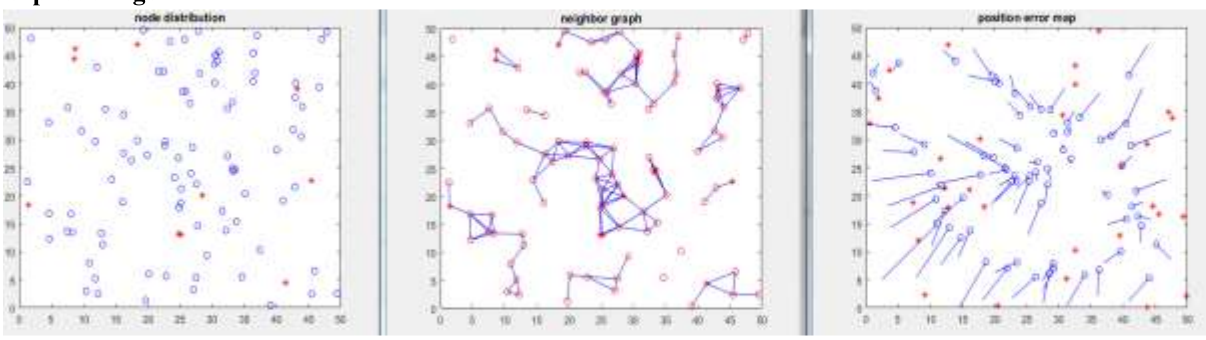
To get a reliable depiction of what each algorithm can accomplish under various circumstances, simulation tests were created. Each of the four algorithms was put to the test with different settings for associated variables like communication range, anchor ratio, deployment pattern, and deployment density. Accordingly, the effect of these metrics on the approximation of location error of each algorithm was examined. The tests in this section focus on the performance of individual algorithms. This is performed by adjusting the related parameters within the algorithm and testing how the algorithm reacts to different setups. A modest deployment area and few nodes were used, to measure the performance of the algorithms. As a result, the experiment parameters are as follows:

i. Area of sensor deployment = 50m x 50m,
ii. Sensor nodes deployed = 100,
iii. Anchor nodes = 10 and 30. ANR = 10% and 30%'
iv. Communication range = 5m and 30m.
v. Deployment = Random.

Four alternative simulation settings were created based on these inputs. The settings took into account the effect of communication range and anchor ratio on position estimate inaccuracy, as well as the number of anchors that could not be correctly localized. This configuration was subjected to two extreme scenarios. The simulations employed a low anchor ratio of 10% and a high anchor ratio of 30%, with low connectivity of 5m and high connectivity of 30m. These numbers were chosen to investigate the effects of weak and good connection, as well as low and high anchor ratios, on the localisation process by each of the four algorithms.

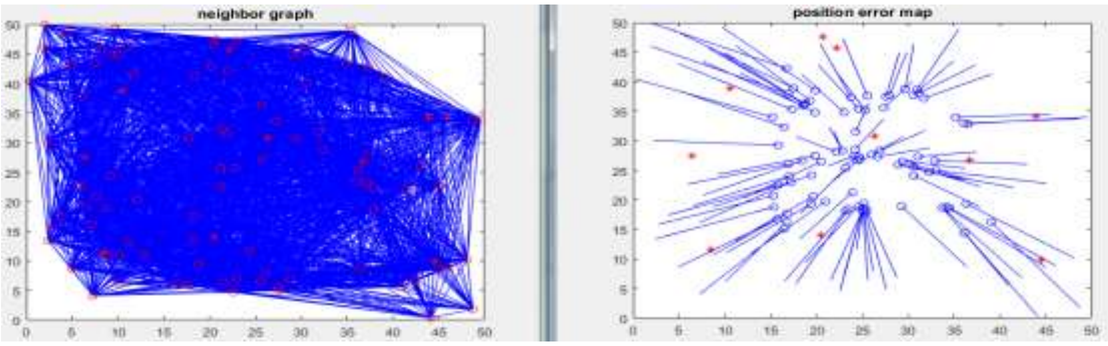
4.2 Results of the Simulation Experiments

4.2.1 Amorphous Algorithm

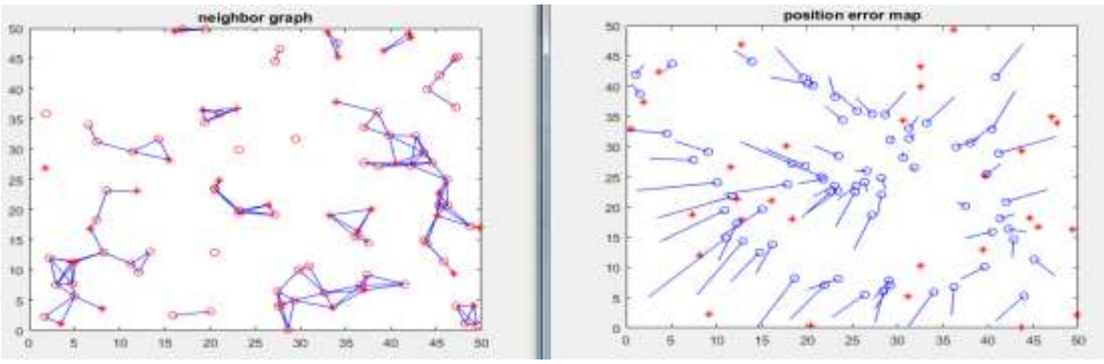


The average position estimation error was found to be 2.0902 but 100 % coverage

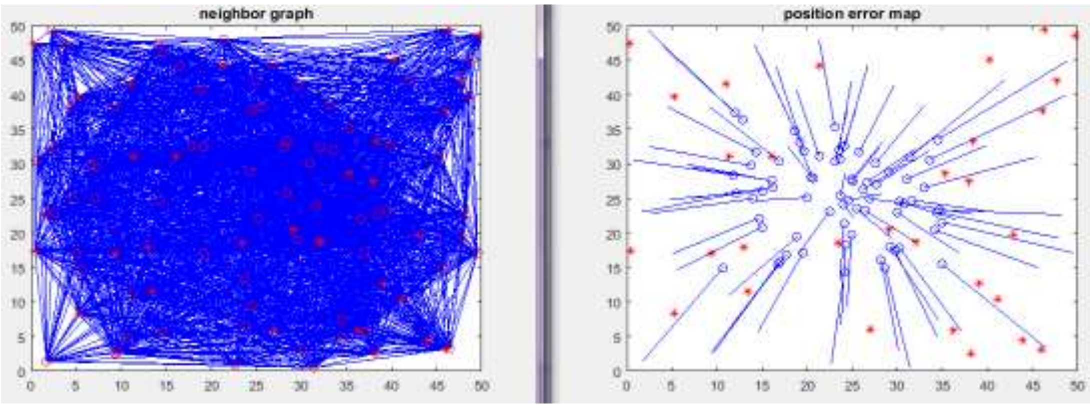
Figure 4.2.1(a) Random deployment with 10 anchors and 5m communication range.



