

# An Improved Indoor Location Technique Using Combination of Kalman Filter and Centroid Positioning

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**Abstract**—Indoor positioning technique is used to trace the location of entities within a non-space environment riding from the incapability of GPS to do so. Most of indoor localization techniques proposed by researchers to discover an optimized solution for indoor location tracking that has high precision and accuracy. This paper proposes an improved indoor location technique by implementing Trilateration and Kalman Filter that can manipulate noise signal reduced from raw Received Signal Strength Indicator (RSSI). This paper also proposed the uses of Centroid Positioning that be amended on top of Kalman Filter which to study whether it can improve the accuracy rate or not. Upon implementing the technique, observation and comparison are made to measure the effectiveness and reliability of the uses of Kalman Filter and Centroid Positioning. Our analysis and finding show that the enhanced indoor positioning technique has improved the accuracy tremendously.

**Index Terms**—Indoor Positioning Technique, Kalman Filter (KF), Centroid Positioning (CP), Received Signal Strength Indicator (RSSI), Trilateration

## I. INTRODUCTION

Today, a technology called indoor location tracking has become one of the popular topics that be used to track an object or person in a close-environment such as inside a building due to the incapability of GPS [1]. Various technologies of indoor location tracking system have been proposed or even developed by using wireless communication and mobile computing where the development of location-based services (LBSs) is very much demanded [2].

Wi-Fi infrastructures enable the positioning within the non-open environment without the needs of implementing an extra network gadget [3]. However, the implementation of indoor location tracking gives more complexity rather than outdoor that used GPS due to the presence of interference that exists inside the building environment. It comes with great challenges in which the signal usually will be fluctuated due to many obstacles such as walls, furniture, the presence of human beings and the wireless signal level [4]. The interferences yield

in errors in positioning as the accuracy is not the same with the actual location of an object itself. In fact, the huge differences in accuracy produced on the observed location when compared to actual location make the indoor location tracking technology is an unreliable system to be used.

In another point of view, the mechanism and technology indoor location tracking also not limited to one uses as it also has the same functionality and uses to what GPS gives to the outdoor environment. Instead on tracking an object or person within an indoor environment; proximity, monitoring and navigation is what the system also provides as the implementation of the technology engages with multiple of application for example. Indoor location tracking is considered as one of the best solutions that uses to secure and monitor company assets and also to the event that deals with lots of audience in one closed environment.

This paper will briefly explain about several indoor location tracking techniques that have been proposed by other researchers in Section 2. We introduced our proposed model in Section 3. The experiment and analysis of the output from the experiment is discussed in Section 4. We conclude the paper with some observation and suggestion based on the findings from the experiment in Section 5.

## II. RELATED WORK

Indoor location tracking mechanism may be developed using various types of technology and the localization process can be executed using different of techniques. Currently, wireless technology has become one of the most preferred choices and widely used due to its reliability, low cost of implementation scalable and easy to manage [5]. As far as it may concern, the localization process for wireless approach differs from one technique to another in term of the process and implementation. The implementation of wireless technology for indoor location tracking is depending on RSSI that is used to communicate and estimate the devices' or objects' position in the non-open space environment.

In [6] a positioning technique based on RSSI and trilateration method was proposed. The authors used trilateration method that compromised a minimum three Access Points (APs) to determine the relative location of an object or person by calculating the distance from

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point-to-point using geometry properties. To calculate or determine distance, RSSIs are put as a determining tool where the transmitted value of RSSIs from devices to APs is taken as the data to calculate the distance. In getting the RSSIs for distance measurement process, it was collected for ten consecutive times and then averaged to get the most optimum signal value. From the captured data, it then converted into distance by using some mathematical formulas. Reference Point (RP) is set manually depends on the layout of the environment i.e. whether it has less, more or open-free obstacles. Then the distance from every selected RP to devices is calculated and stored in a database during the offline stage. Once the information is gathered from all deployed APs, the system trilaterates the data to calculate the distance of the device from all APs and observe the coordinate. From the result of device coordinate produced, the system again uses the stored data of RP to determine the best RP that can be used for reference by the devices in order to get a closer location. The selection of RP is determined based on the smallest distance difference of RP to APs. Once found, the RP coordinate and device coordinate are sum up and averaged as it will produce the final coordinate of the devices. Throughout the entire process, this technique actually depends on the setup of the location of RP in which if the location is not properly considered, the error rate of devices coordinate will be high.

In [7] the author proposed a technique to detect and tracking human body without the need of carrying any radio devices during the localization process. The positioning process is based on the change in human body gesture and/or movement that affects the Received Signal Strength Indicator (RSSIs) of WLAN environment. This proposed technique is equipped with the use of extensive deployment of Wi-Fi network installed within the parameter. The process works when there are movement and presence of human body within the Wi-Fi range, then the RSSI value will be affected. The changes of value on RSSI will be used to calculate and predict the location of the human within Wi-Fi range parameter. By means, the proposed technique solely depends on the Radio Frequency (RF) sensor for indoor localization. The drawback of the system is that it may consume more energy as the APs need to always put in standby mode due to uncertainty of human presence within the area for localization purposes.

