FINAL YEAR PROJECT

Dissertation Report

GPS-free Localization technique using a Wireless Sensor Network

By

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Preliminary report submitted in partial fulfillment of the requirements for the Bachelor of Engineering (Hons)

(Electrical and Electronic Engineering)

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Universiti Teknologi PETRONAS

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31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

____

(Dr Azrina Abd Aziz)

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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SYEREEN ELSA BINTI SHAHARUDDIN

ABSTRACT

Improvements in localization based technologies have led to a growing business interest in location-based applications and services. Nowadays, locating the physical belonging indoor and outdoor environment become one of the application requirements. Localization is the technique to obtain the location information of objects. The location information of objects can be obtained by using wireless sensor networks in the sensor localization. Global Positioning System (GPS) is one of the device that use wireless networks to obtain location information. However, due to the expensive cost and it is unable to be used in indoor environment, an alternatives need to be figured out. Thus, the aim of this project is to build a reliable and cheaper local positioning system, which can function in indoor and outdoor setting. Literature review on some techniques has been done and from the review, the features, advantage and disadvantage of all techniques discussed are compared. The techniques that have been discussed in this study are time of arrival (TOA), time different of arrival (TDOA), angle of arrival (AOA) and received signal strength indicator (RSSI).Based on the comparison of 4 techniques above, the TOA approach has been selected to be focus further and will be implement in Matlab software for future work. The parameters are varied to compare the performance of node localization. By using the baseline value, the performance comparison is done by varying some parameters which are network area, numbers of anchors, anchors arrangements, and number of run. From the results obtained, four conclusions can be made. First, percentage of accuracy is higher with smaller network area. Second, less number of anchors will increase the percentage error, third, increase in the number of run will yield lower percentage error and the final one is the best topology of anchor are in hexagon arrangement.

ACKNOLEDGEMENT

First and foremost, I would like to praise and thanks Allah S.W.T for His blessings and the strength He granted me, I am able to complete my final year project within the allocated 8 months period in Universiti Teknologi PETRONAS (UTP).

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Not to forget, my parents, Shaharuddin Bin Ismail and Maryam Bt Fakhuradzi who are very supportive. Their encouragement and motivation has been one of the keys that strengthen me in completing this final year project.

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CHAPTER 1
INTRODUCTION

1.1 Background

Wireless sensor networks (WSNs) are one of the technologies that currently are broadly used in various environments and applications such as, in military applications, medical applications, and civilian domains. One of the most significant research interests of WSNs is the network localization. Localization is the technique to obtain the location information of objects. The position information is then transmitted to the base station via wireless transmission. Although this GPS system contributes to accurate location information, the drawback of using this system is that the expensive cost and cannot be used in indoor environment due to it necessitates line-of-sight from the receiver to the satellite.

Therefore, the challenge lies in building a reliable and cheaper local positioning system, which can function in indoor and outdoor setting. In order to realize this, there is a need to design a model that will detect and calculate the position of deployed node. In current era, there are many research works regarding the localization techniques to detect the location of the nodes. Some of these techniques are received signal strength indicator (RSSI), angle of arrival (AOA), time of arrival (TOA), and time difference of arrival (TDOA). There are advantages and disadvantages in the above mentioned localization technique. Thus, to ensure the localization of the nodes can accurately estimate, some of the techniques need to be studied and compared.

1.2 Problem Statement

The position of the device can be determined using WSNs. Global positioning system (GPS) is a common example of local positioning system that is widely used. GPS can provide accurate position information, but using GPS to locate object is expensive and since it needs line-of-sight from the receiver to the satellite, this system only works for outdoor environment. Hence, there is a necessity to build a reliable local positioning system, which can work for both indoor and outdoor environment.

1.3 Objectives

The objectives of the research are as follows:-

1. To study different localization techniques for WSNs
2. To compare the features of localization techniques and decide the best technique based on research.
3. To implement one of the localization techniques in MATLAB

1.4 Scope of Study

From the research, below are several things that need to be covered in this study:

i. Conduct literature review on localization techniques in wireless sensor networks
ii. Study the algorithms of some localization techniques
iii. Compare the localization techniques and choose best technique
iv. Implement algorithm of the chosen localization technique in Matlab

1.5 Relevancy and Feasibility

The project is within the capability of a final year student to be executed with the help and guidance from supervisor and coordinator. Besides, this project used network simulator and since Matlab is an open source that able to conduct this network simulation, this project is relevant and feasible to be conduct within time frame provided. The feasible time frame of the project will ensure that the project can be completed within the time allocated, thus all the objective of the project can be achieved.

CHAPTER 2
LITERATURE REVIEW

2.1 Definition of Wireless Sensor Network

Wireless Sensor Networks (WSNs) have proliferated due to development in radio and embedded systems. The potentials of WSNs in many applications have attracted a great deal of research attention during the past few years. Wireless sensor network consists of network of many small sensing nodes with low cost, and power capabilities. WSNs gathered data by sensing interfaces and propagate those data to the central computer, thus, monitoring the environment will be easier. Typically, a WSN consists of many nodes and the network will be connected to a more capable computer by base station as shown in Figure 1 [8].

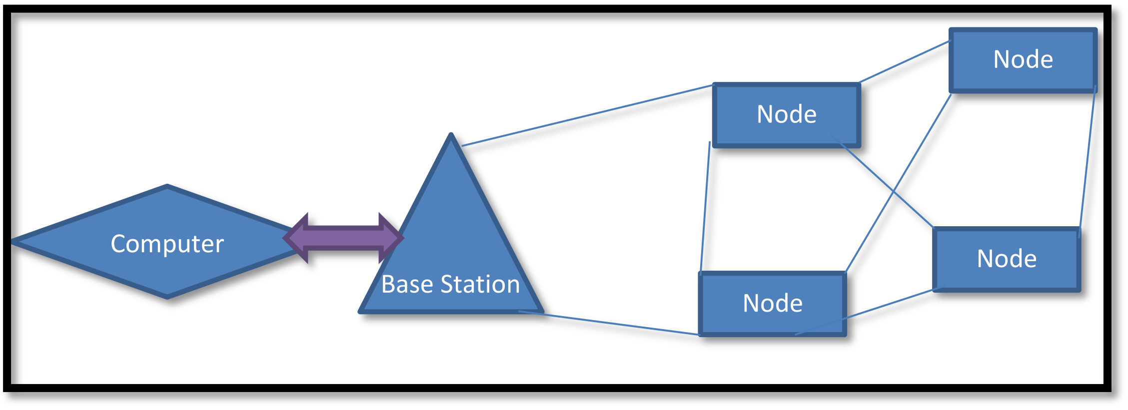


Figure 1: Example of Wireless Sensor Network [8]

As shown in Figure 2, sensor node consists of four basic components consist of a transceiver unit, a sensing unit, a power unit, and a processing unit and in some additional application-dependent components may have location finding system, power generator, and mobilizer[1]. Sensing unit consists of sensor and analog to digital convertor (ADC). As sensor produced the analog signal, the signal then is converted to digital signals by ADC before the signal were transferred to processing unit[1]. The processing unit ensures that the sensor nodes are collaborating with the other nodes to carry out the allocated tasks, and a transceiver unit connects the node of the network. Meanwhile, power unit may be supported by power scavenging device [1]. Some of important feature of nodes are low power consumption, high densities deployment, and low manufacturing cost [8], [1].

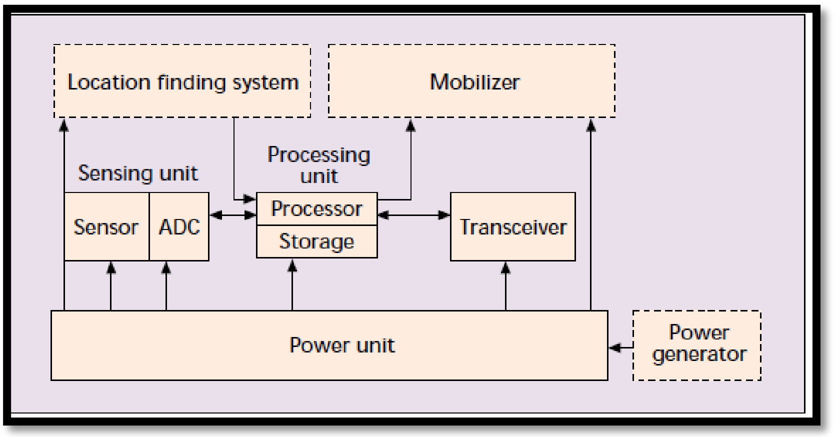


Figure 2: Components of sensor networks [1]

2.2 Localization Techniques

The terminology "Localization" is defined as a process to determine the position of object or people, also can be considered as tracking the location of nodes. By using WSNs in the sensor localization, the location information of objects is obtained.

GPS is one of the successful inventions in local positioning system to locate an object. However, this device is only functioning in outdoor environment. Thus, a few researches and studies about local positioning system are conducted, so that it can be used for indoor and outdoor environment. Via wireless transmission, the information is transmitted to the base station. The localization sensors are one of the most popular fields in WSNS. This is due to many applications are depending on the location of the node's sensor.