The average position estimation error was found to be 0.30255 but 100 % coverage
Figure 4.2.1(b) Random deployment with 10 anchors and 30m communication range.



The average position estimation error was found to be 2.1297 but 100 % coverage
Figure 4.2.1(c) Random deployment of 100 nodes with 30 anchors and 5m communication range.



The average position estimation error was found to be 0.29095 but 100 % coverage
Figure 4.2.1(d) Random deployment of 100 nodes with 30 anchors and 30m communication range.

Figures 4.2.1 a and b show the position of the nodes produced at random, as well as the nearby connectivity network and position error map. Figure 5.2.1 (b-d) solely depicts the neighboring graph and the position error graph. This is due to the fact that the node distribution was random in all four tests. As a result, the random distribution graphs stay comparable, and the node distribution is omitted. The neighboring graph in all four results demonstrates how differences in communication ranges and anchor ratio can affect the performance of amorphous algorithms, in order to test each of the four algorithms' localisation processes with weak and excellent connectivity; low and high anchor ratios. The neighboring graphs in figure 4.2.1 (b and d) above showed very high connectivity since there were more connections available with more nodes. This is caused by the 30 m-long communication range. As a result, the results of the position estimation errors in these two figures (b and d) were significantly better than those in figures (a and c), where the connectedness in the neighboring network was very low and only a small number of nodes were connected to one another. Therefore, it is obvious that the amorphous algorithm must work satisfactorily and that a greater communication range of the anchor about the sensor field is necessary. When the anchor ratio is changed from 10 to 30, the positioning accuracy somewhat increases. However, based on the outcomes of the four simulations, the positioning for the coverage rate was 100% in every instance. This is one of the amorphous algorithm's best features. Therefore, it can be concluded that the amorphous scheme could localize all the blind nodes even with limited connection and few anchor nodes. However, as evidenced by the values of the average positioning errors, with varied degrees of precision. Similar outcomes were discovered in several studies, which point to a good amorphous coverage rate and minimal placement error when compared to alternative range free algorithms [18, 19]. The quality-of-service requirement of the application will determine the number of anchor nodes to be used and the type of communication rages the transmitters may employ, so applications that require complete localization of all the blind nodes can use an amorphous localization algorithm.

The average positioning errors were calculated and plotted as shown in figure 4.2.1(e), taking into account the impact of communication ranges on the performance of the amorphous algorithm. Using the same settings, 10 anchors and 30 anchors were simulated using various communication ranges from 5 to 30m.

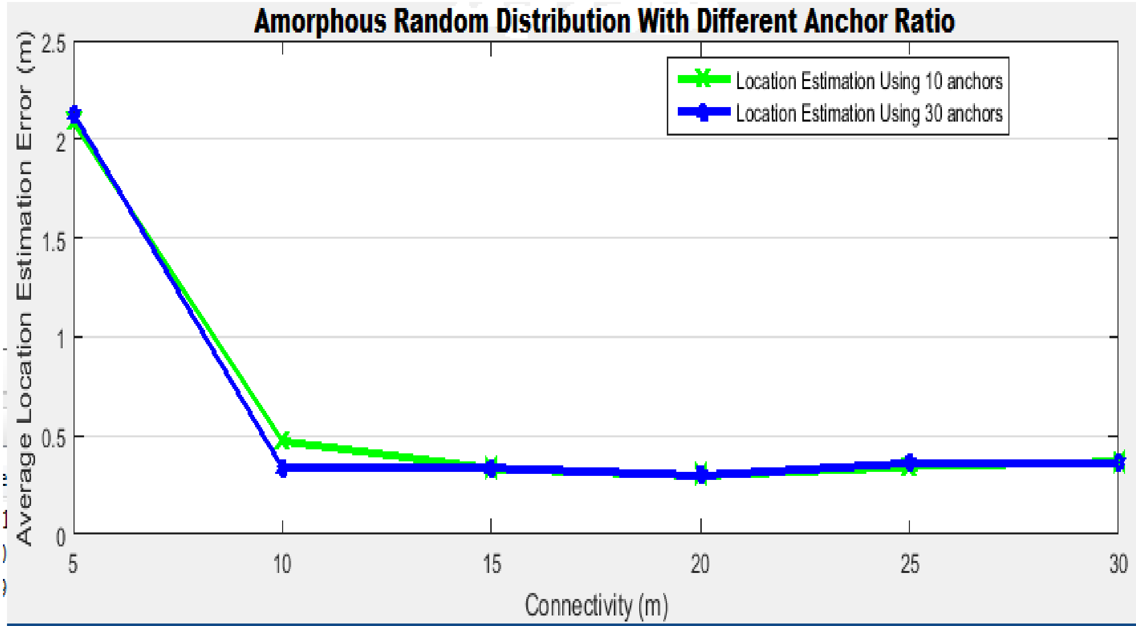
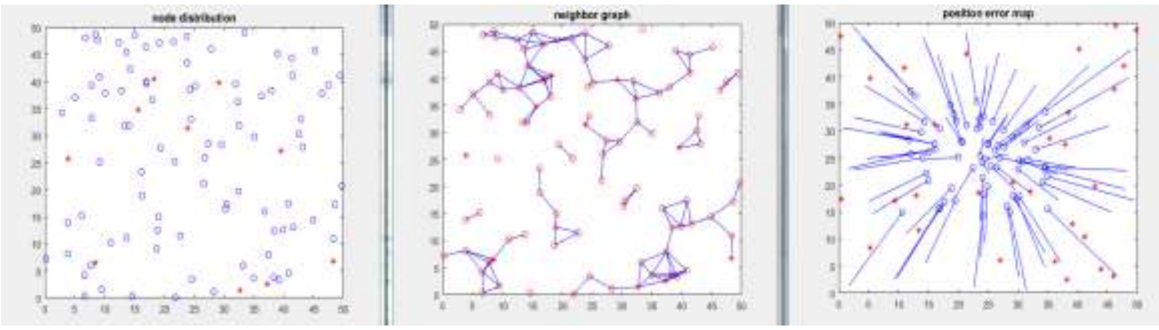