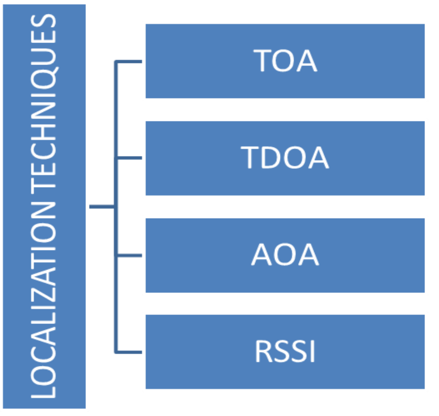


Figure 3: Examples of Localization Techniques

As shown in Figure 3, received signal strength indicator (RSSI), angle of arrival (AOA), time of arrival (TOA), and time difference of arrival (TDOA) are the common techniques of localization [2]. TOA, TDOA and RSSI measurement gives the distance calculation between the source sensor and receiver sensor while AOAs provide the information of the angle and the distance measurements from the source and the receiver. The details of these techniques are discussed in section 2.2.1, 2.2.2, and 2.2.3.

2.2.1 Time of Arrival (TOA) or Time Different of Arrival (TDOA)

Ravindra,S. [11] mentioned in his research that Time of arrival (TOA) is the one- way propagation time of the signal travelling between a source and a receiver. This means the TOA is calculated by measuring the time of signal travelling between the object and a destination point at a known velocity [8]. Basically, the calculation of TOA and TDOA technique is nearly same. For TOA, the propagation time can be directly translated into distance, based on known signal propagation speed whereas TDOA is using time difference of arrival [3].

TOA and TDOA may use different signals such as RF, acoustic, infrared and ultrasound. On the other hand, in line of sight condition, accurate result can be obtained by using this technique. Disadvantage of this technique is it needs a synchronization of all the devices [10].

Figure 4 shows the method to locate the receiver node. When signal is sent at time t_1 and reach the method of locating the receiver node at time t_2, the distance, D between sender and receiver can be calculate as:

$$D = s\,(t_2 - t_1) \quad (1)$$

Where s is the propagation speed of the radio signal, t_1 is times when signal is sent and t_2 is times when signal is received. Thus, this technique needs synchronization of nodes and the time which signal leaves the node must be in the packet that was sent [4].

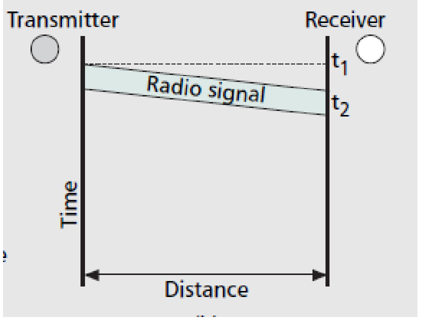


Figure 4: Method to calculate distance using TOA technique [4]

On the other hand, Figure 5 shows the method to calculate distance using TDOA technique. This technique is based on the difference in times at which multiple signals from the transmitter arrive at another node. Thus, In this case, an extra hardware need to be equipped at the node so that it can send two types of signal simultaneously. The distance of the node can be calculated by using equation of distance from sender to receiver,

$$D = (s_r - s_s) * (t_2 - t_1) \quad (2)$$

Where $s_r$and s_r speed of signal of radio and ultrasound signal respectively [4].

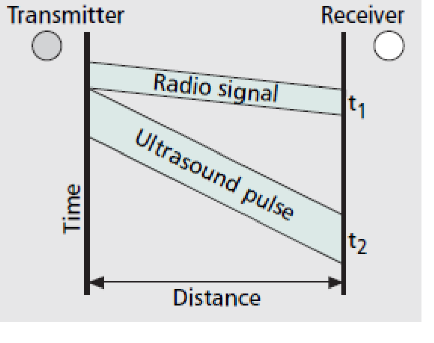


Figure 5: Method to calculate distance using TDOA technique[4]

2.2.2 Angle of Arrival (AOA)

`AOA will calculate the angle, which signals are received. The distance between a transmitter from the antenna, R_i and the number of antenna element, id can be approximated by,

$$R_i \approx R_0 - id\cos\theta \tag{3}$$

where R_0 is the distance between the transmitter and the first antenna element, and θ is the bearing of the transmitter with respect to the antenna array. The AOA approach gives higher accuracy result than the RSSI approach. Unfortunately, the hardware used for this technique is quite expensive since it needs directional antenna or antenna array to find direction [6]. Based on the arrival times of the signal at each of the receivers, AOA of the signal can be estimated, thus, location of the node can be calculated [4]. As shown in Figure 6, it is possible to estimate AOA of this signal based on the arrival times of the signal at each of the receiver.

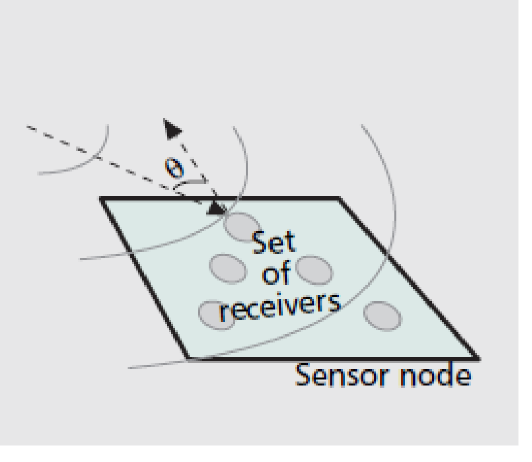


Figure 6: Decrease in Signal Strength from transmitter [4]

2.2.3 Received Signal Strength Indicator (RSSI)

In RSSI technique, an unlocated sensor can localize itself by searching the expected position of beacon point such as the maximum point. The distance between transmitter and the receiver can be estimated using existing data of received signal strength found in different area [10]. As shown in Figure 7, a sensor node sends a signal with a known strength that fades as the signal propagates. Thus, the bigger the distance to the receiver node, the lesser the signal strength arrived at node [4].To calculate the distance, the equation used are:

$$RSSI = 10 \propto \log(d)$$

Where,

$$d = 10^{(RSSI - RSSI_{calibration})(-10\propto)} + d_{calibration} \qquad (4)$$

Where d is the distance between the transmitter and receiver, RSSI is the received signal strength measurement, $RSSI_{calibration}$ is the RSSI offset, α is the path loss gradient of the environment, and $d_{calibration}$ is the distance offset.

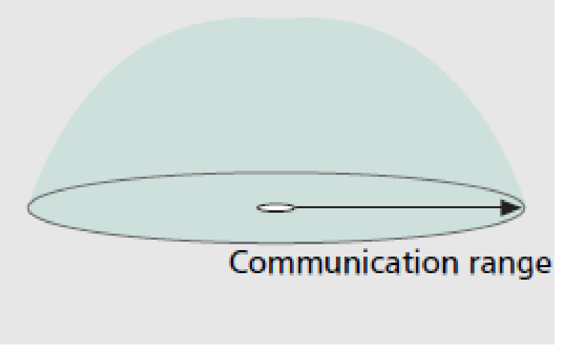


Figure 7: Decrease in signal strength[4]

2.2.4 Comparison of Techniques in localization

In localization, there are four main approaches for measuring location in WSNs. Table 1 shows the comparison of four Localization techniques that are TOA, TDOA, AOA and RSSI. TOA and TDOA can used varies type of signals. This is one of the advantages if TOA or TDOA techniques are implemented. Since TOA and TDOA technique is the simplest and with lowest cost, TOA technique has been the focus of this project.

Table 1: Comparison of some Techniques in Localization[10]

	TOA	TDOA	RSSI	AOA
General description	Propagation time can directly translate into distance based	Propagation time can directly translate into distance based	Measure power of signal at receiver and based on known transmit power	Estimates angle at which signal are received

	on speed propagation	on speed propagation		
Advantage	Accurate under Line of Sight condition, cheap	Accurate under Line of Sight condition, nodes need to be equipped with extra hardware to sending 2 types of signal simultaneously	Cheap without any extra devices	More accurate localization than RSSI
Disadvantage	Requirement for precise time synchronization of all the devices	Need at least two different types of signal	Not as good as other ranging techniques due to multipath propagation of radio signals	Expensive and accuracy measurement limited by directivity of the antenna
Signal	Radio Frequency, Acoustic, Infrared, Ultrasound	Radio Frequency, Acoustic, Infrared, Ultrasound	Radio Frequency	Radio Frequency

CHAPTER 3
METHODOLOGY

This chapter presents the methodology used during conducting the project. Section 3.1 explains the step taken to achieve the objectives while section 3.2 includes the project activities of the first phase and second phase, project flowchart, and the Gantt chart of activities in this project.

The activities for designing the proposed project comprise two phases. The first phase of the project would mainly involve research and studies on related topic and the second phase would focuses on the implementation of the project using Matlab software.

3.1 Methodology of project execution in Matlab

The project flowchart for Matlab's simulation for TOA technique is shown on the flowchart in Figure 8. Further explanations on each of the activities are elaborated in Sections 3.1.2 until 3.1.7

3.1.1 Flowchart of Matlab's Simulation for TOA technique

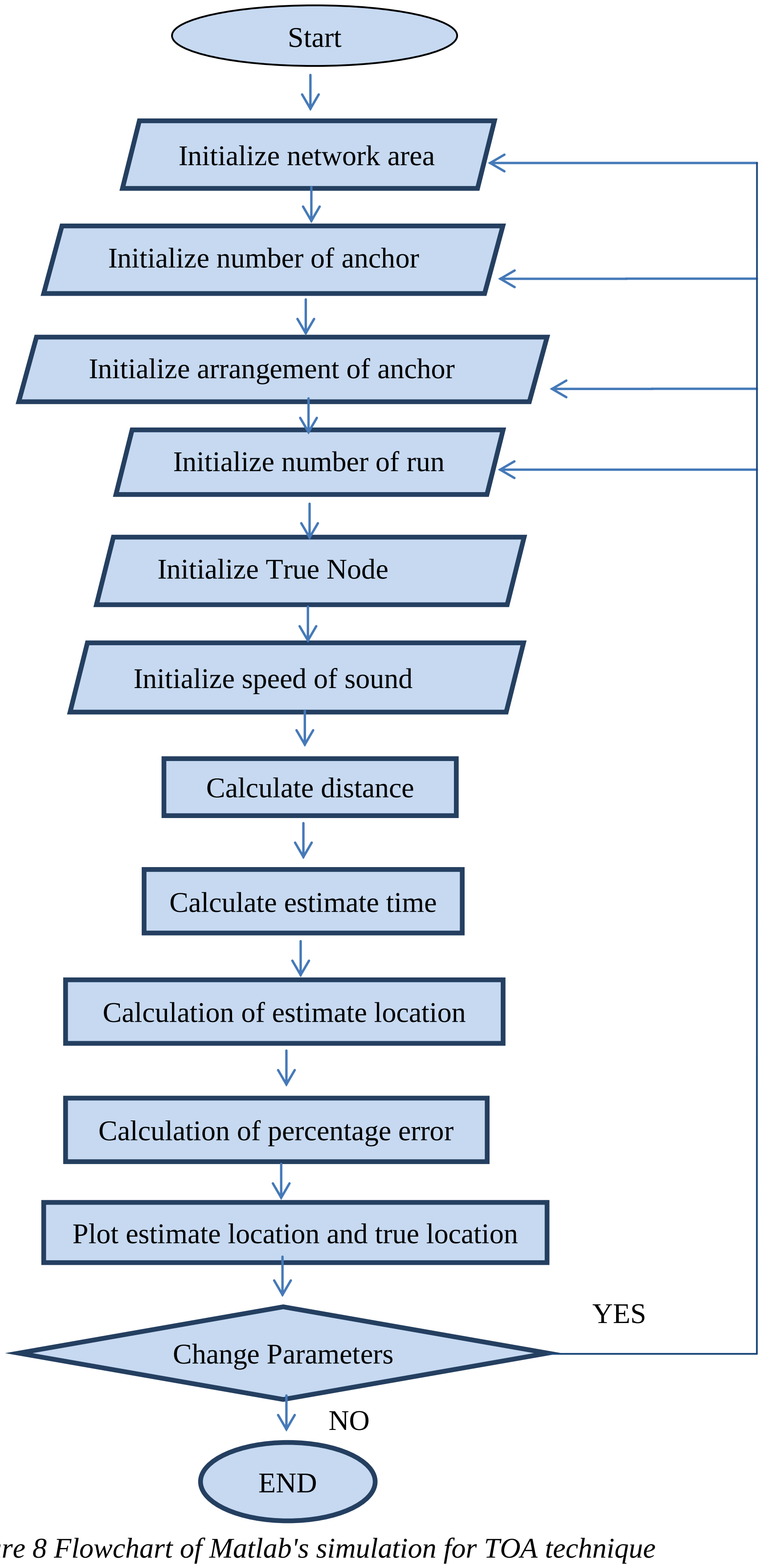


Figure 8 Flowchart of Matlab's simulation for TOA technique

3.1.2 Project implementation

This project is conducted using simulation in Matlab. The coding is built based on algorithm that had been studied. From research that had been done, TOA technique have been chosen to be implemented in this project since this technique is the simplest and have the lowest cost compared to other technique [10]. Since it has the lowest cost and simplest algorithm, the implementation of the technique into prototype will be uncomplicated.

3.1.3 Algorithm implementation in Matlab

In obtaining the location of node estimation, the maximum likelihood method and mean squared errors are used. Using maximum likelihood method, each point of coordinate in a certain range is searched in determining point with the smallest mean square error. Thus, all point of coordinates in a given range need to be converted into a time measurement that can be implemented in TOA technique. The time measurement can be calculated by using equation (5).

$$T = \frac{D}{C} \tag{5}$$

Where, T is time estimated, D is distance from each searched coordinate to the anchor location and C is speed of sound, which is a constant with value of 343.2 m/s. Thus, by using this equation, the time of node arrival can be determined, and the location of estimate node can be obtained.

TOA of a signal τ_i^T is a matrix of i x T matrix, where i is the number of anchor in the network and T is the number of signal sampling. The time of arrival at the i^{th} sensor is as equation (6).

$$\tau_i^T = \frac{r_i}{c} + \tau_0 \tag{6}$$

Where r_i is the distance from i^{th} to the anchor and τ_0 is the time origin of the signal output from node.

For noise measurement, as σ decreased, the signal-to-noise ratio (SNR) is increased [12]. SNR measures the noise level relative to the overall signal strength. Based on other research, the equation of SNR can be calculated as shown below [12],

$$\text{SNR} = 10\ log_{10}(\frac{Signal\ Power}{Noise}) \tag{7}$$

Based on equation (7), equation (8) is derived to be used in this project.

$$\text{SNR} = 10\ log_{10}\left(\frac{\frac{avg(r)}{c}}{\sigma^2}\right) \qquad (8)$$

Where;

σ= noise level

c = speed

avg (r)= average of the arrival times of signal to anchor

The value for noise measurement that is used in this project is based on other researches which is σ= 0.1.

3.1.4 Baseline system setup

By using maximum likelihood estimation, several different parameters are varied. The following parameters are used as baseline system setup:

Number of run, T = 10

Number of anchors, M = 8

Noise level, σ= 0.1

Actual node's location = (network area/2, network area/2)

Network area = 100

Anchor Location = hexagon position

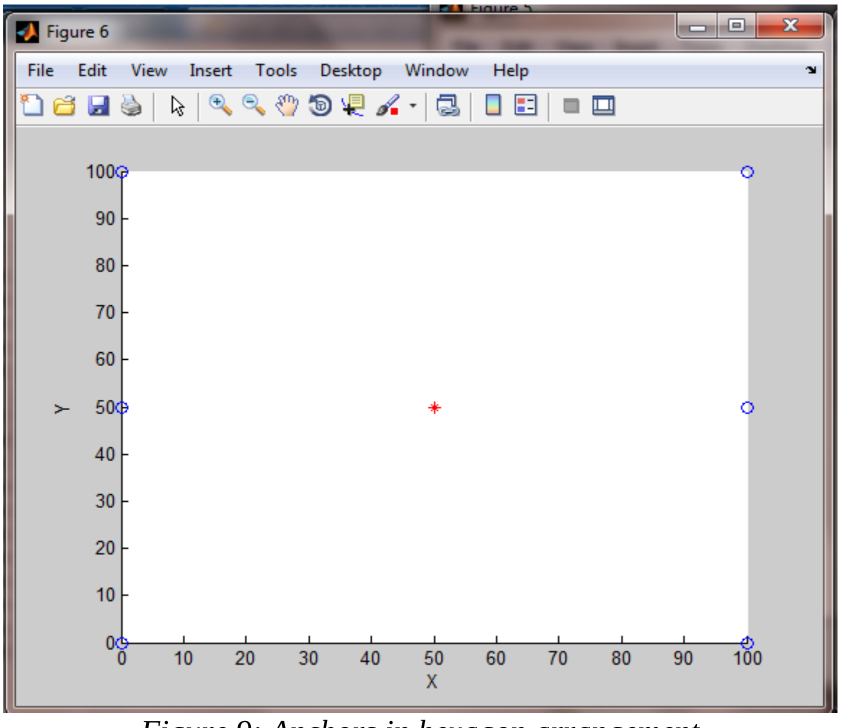


Figure 9: Anchors in hexagon arrangement

As shown in figure 9, the anchors are in hexagon arrangement. The blue circle represents the anchor whereas the red star represents the actual location of node.

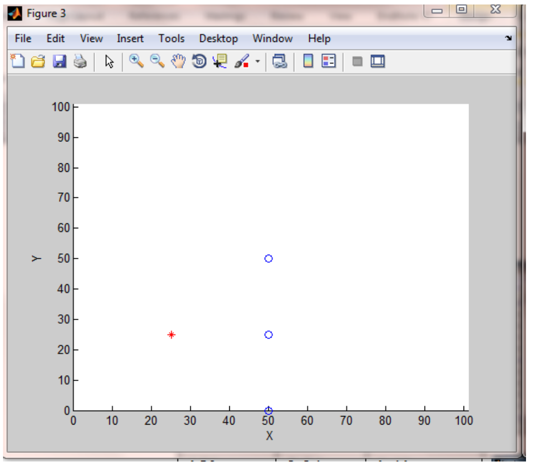
3.1.5 Performance comparison

The parameters are varied to compare the performance of node localization. The parameter that is chosen to be varied will give different result when the parameter is changed. Thus, the performance is determined by comparing the value of estimated error in meter with true location of nodes. By using the baseline value as stated in Section 3.1.3, the performance comparison is done by varying some parameters which are,

- **Variation of Network Area value**

For network area comparison, the area is varied from 50 $meter^2$ to 200 $meter^2$ with 50 $meter^2$ increments. The network topology in Matlab is as shown in table 2.