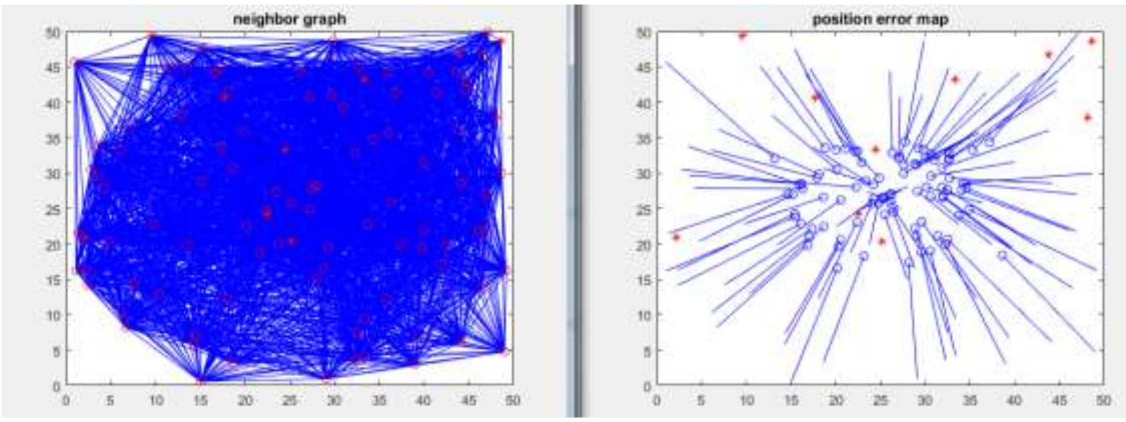
Figure 4.2.1(e). Positioning error graph of the amorphous algorithm.

According to the above graph, an amorphous algorithm could estimate a position in a space of about 100m × 100m using 100 nodes by using about 10% of the nodes as anchors and a communication radius of about 15m or 30% of the nodes as anchors and a communication radius of about 10m. However, the placement error only slightly improves when the number of anchors is increased from 10 to 30. In fact, the graph showed that regardless of whether the anchors make up 10% or 30% of the nodes, average position estimation remains the same for communication ranges above 15 meters. In the amorphous design, having fewer anchors but ones with greater communication range is more crucial.

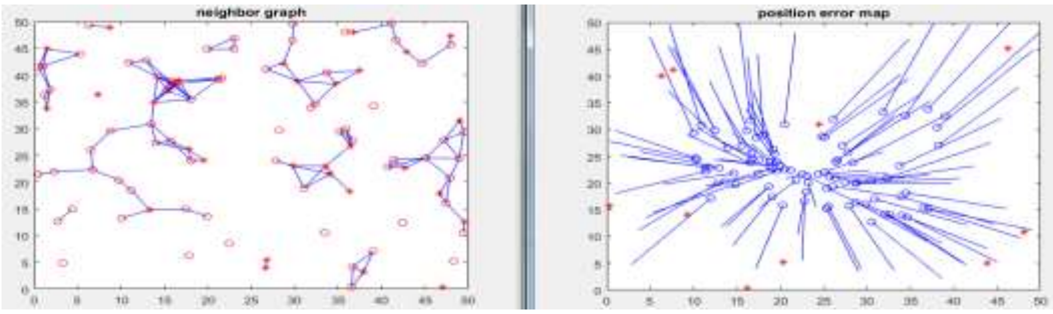
4.2.2 DV-hop Algorithm



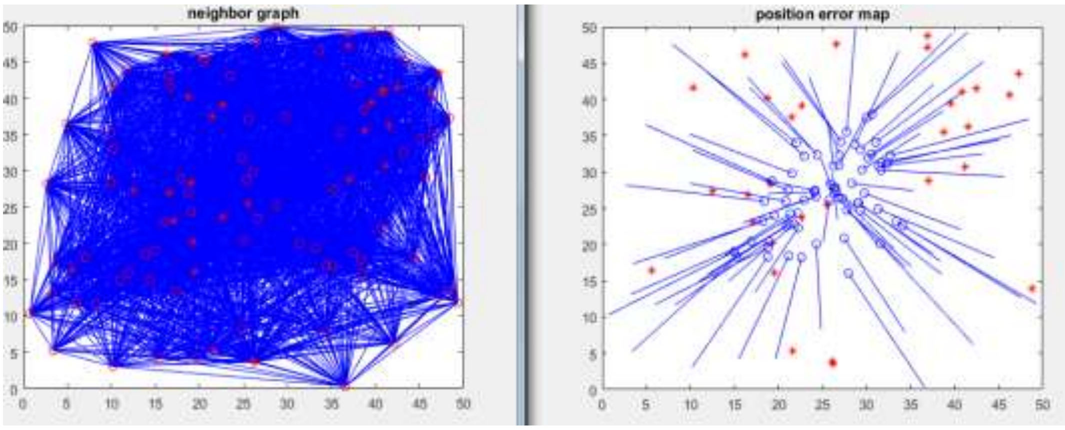
The average position estimation error was found to be 2.3725 but 100 % coverage
Figure 4.3.2(a) Random deployment with 10 anchors and 5m communication range.



The average position estimation error was found to be 0.43457 but 100 % coverage
Figure 4.2.2 (b) Random deployment with 10 anchors and 30m communication range.



The average position estimation error was found to be 0.8975 but 100 % coverage
Figure 4.2.2 c: Random deployment with 30 anchors and 5 m communication range.



The average position estimation error was found to be 0.4052 but 100 % coverage
Figure 4.2.2 d: Random deployment of 30 anchors and 30m communication range.

The outcomes of replicating DV-hop's performance were comparable to those of an amorphous algorithm. The positional coverage rate for the two algorithms is 100%. Communication ranges and anchor ratio both had essentially the same influence on average position estimate. On the other hand, it was discovered that the total location estimation errors in each of the four circumstances were more than those of the matching amorphous approach. The positioning error was around 2.372 when 10 anchors were utilized, according to the results obtained in figures 4.2.2 (a and c) when the communication range was 5m. When the anchor ratio was increased to 30, though, this fell dramatically, to roughly 0.897. This illustrates how, in order to reduce estimated location error, the DV hop algorithm depends on using more anchors at closer communication ranges. Contrary to amorphous algorithms, which only slightly alter the average predicted positioning inaccuracy at reduced communication radii, anchor percentages do not. The average position error findings were collected and presented in figure 4.2.2(e) below for the two distinct anchors ratios (10 and 30), which were simulated utilizing varied communication ranges for a better study of the DV-hop algorithm.

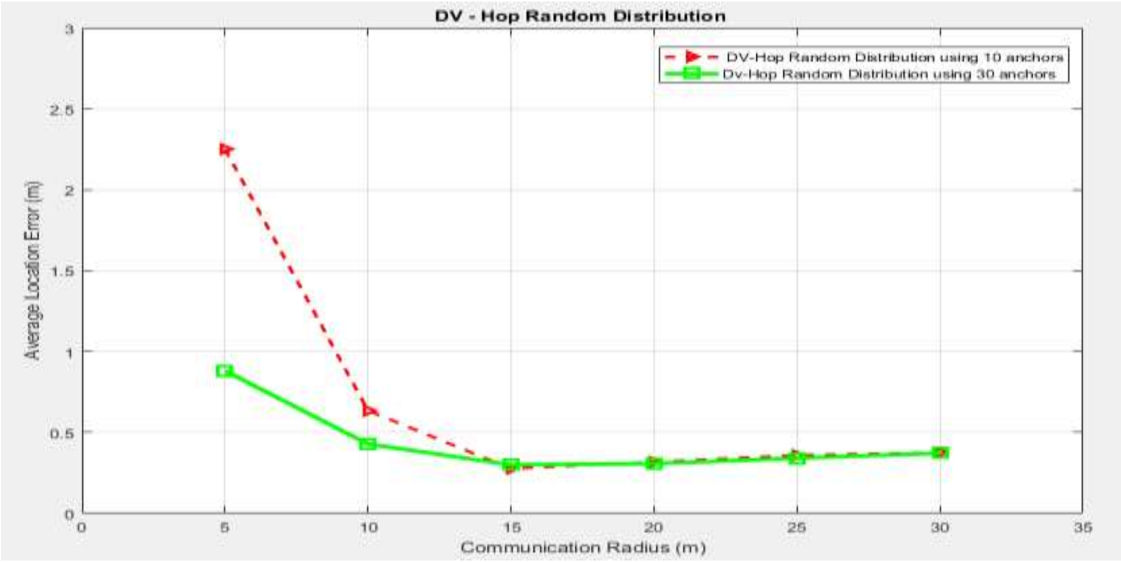


Figure 4.3.2(e). Positioning error graph of the DV-hop algorithm.

4.2.3 APIT Algorithm

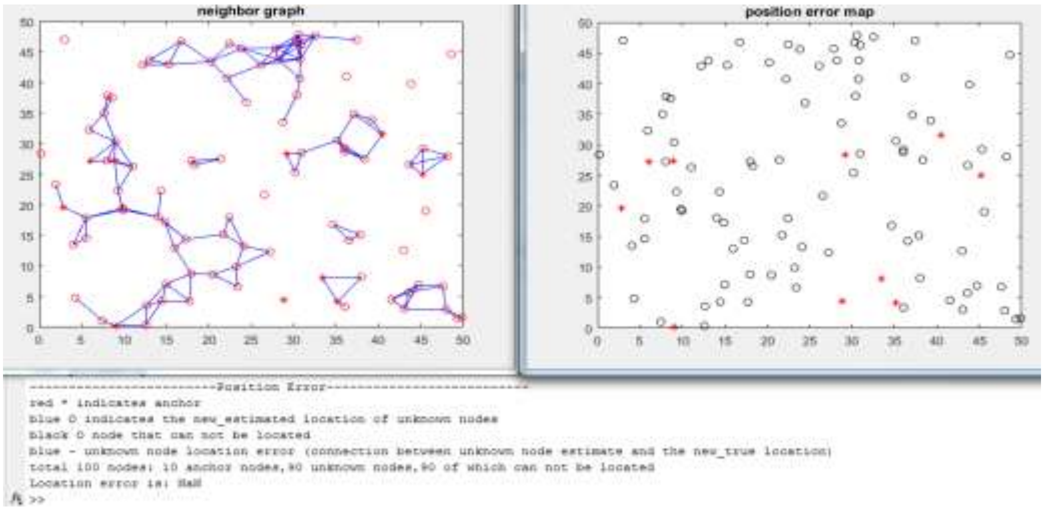
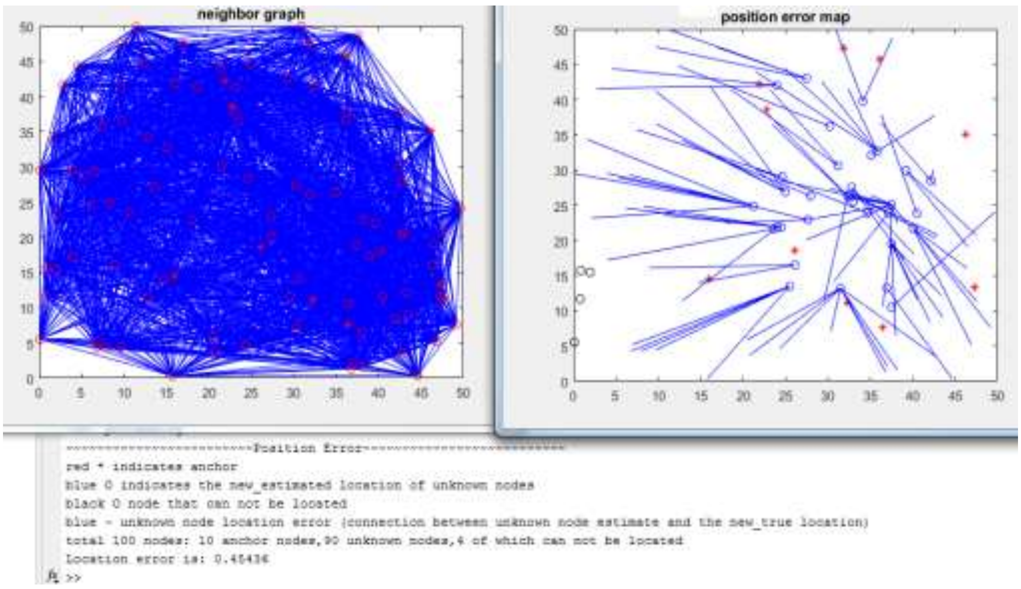
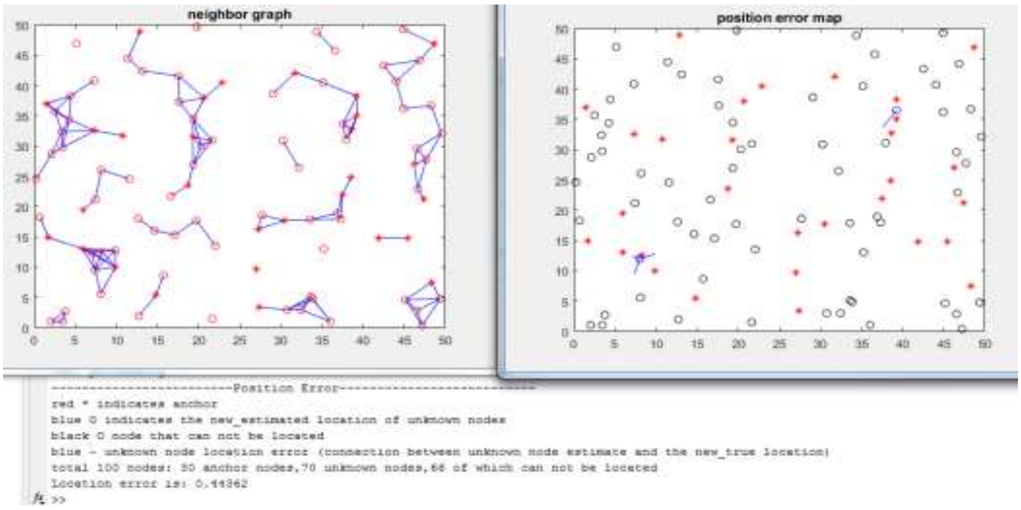


Figure 4.2.3 a: Random deployment with 10 anchors and 5m communication range.