Table 2: Network topology in Matlab when network area is varied

<table>
<tr><th>Network Area (meter^2)</th><th>Network topology in Matlab</th></tr>
<tr><td>50</td><td>
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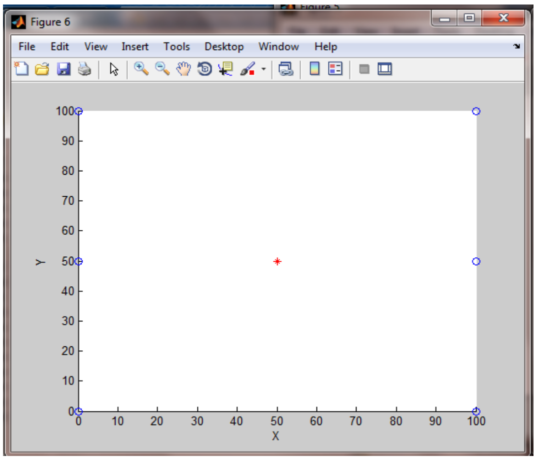
<tr><td>100</td><td>
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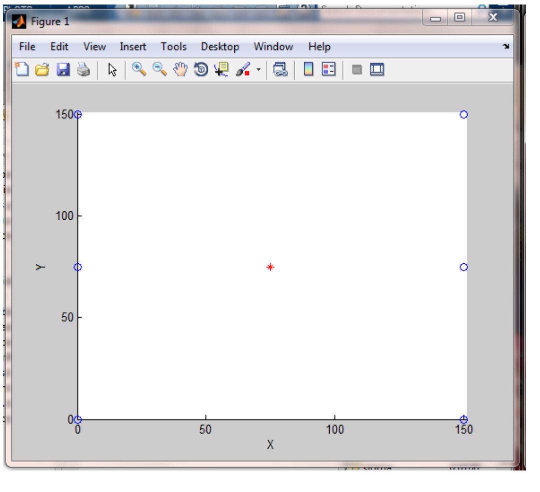
<tr><td>150</td><td>
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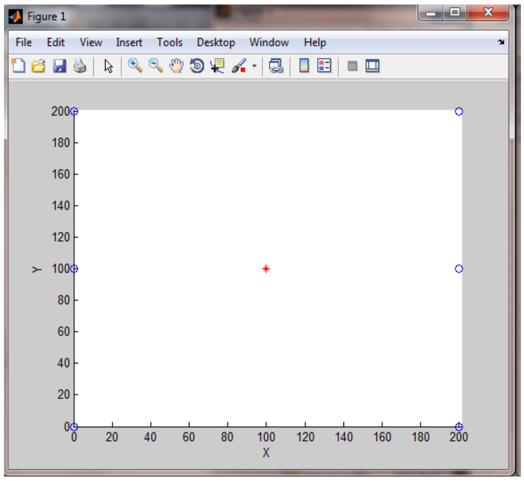
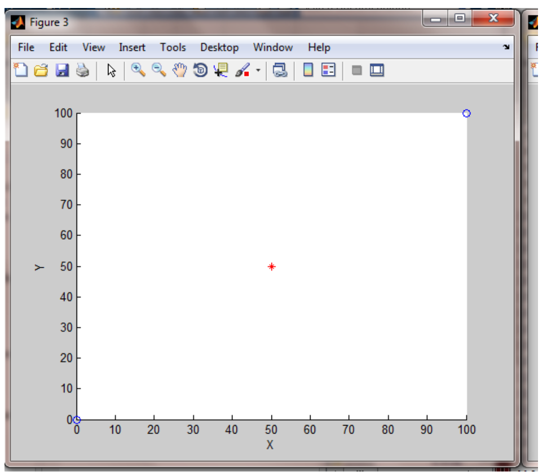
<tr><td>200</td><td>
</td></tr>
</table>

- **Variation of number of anchors**

The number of anchor is varied from 2 to 8 with 2 increments to compare the performance. The network topology in Matlab is as shown in table below.

Table 3 : Network topology in Matlab when number of anchor is varied

<table>
<tr><th>Number of anchors</th><th>Network topology in Matlab</th></tr>
<tr><td>2</td><td>
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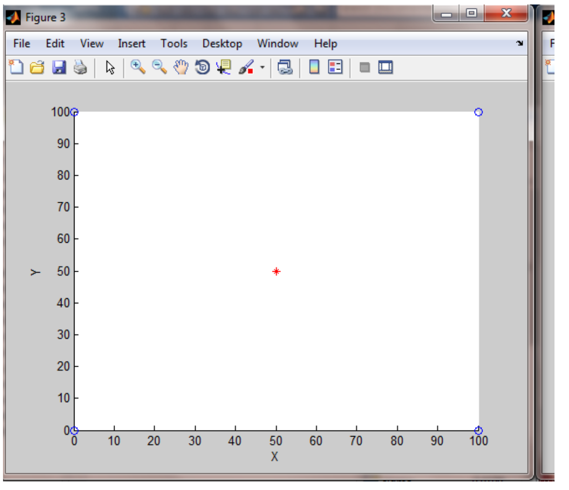
<table>
<tr><td>4</td><td>
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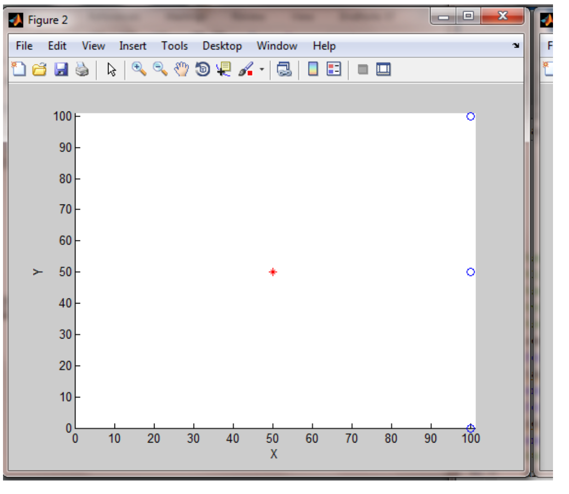
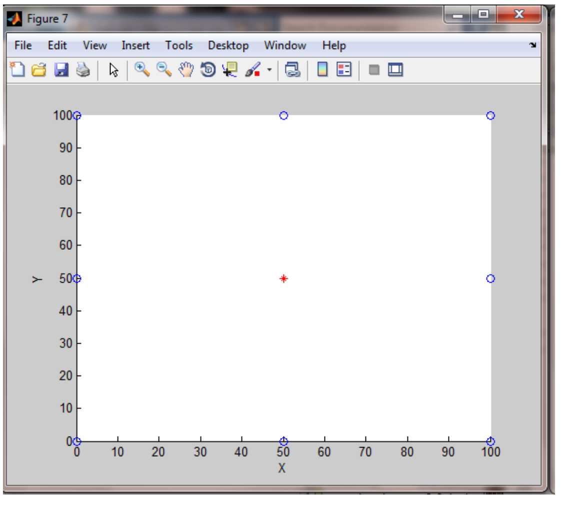
<tr><td>6</td><td>
</td></tr>
<tr><td>8</td><td>
</td></tr>
</table>

- **Variation of number of run**

The number of run is varied from 1 to 10 with increments of 2. The purpose in varying number of run is to acquire more accurate result of node location. Since the location of estimated nodes is randomly calculated, calculation performed with number of run from node will gives different result. The example of topology network in Matlab is same for every run.

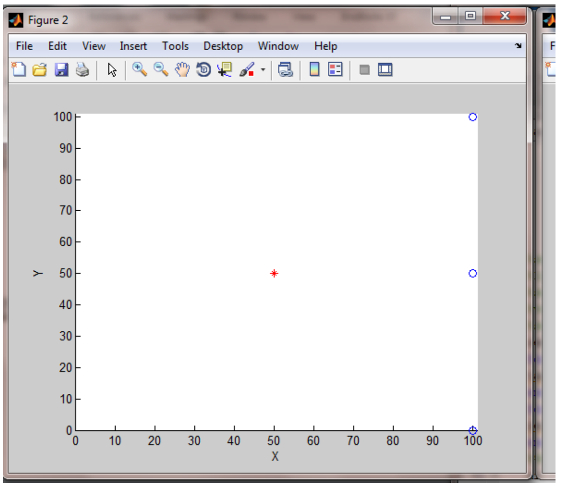
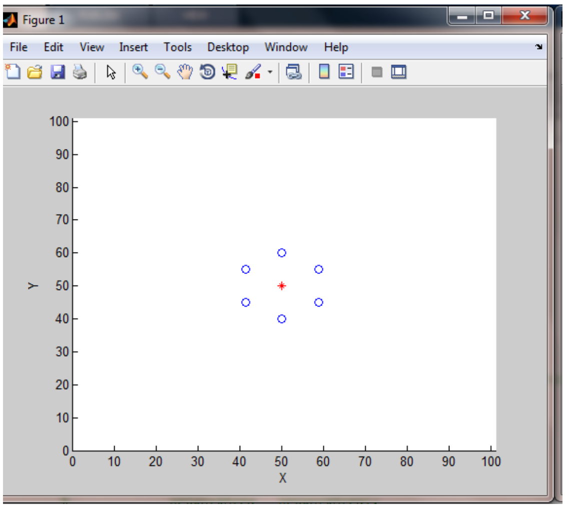
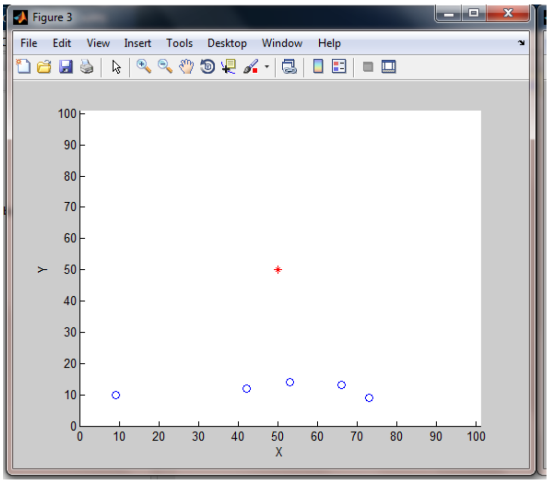
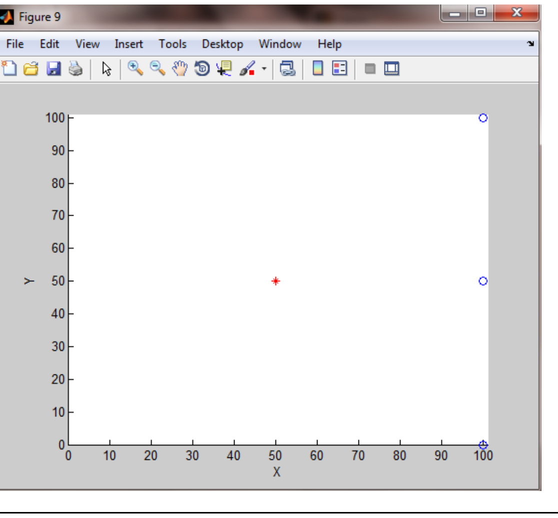


Figure 10: Topology of network in Matlab for variation number of run

- **Variation anchors arrangement**

The anchors are arranged with different arrangements, which are random arrangement, circular arrangement, edge arrangement and hexagon arrangement. The network topology in Matlab is as shown in table 4.

Table 4: Network topology in Matlab when topology of anchor is varied

Topology of Anchors	**Network topology in Matlab**
Circular	
Random	
Hexagon	

3.1.6 Validation of algorithm

The validation of algorithm is determined by comparing the estimated location that being derived from simulation with actual position of the node. Thus, the accuracy of this system can be determined by calculating the difference in distance of estimated location of node with the actual location. Moreover, the best parameter also can be determined using this comparison.

3.1.7 Result Analysis

All the result that has been obtained is analysed. The performance comparisons are then concluded and the best parameters are decided. Further discussion on the result analysis is discussed in next chapter, chapter 4 and chapter 5.

3.2 Project activities

The project activities for first phase and second phase are shown on the flowchart in Figure 8 and Figure 9 respectively. Further explanations on each of the activities are elaborated in Sections 3.2.1 until 3.2.6

3.2.1 Project Flowchart First Phase

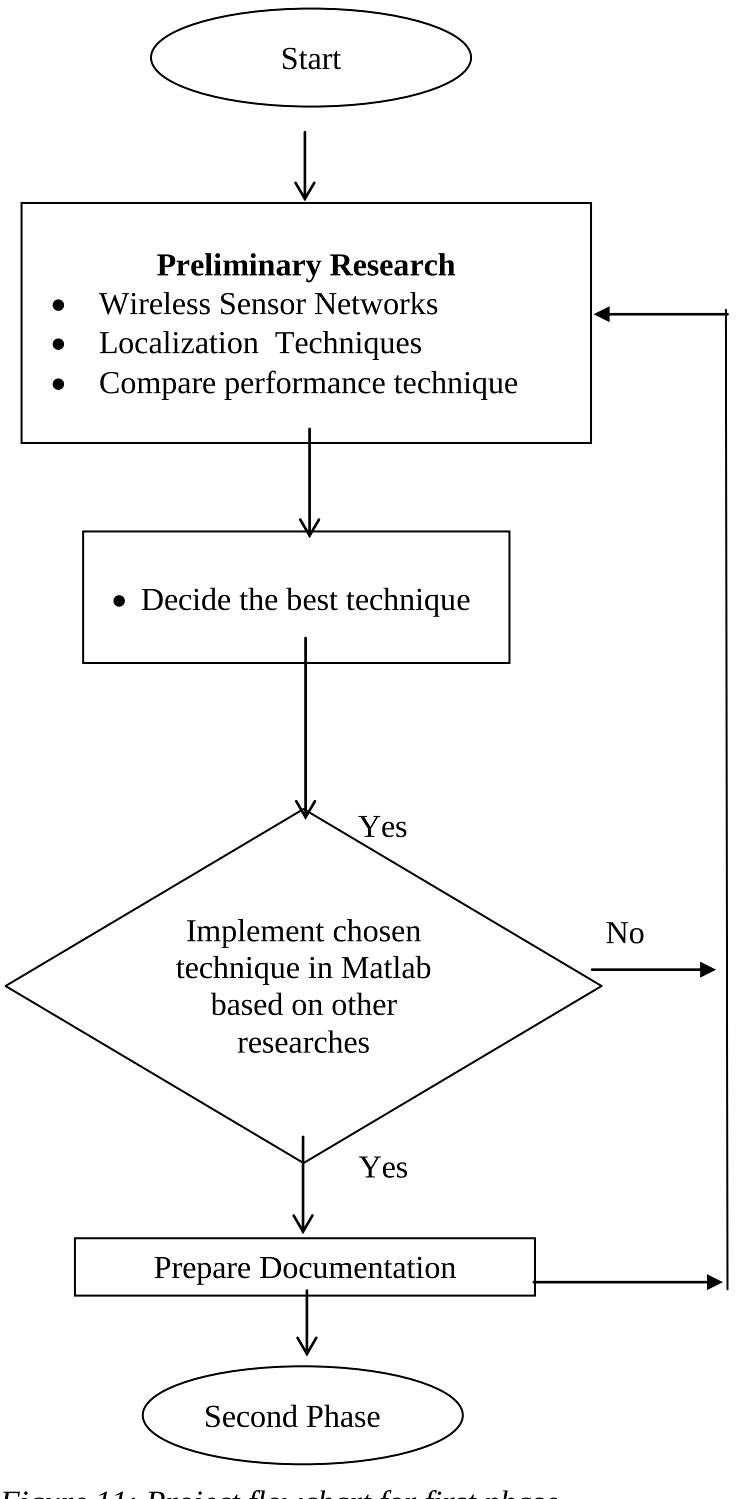


Figure 11: Project flowchart for first phase

3.2.2 Project Flowchart Second Phase

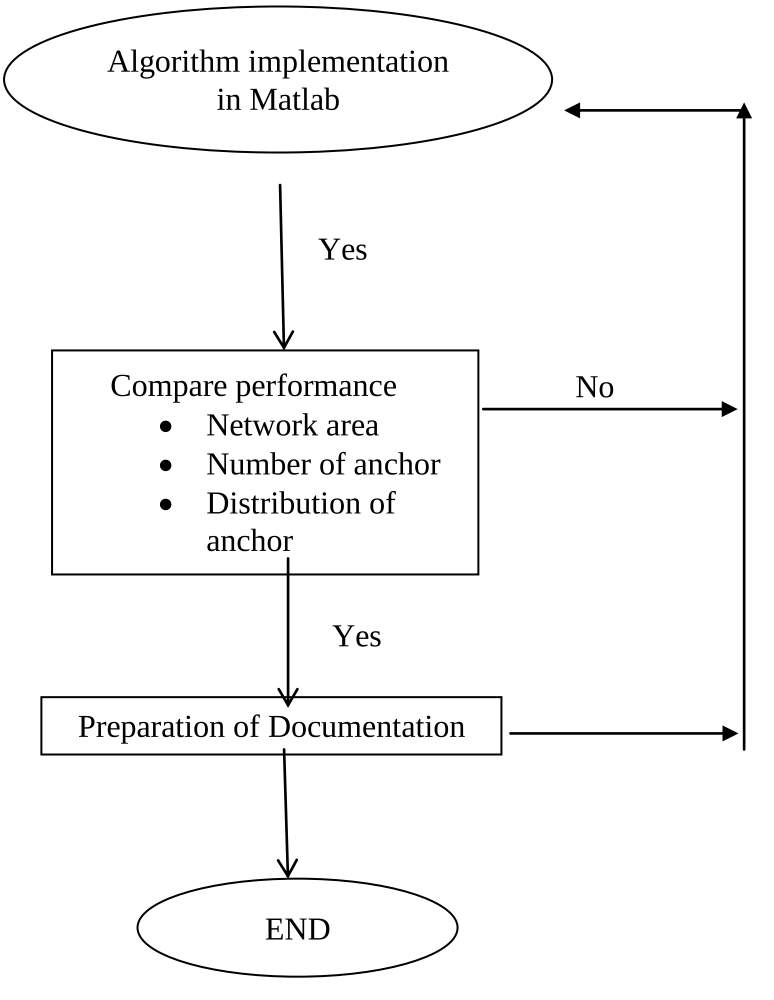


Figure 12: Project Flow for Second Phase

3.2.3 Preliminary research and Literature Review

After project title selection is completed, further studies and research on the localization in WSNs are conducted. The research covers the background studies on wireless sensor network, the techniques of localization, the feature of each approaches, and the categories of localization.