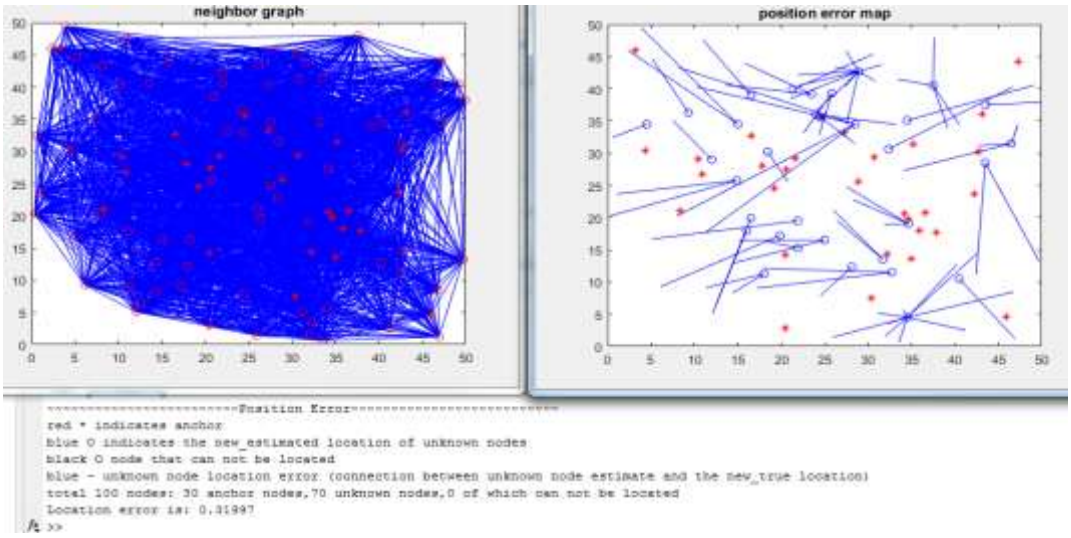
The average position estimation error was found to be 0.45436

Figure 4.2.3 b: Random deployment with 10 anchors and 30m communication range.



The average position estimation error was found to be 0.44362

Figure 4.2.3 c: Random deployment with 30 anchors and 5m communication range.



The average position estimation error was found to be 0.31997

Figure 4.2.3 d: Random deployment with 30 anchors and 30 m communication range.

In order to reduce estimated position inaccuracy, the DV hop algorithm relies on a greater number of anchors at shorter communication ranges. In contrast, the amorphous algorithm shows little change in the percentage of anchors at reduced communication radii for the average estimated positioning inaccuracy. The two distinct anchors ratios (10 and 30) were simulated utilizing various communication ranges for a better understanding of the DV-hop method. The average position error findings were obtained and presented in the figure 4.2.3(e) below.

The estimated position inaccuracy, however, was roughly 0.45. In situations where the placement of the node is not as strictly required, this result is acceptable. Figures (a and c) are two examples of how anchor ratio affects algorithm performance. Although both figures have a communication range of 5m, their respective anchor ratios are 10% and 30%. Figure (c) reveals that 66 out of 90non-anchor nodes were located, in contrast to figure (a), which shows that none of the non-anchor nodes were found. Consequently, APIT algorithm has higher computing demand and cost in terms of the required at a lower coverage rate and lower position estimate when compared to DV-hop and centroid. Coverage rate and location estimate error were simulated using various communication ranges in both the deployment of 10 and 30 anchors to provide a summary of the performance of APIT algorithms. Figure 4.2.3(e) and (f) show the outcome graphically.

Figure 4.2.3 e: Percentage of nodes not located with different communication ranges.

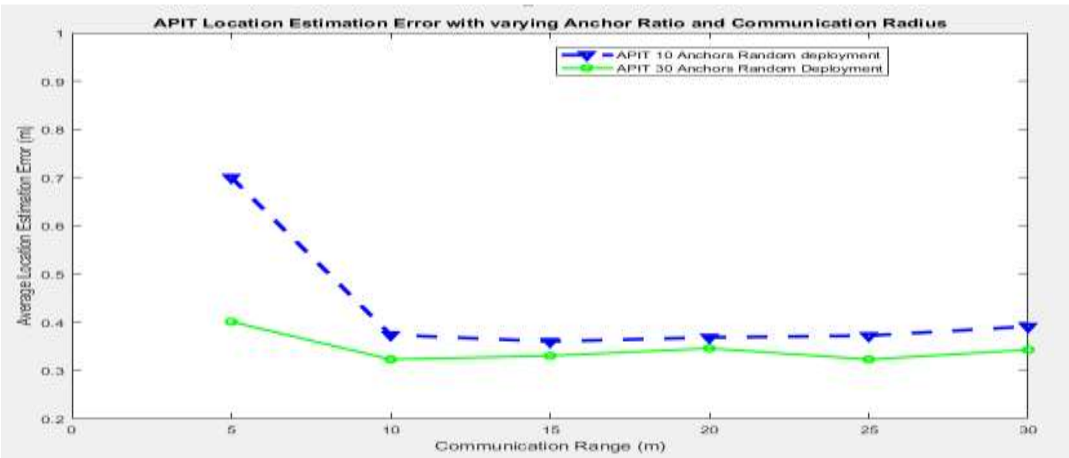
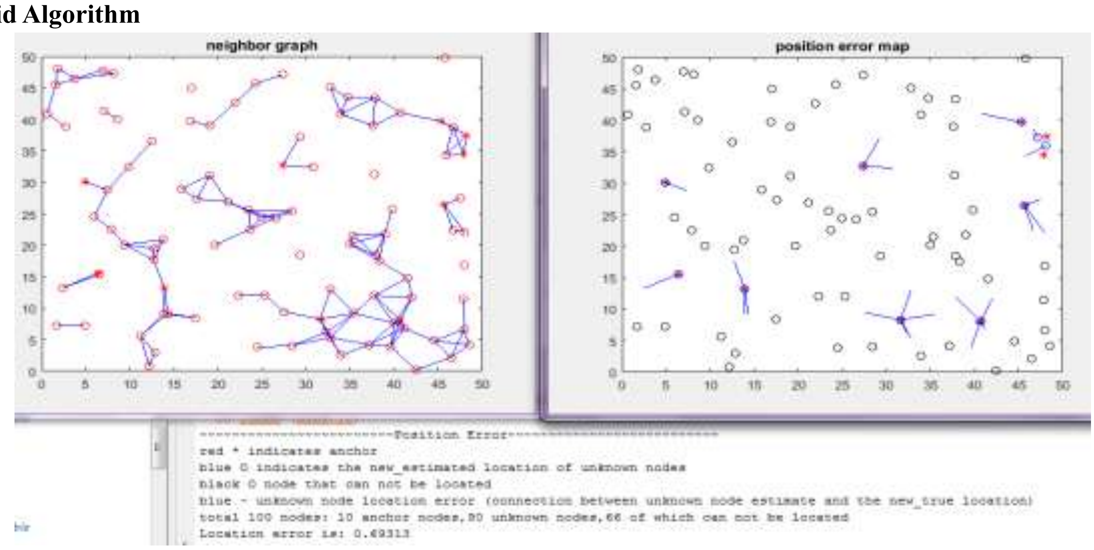


Figure 4.2.3 f: Average Location Estimation error graph.

According to the graph in figure 4.2.3e, a greater anchor ratio is needed to determine the locations of all the blind nodes. This is such that the blind nodes could not be situated entirely within the communication range of 5 to 30 meters, as shown by the graph of the 10% anchor ratio. On the other hand, employing 30% anchors, a communication radius of 20 meters or more could localize any node that wasn't an anchor.

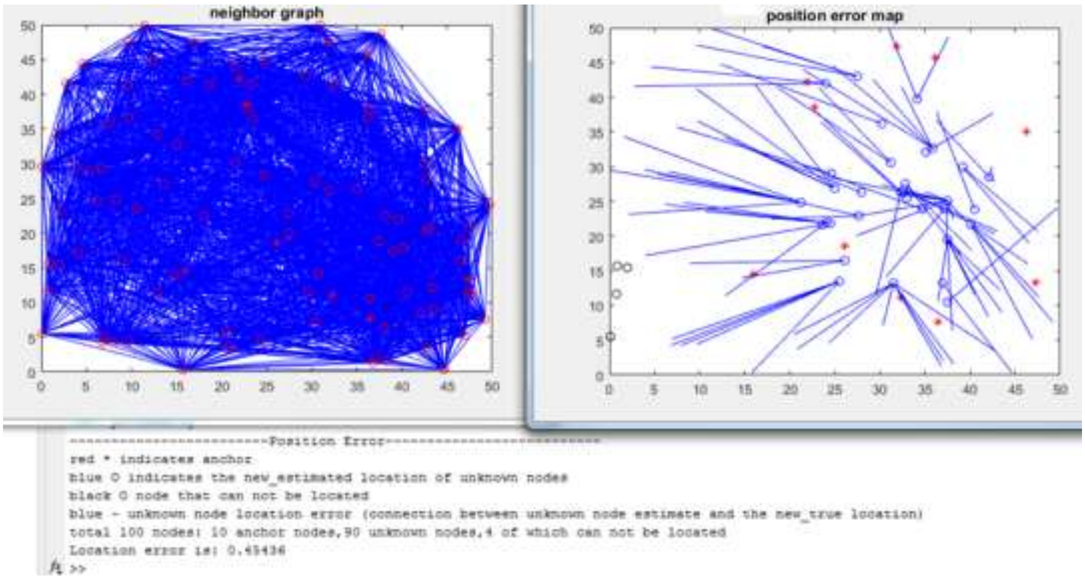
Analysis of the second graph in figure 4.2.3e, reveals that for each of the two anchor ratios, blind nodes that are effectively localized can be estimated to be in a place that is satisfactory from a communication radius of 10m and above. Therefore, to identify the APIT algorithm's optimal performance, both of the two graphs are needed.

4.2.4 Centroid Algorithm



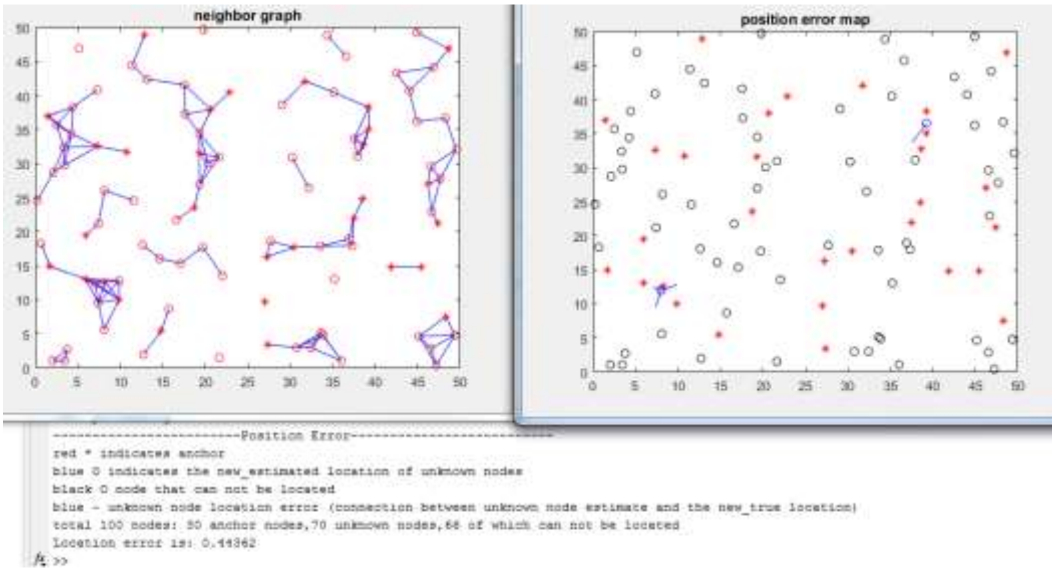
The average position estimation error was found to be 0.69313

Figure 4.2.4 a: Random deployment with 10 anchors and 5m communication range.