3.2.4 Comparison of four localization techniques

The features, advantages and disadvantages of all existing techniques are compared based on other people's research. Then, from featured that has been listed, the best technique for localization is chosen.

3.2.5 Documentation and Simulation in Matlab

For the first phase activities, the documentation of the research is done. Simulation work by using Matlab is conducted based on other people's research and the result is observed.

3.2.6 Documentation and Simulation in Matlab

At the end of the project, the result from the simulation will be observed and documented.

3.2.4 Gantt chart (FYP1 and FYP 2)

Table 5: Gantt chart for FYP 1 and FYP 2

Activities	FYP 1(FIRST PHASE)													FYP 2 (SECOND PHASE)														
	Week No.																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Selection of Project Topic	■	■																										
Preliminary Research Work		■	■	■	■	■																						
Submission of Extended Proposal							❖																					
Proposal Defense								■	■																			
Further research on techniques available; the concept and algorithm										■	■	■	■															
Submission of Interim Report														❖														
Project Work – Implementation of algorithm technique in Matlab															■	■	■	■										
Comparison of performance based on certain parameters																			■	■	■							
Submission of Progress Report																					❖							
Project Work – Implementation of algorithm of others technique in Matlab																						■	■					
Comparison of performance of other techniques																						■	■	■				
Pre-SEDEX																								❖				
Submission of Draft Final Report																									❖			
Submission of Dissertation & Technical Paper																										❖		
Viva																										❖		

❖ Key milestone ■ Process

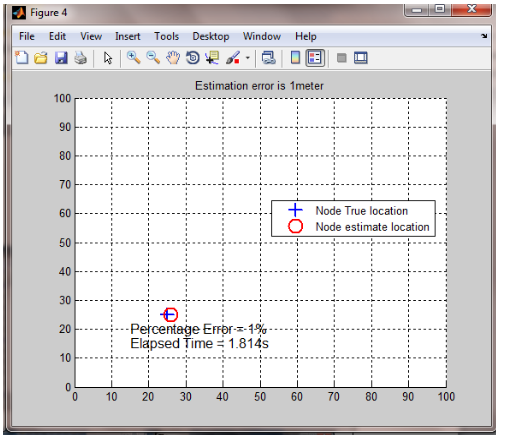
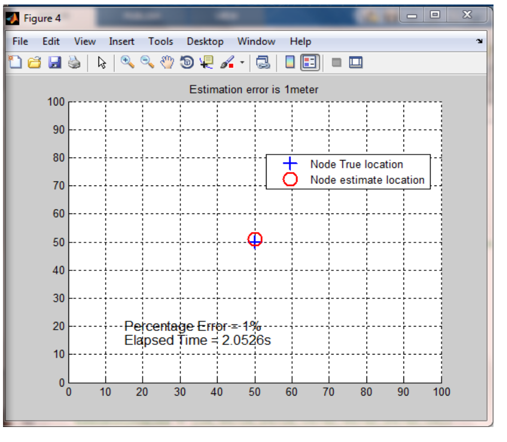
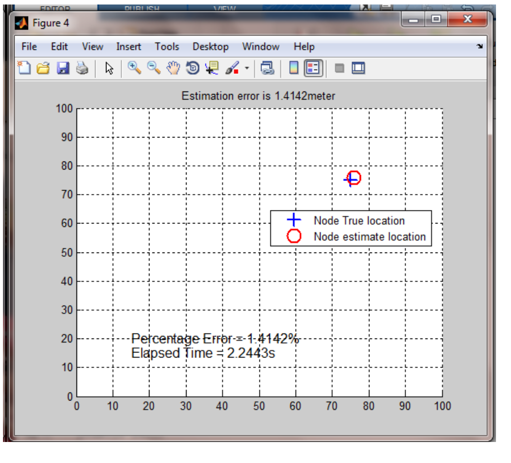
CHAPTER 4
RESULT & DISCUSSION

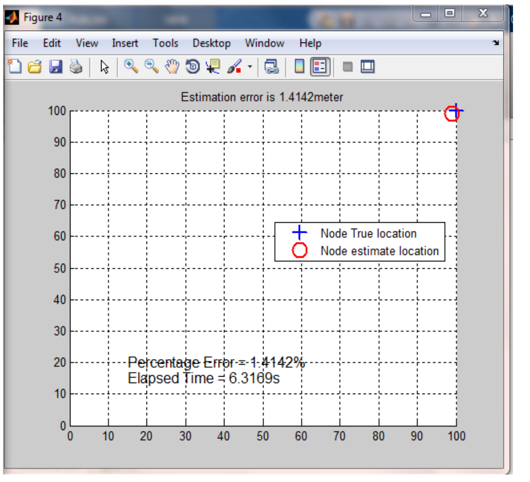
Matlab simulation is used to simulate the algorithm and to obtain the result for this project. The Matlab coding is varied for certain criteria to acquire the percentage error for that particular value. The estimated error is obtained by using 'root mean squared error' formula. The elapsed time shows time consumes to obtain the estimated node location. The parameters that have been varied are network area, number of anchors, anchors topology and number of runs.

4.1 Network area

Table 6 shows the performance of localization algorithm when the area is varied. The network area is varied from 50 meter to 200 meter with 50 meter increment. Figure 13 shows the graph of network area versus performance of localization of nodes. From the graph, the percentage error and elapsed time increased as the network area is increased. This is because, as the number of anchor used for all conditions is the same which is six, thus, the estimated error to be calculated in larger network area is expected to be higher. As conclusion, for larger area of network, the performance will be decreased if the same number of anchor is used.

Table 6: Performance variation of network area

Network Area (meter^2)	Elapsed Time (s)	Percentage Error (%)	Matlab's Simulation Result
50	1.81	1.00	
100	2.06	1.00	
150	2.24	1.41	

200	6.32	1.41	

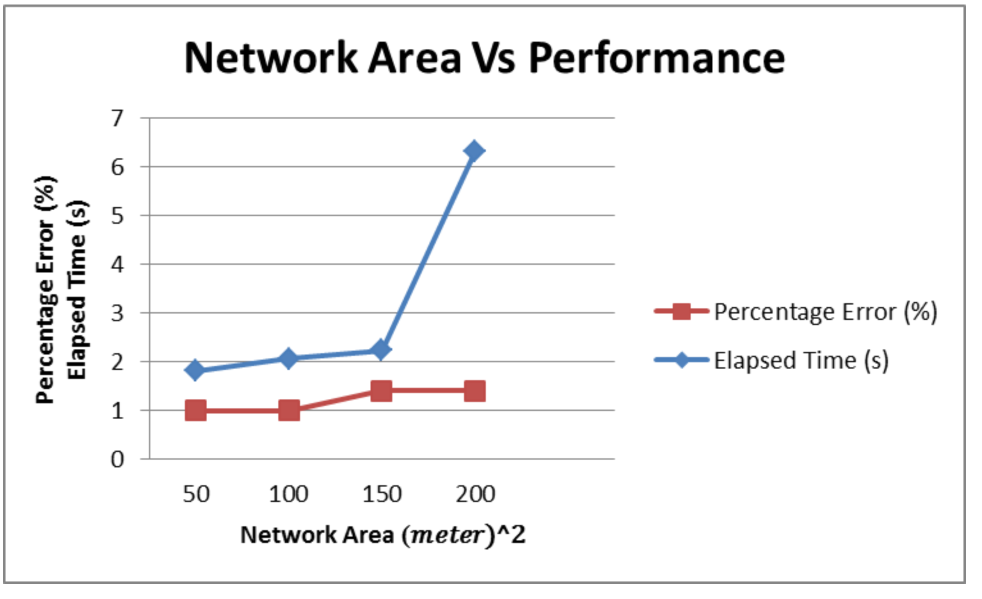
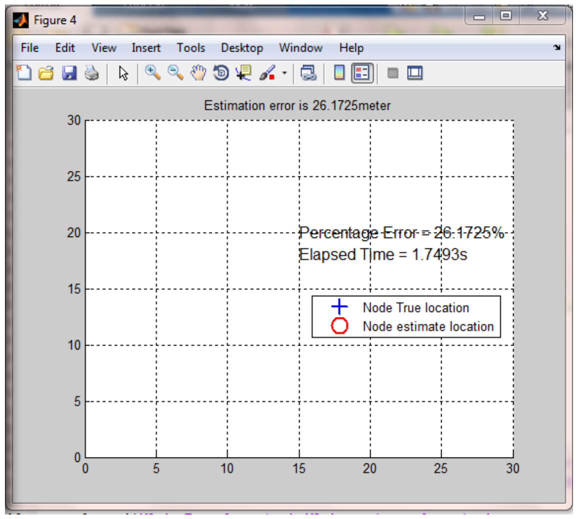
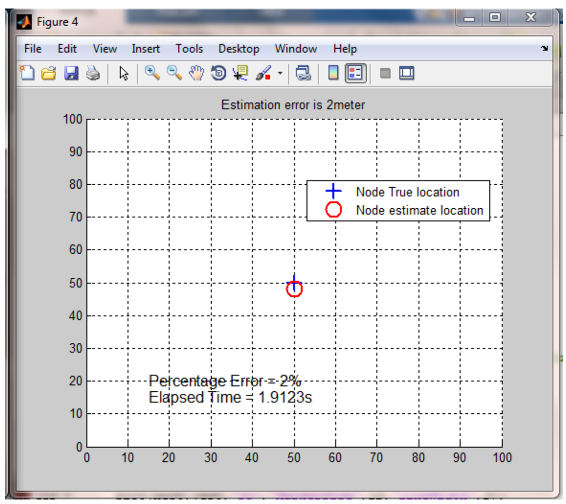