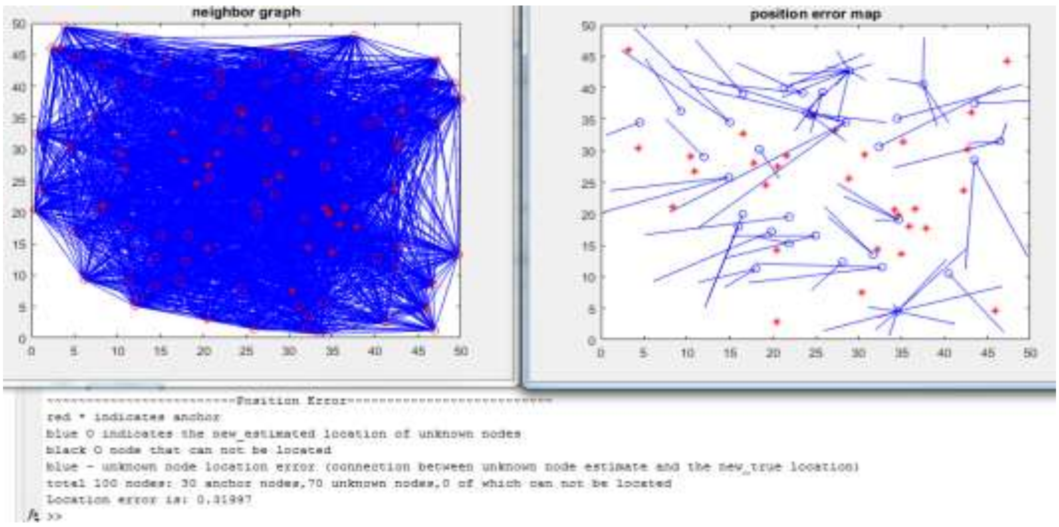
The average position estimation error was found to be 0.45434

Figure 4.2.4 b: Random deployment with 10 anchors and 30m communication range.



The average position estimation error was found to be 0.44362

Figure 4.2.4 c: Random deployment with 30 anchors and 5m communication range.



The average position estimation error was found to be 0.31997

Figure 4.2.4 d: Random deployment with 30 anchors and 30m communication range.

The performance of the centroid method is influenced by the coverage rate, just like the performance of APIT algorithms, and in some cases, part of the nodes cannot be properly localized. Figure 4.2.4 (a) demonstrates that 66 of the 90 non-anchor nodes could not be properly localized, while figure (c) demonstrates that 34 of the 90 nodes could. The lower communication radius of 5m causes this condition to occur. However, all of the nodes were properly localized when the communication radius was raised to 30 meters, as shown in figures (b) and (d), respectively. While at the same communication radius, their average location estimation reveals the tiniest distinction between the two anchor ratios. Overall, the centroid approach outperforms APIT in the same environment in terms of coverage rate and location estimation. Figure 4.2.4 (e and f) summarizes the performance of the centroid algorithm in terms of coverage rate and location estimation error.

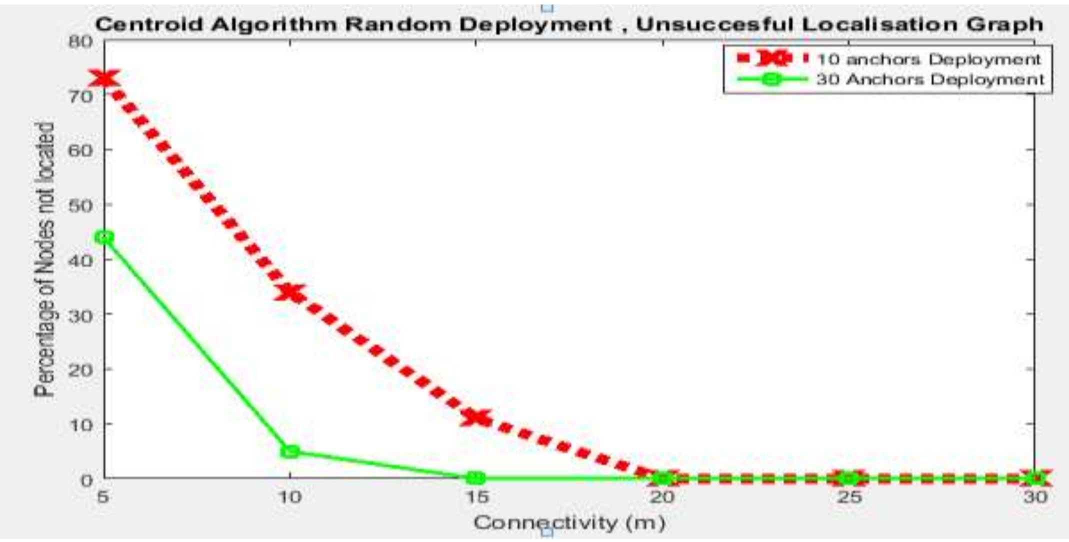


Figure 4.2.4 e: Percentage of nodes not located with different communication ranges.

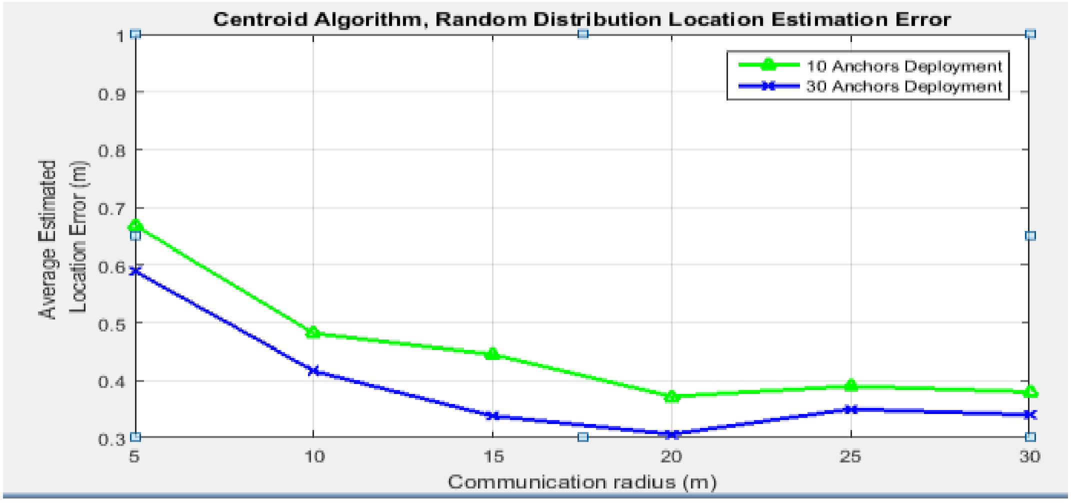


Figure 4.3.4 f: Average Location Estimation error graph.

5.0 SUMMARY

The simulation tests were conducted to evaluate the overall performance of the four algorithms under the identical conditions and to critically analyse the individual performance of each of the selected methods. The anchors may be tested in both a small deployment area of 50m x 50m and a wide area of 1km x 1km using the simulation experiment. The algorithms' location estimate error was examined utilizing various anchor ratios and communication radii. The findings show that the nodes' communication range and the number of deployed anchors can both have a significant negative impact on the localization algorithm's accuracy. Therefore, by deploying the necessary anchor to node ratio and employing the proper communication range, any algorithm may be modified to achieve maximum performance in a specific set-up. Therefore, in order to get the best performance out of any algorithm, the optimal configuration must always be determined, taking into account the financial advantages of the range free algorithm and the requirement for positioning accuracy. For instance, among the four simulated algorithms, the amorphous method could achieve the greatest localization performance when it has an anchor ratio of 15% and a communication radius of 200m in the prior environment where 250 nodes were randomly placed in an area of 1000m × 1000m.

5.1 CONCLUSIONS

Wireless Sensor Networks have the potential to provide a flexible approach to observe the surrounding environment, and respond to events. The availability of tiny battery-powered sensor nodes, embedded with sensing, processing, and communication capabilities, which are wirelessly networked together through multi-hop communication, increases the opportunities for WSNs to find applications in a wide range of areas. Along with the possibilities, there are also challenges and requirements for the successful localization, deployment, and operations of WSNs. Localization in wireless sensor network is one of the prime concerns for various event sensitive applications. The challenge of sensor node localization has been addressed through various algorithms. State-of-art localisation schemes divide the algorithms into centralised and distributed schemes. Their evaluations regarding accuracy, cost and robustness show that centralized are costly and sometimes they lack robustness. However, they appear to be more flexible because more rigorous algorithms can be implemented and more accurate than those of distributed algorithms. Distributed localization, is a very active field and are gaining more interest recently. They are relatively cheap, robust, can be used in both indoor and outdoor environments. The major drawback is the fact that computation has to take place within the nodes rendering the need for energy and resources unavoidable. The distributed algorithms are classified as range-free or range-based schemes based on connectivity information and range measurement techniques. Range based algorithms achieved better position accuracy, but their principle requires hardware such as speakers, microphones or RSSI. The hardware increased the cost, complexity and affected the flexibility of the sensor nodes. In comparison, the performance of these four algorithms, the results proved that in most of the scenarios amorphous algorithm has the minimum localization error. Also, results proved amorphous, and DV-hop algorithms have 100 percent coverage rate in all the scenarios that were simulated. However, it is commonly known that the efficiency and robustness of these algorithms strongly depend on different control parameters upon which they are simulated. On the other hand, Centroid and DV-HOP algorithms were also seen that they could achieve impressive localization accuracy under specific node density, anchor percentage, and radio range. On the contrary, APIT algorithm has the least accuracy of localization under some circumstances. Similarly, the results show that Centroid and APIT algorithms tend to have a very low coverage rate at lower communication radius relative to sensor area of deployment.

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REFERENCES

1. W. Dargie and C. Poellabauer, *Fundamentals of wireless sensor networks: theory and practice*. John Wiley & Sons, 2010.
2. M. Marien, "10 emerging technologies that will change your world," *IEEE Eng Manage Rev,* vol. 32, p. 20, 2004.
3. G. Fan and S. Jin, "Coverage problem in wireless sensor network: A survey," *Journal of networks,* vol. 5, no. 9, p. 1033, 2010.
4. P. Biswas and Y. Ye, "Semidefinite programming for ad hoc wireless sensor network localization," in *Proceedings of the 3rd international symposium on Information processing in sensor networks*, 2004, pp. 46-54.
5. I. Nemer, T. Sheltami, E. Shakshuki, A. A. Elkhail, and M. Adam, "Performance evaluation of range-free localization algorithms for wireless sensor networks," *Personal and Ubiquitous Computing,* vol. 25, pp. 177-203, 2021.
6. Q. Zhang, J. Wang, C. Jin, J. Ye, C. Ma, and W. Zhang, "Genetic algorithm based wireless sensor network localization," in *2008 Fourth International Conference on Natural Computation*, 2008, vol. 1, pp. 608-613: IEEE.
7. G. Mao and B. Fidan, *Localization Algorithms and Strategies for Wireless Sensor Networks: Monitoring and Surveillance Techniques for Target Tracking: Monitoring and Surveillance Techniques for Target Tracking*. IGI Global, 2009.
8. H. Suo, J. Wan, L. Huang, and C. Zou, "Issues and challenges of wireless sensor networks localization in emerging applications," in *2012 International Conference on Computer Science and Electronics Engineering*, 2012, vol. 3, pp. 447-451: IEEE.
9. S. S. Mohar, S. Goyal, and R. Kaur, "Localization of sensor nodes in wireless sensor networks using bat optimization algorithm with enhanced exploration and exploitation characteristics," *The Journal of Supercomputing,* vol. 78, no. 9, pp. 11975-12023, 2022.
10. M. W. Khan, N. Salman, and A. H. Kemp, "Optimised hybrid localisation with cooperation in wireless sensor networks," *IET Signal Processing,* vol. 11, no. 3, pp. 341-348, 2017.
11. J. Yick, B. Mukherjee, and D. Ghosal, "Wireless sensor network survey," *Computer networks,* vol. 52, no. 12, pp. 2292-2330, 2008.
12. H. P. Mistry and N. H. Mistry, "RSSI based localization scheme in wireless sensor networks: A survey," in *2015 Fifth International Conference on Advanced Computing & Communication Technologies*, 2015, pp. 647-652: IEEE.
13. S. P. Singh and S. C. Sharma, "Range free localization techniques in wireless sensor networks: A review," *Procedia Computer Science,* vol. 57, pp. 7-16, 2015.

14. S. J. Ramson and D. J. Moni, "Applications of wireless sensor networks—A survey," in *2017 international conference on innovations in electrical, electronics, instrumentation and media technology (ICEEIMT)*, 2017, pp. 325-329: IEEE.
15. A. M. Abu-Mahfouz and G. P. Hancke, "Localised information fusion techniques for location discovery in wireless sensor networks," *International Journal of Sensor Networks,* vol. 26, no. 1, pp. 12-25, 2018.
16. N. A. Alrajeh, M. Bashir, and B. Shams, "Localization techniques in wireless sensor networks," *International journal of distributed sensor networks,* vol. 9, no. 6, p. 304628, 2013.
17. I. F. Akyildiz, W. Su, Y. Sankarasubramaniam, and E. Cayirci, "Wireless sensor networks: a survey," *Computer networks,* vol. 38, no. 4, pp. 393-422, 2002.
18. S. Li, X. Ding, and T. Yang, "Analysis of five typical localization algorithms for wireless sensor networks," *Wireless Sensor Network,* vol. 7, no. 04, p. 27, 2015.
19. J. zeng Wang and H. Jin, "Improvement on APIT localization algorithms for wireless sensor networks," in *2009 International Conference on Networks Security, Wireless Communications and Trusted Computing*, 2009, vol. 1, pp. 719-723: IEEE.