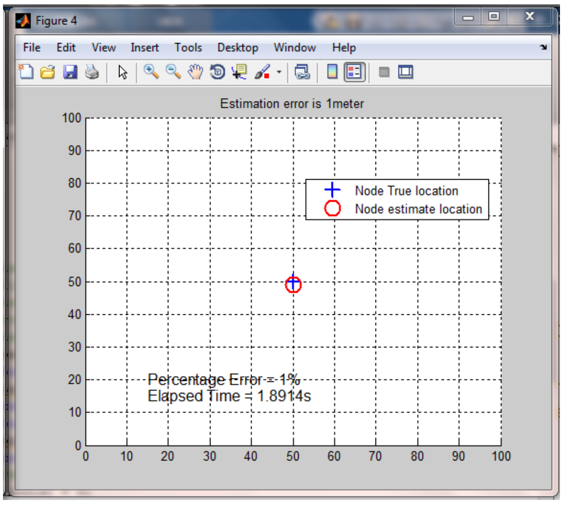
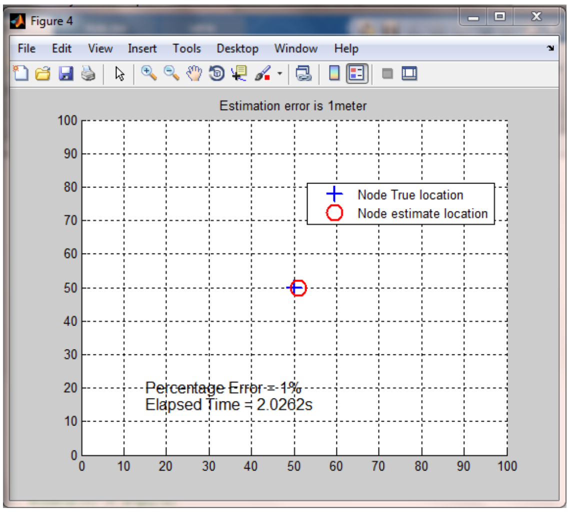
Figure 13: Network Area Versus Performance graph

4.2 Number of Anchor

Table 7 shows the result of localization performance when the number of anchor is varied. The number of anchor is varied from 2 to 8. The purpose of having variation number of anchor is to estimate the best number of anchor needs in certain area of network. Figure 14 shows the graph of Number of Anchor versus Percentage Error and Elapsed Time. From the graph, the percentage error increased when the number of anchor is decreased. This is because, when the number of anchor is decreased, the calculation of estimated node location will be affected due to known location node is decreased. The elapsed time increased as number of anchor increased except when number of anchor is four and six, the elapsed time does not increased, but, it decreased by 2 seconds. This shows that the best number of anchor used in certain network area is six.

Table 7: Performance variation of number of anchors

Number of anchors	**Elapsed Time (s)**	**Percentage Error (%)**	**Matlab's Simulation Result**
2	1.75	26.17	
4	1.91	2.00	

<table>
<tr><td>6</td><td>1.89</td><td>1.00</td><td>
</td></tr>
<tr><td>8</td><td>2.03</td><td>1.00</td><td>
</td></tr>
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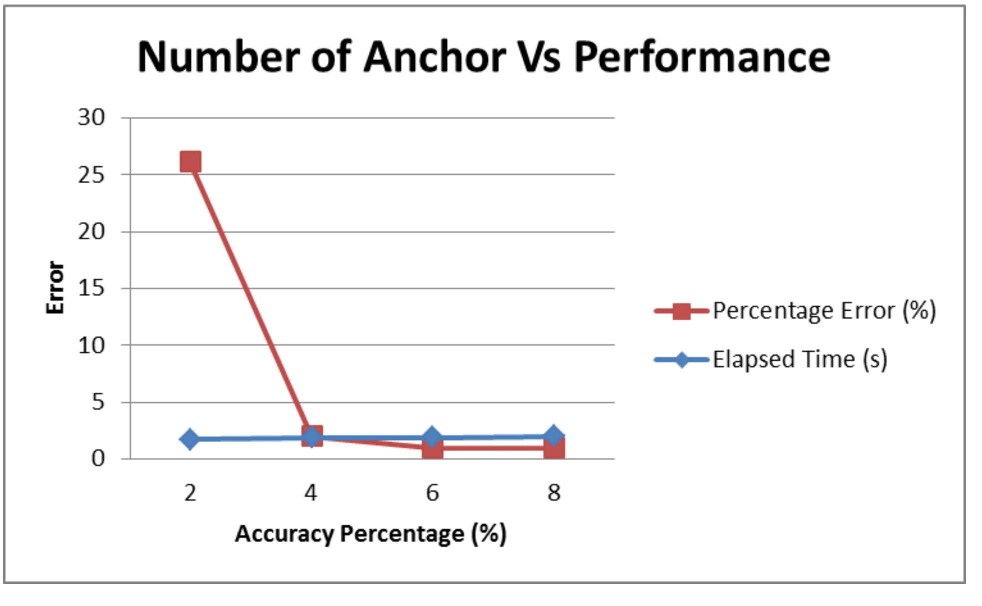
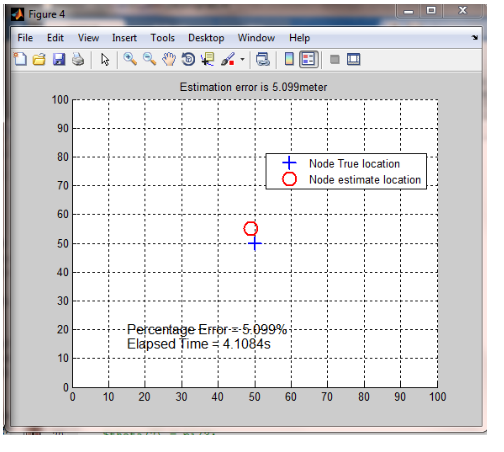
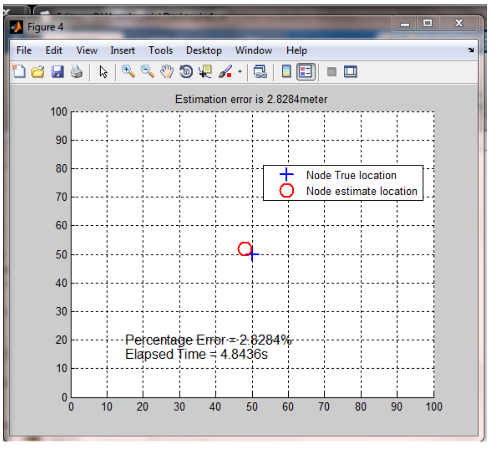


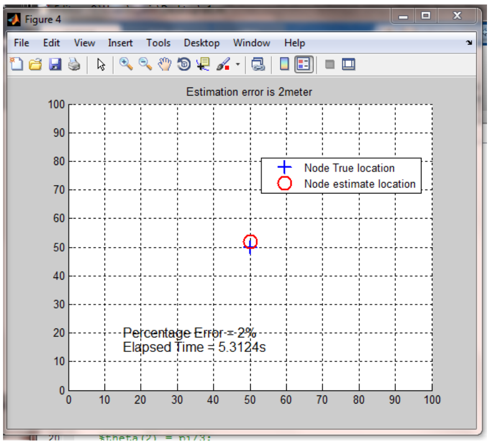
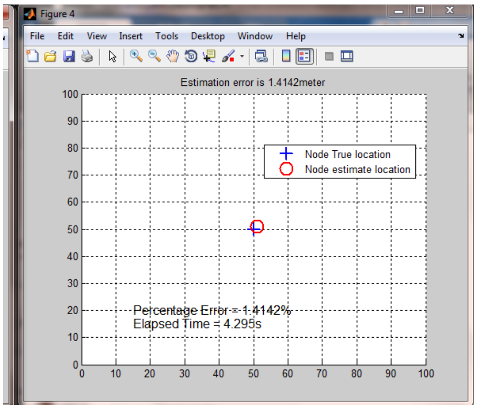
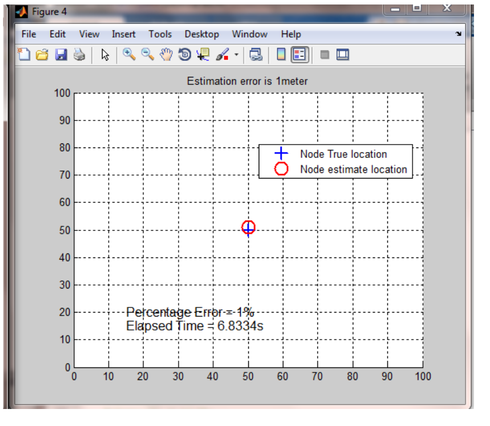
Figure 14: Number of Anchor Versus Performance graph

4.3 Variation number of run

Table 8 shows the performance of localization when the number of run from node is varied. The number of run is varied from 1 to 10 with increments of 2. The purpose of varying the number of run is to acquire more accurate results of node location. Since the location of estimated nodes is randomly calculated, the calculation that was performed using number of run from node will gives different result. Figure 15 shows the graph of Number of run versus Percentage Error and Elapsed Time. From the graph, the elapsed time decreased and percentage error increased as number of run from node is decreased. This is because, higher number of run from node will gives higher accuracy, and this will yield to a lower percentage error.

Table 8: Performance variation of signal sampling from node

Number of run	Elapsed Time (s)	Percentage Error (%)	Matlab's Simulation Result
1	4.11	5.10	
3	4.84	2.83	

5	5.31	2.00	
7	4.29	1.41	
10	6.83	1.00	

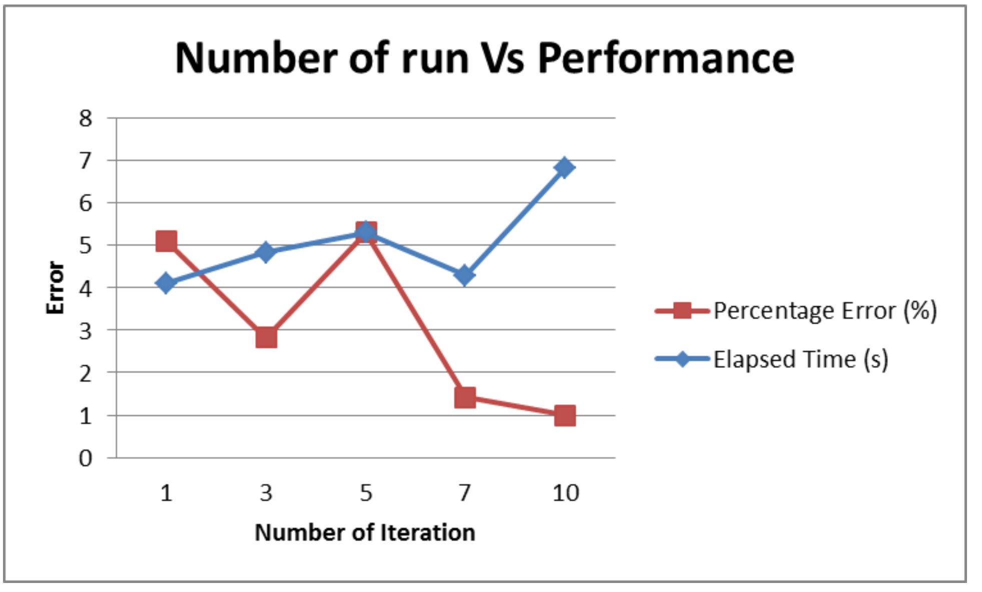
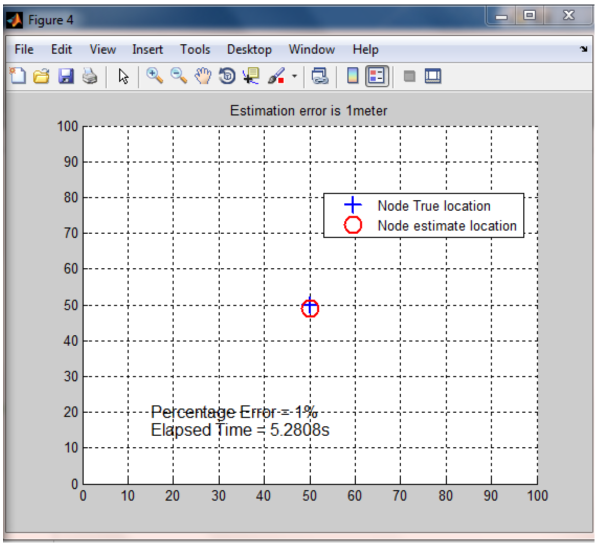
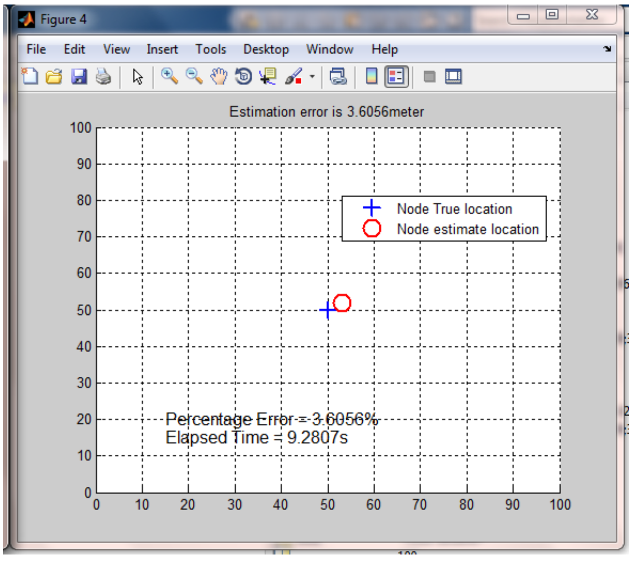


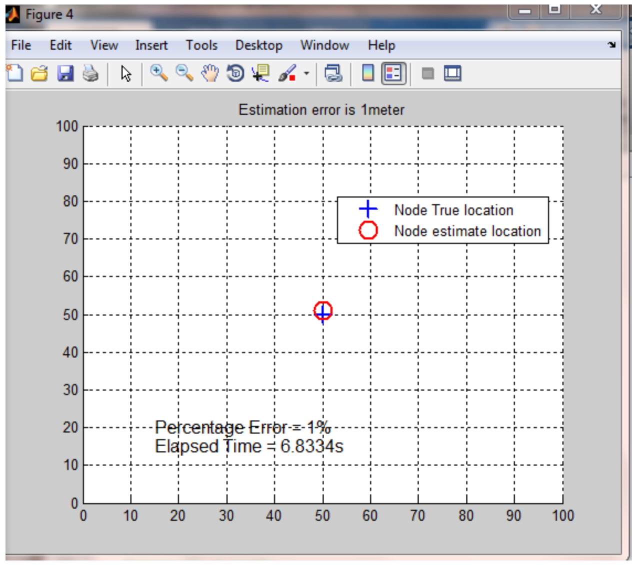
Figure 15: Number of run Versus Performance graph

4.4 Distribution of anchors

Table 9 shows the performance of localization when the anchors are distributed with different arrangements. By using same number of anchors which is 6, the anchors were arranged with different arrangements. They are random arrangement, circular arrangement, and around arrangement. This aims to determine the best arrangement of anchors in ideal squared room. Figure 16 shows the graph of type of distribution anchor vs. performance. From the graph, the circular and around arrangement gave the highest accuracy as compared to the random arrangement. However, circular arrangement is not realistic because the position of node was unknown. Thus, the best arrangement of anchors is the around arrangement.

Table 9: Performance variation of distribution anchor

Topology of Anchors	Elapsed Time (s)	Percentage Error (%)	Matlab's Simulation Result
Circular	5.28	1.00	
Random	9.28	3.61	

Hexagon	6.83	1.00	

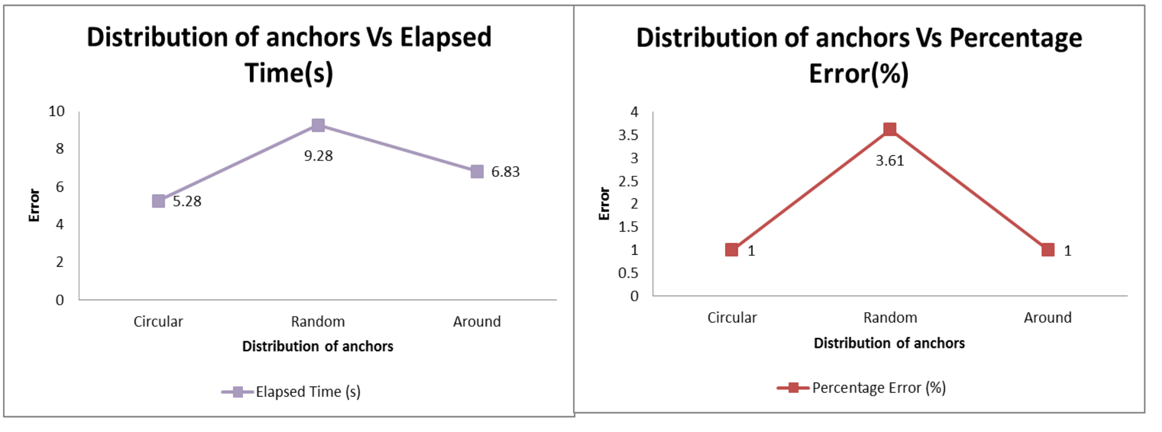


Figure 16: Distribution of anchors VS Performance

CHAPTER 5
CONCLUSION AND RECOMMENDATION

This report provides the explanation and discussion on the project entitled "GPS-free Localization Technique Using a Wireless Sensor Network". As conclusion, the theory and techniques in localization can be studied and observed throughout the research that has been conducted. As for the next step, the theory will be implemented as algorithm in the Matlab program. From the research, the technique that has been decided to be used is the time of arrival (TOA) technique. A good localization technique is able to locate accurate position within shorter period of time. Basically, all activities that need to be done in first and second phase have been successfully achieved. From the results obtained, four conclusions can be made. First, percentage of accuracy is higher with smaller network area. Second, less number of anchors will increase the percentage error, third, increase in number of run will yield lower percentage error and the final one is the best topology of anchor are in hexagon arrangement.

As recommendation, further project activities should be continued with the implementation of other techniques in Matlab. The performance will be later compared based on the same parameters used in TOA technique. This aimed to prove that TOA is the best technique for localization.

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