In [8] the author proposed a system model that used a combination of Fuzzy Logic (FL) algorithm and K-Nearest Neighbors (KNN) algorithm for indoor location tracking. The implementation is based on wireless sensor network. The process of localization is divided into two stages which are the offline and online by using the KNN. Fingerprints which represent the received signal strength indicator (RSSI) value are measured between every deployed access points (APs) with tracked nodes during the offline stage. The information then is stored in the lookup table of the system database. During the online

stage, the fingerprints of k-nodes that have the closest RSSI value to the tracked node are taken to be used for fuzzy logic stage. Regarding the accuracy of the tracked node, it is actually determined during the offline stage readings. The author stated that if the fingerprints are set at about  $1\text{m}^2$  areas per point, it will produce a good result of the tracked coordinate. After the process is done, fuzzy logic is used to estimate the location of the target by using triangulation method. Using the RSSI value that has been converted into distance, the fuzzy logic determines the weight for tracked nodes coordinate. The weight values that vary from 0 to 1 determine the tracked nodes in which the closest the tracked node to reference nodes or APs, the high it weight. By having a high weight, the distance is very close to the deployed k-nodes which give an easier task for positioning the tracked node. The proposed technique may give a great accuracy result but it needs lots of k-nodes to be set within the parameter. This somehow may increase the cost of implementation and generate more complexity of hardware or process uses.

In [9] the author proposed a technique for indoor positioning by using the k-nearest neighbour (KNN) to track devices. This technique is based on Wi-Fi technology where the estimation of object coordinates is based on transmitted radio frequency (RF) signal. The system began by accepting the received signal strength (RSS) that were calculated from every nearest neighbour (NN) nodes or the reference nodes to access point (APs). The results for every NN nodes are then stored in the database for future uses. In order to estimate the position of objects or devices, the RSS transmitted from devices is weighed with the NN nodes to learn the closet coordinates of between neighbours and devices location. Once the result is found, the calculation process to obtain the real coordinates of the devices will be executed. For this proposed technique the dependency on NN nodes or reference node is important in estimating the coordinates of the device. Besides, the RSS needs to be at good and optimum state in order to find the best distance for tracking purposes.

#### A. Trilateration

Trilateration is considered as one of the popular and available approaches for indoor location tracking where it combines three access point (APs) that are placed on different points or coordinates. They will exploit the RSSIs from devices. The RSSIs are then converted into distance measurement because the measurement is used to estimate distance. Each of the APs will calculate the distance from device point and enable it to produce a circle with radius ( $r$ ) [10]. Trilateration makes the APs measure the distance of device using the geometry of circles or triangle which will find the intersection point. The intersection and cross line produced from the three APs will pinpoint and represent the device position. This requires the effectiveness and value of the distance from

RSSI information during the localization process. To have a better understanding about the trilateration positioning process, the following steps describe the sequences.

- 1) Setup three APs within certain points of the coordinate of the indoor environment.
- 2) First AP captures RSSI from devices by using geometry circle and converts it into useful distance information.
- 3) Second and third AP repeats the same process as the first AP.
- 4) All the three APs trilaterate to sense and capture the intersection of geometry circle
- 5) Detect the intersection of geometry circle produced by all the Aps.
- 6) The intersection point determines the location of the device within the indoor environment.

Fig. 1 shows an illustration of how trilateration works using APs.

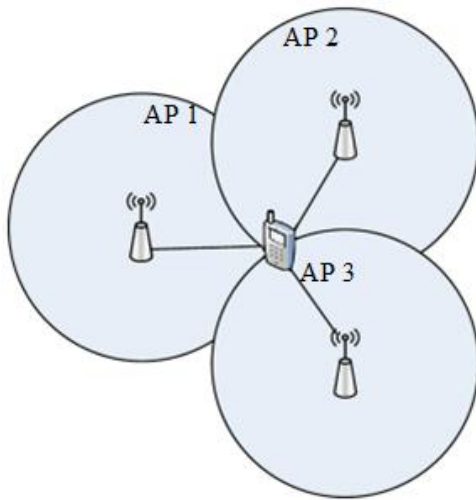


Fig. 1. Trilateration technique

The implementation of trilateration technique is not too complex compared to others and quite popular as it widely adopted and used by researchers. In facts, any technologies that use trilateration approach literally have a low cost of implementation and installation within the indoor environment. Moreover, it can be expanded and converted into Multilateration where it uses four APs to measure distance. To some extent, the trilateration technique put many concerns to the APs respective location in order to find the intersection point of device within the environment

### B. Fingerprinting

Fingerprinting basically compromised the measured RSSI properties against the coordinate point of a grid of Reference Point (RP) in which the measurement is taken from that particular point that necessary for indoor tracking processing [11]. The information is stored in the database where it happens during the offline stage. This method usually requires two stages of implementation where it first collects any related information from node

point during the offline stage followed by localization of object and device in the online stage. The information stored in the database during the offline stage is meant to assist the localization process of devices during the online stage where the device location tracking process is executed. In contrast, several algorithms have been used for fingerprinting techniques in order to find device position and one of it is the deterministic K Nearest Neighbor (KNN) which it considers Euclidean distance in estimating the location of the device [12]. The following manner describes more understandable steps on fingerprinting approach for indoor positioning.

- 1) Determine the scale and reference node coordinate including its ID within the indoor environment conducted in the offline stage.
- 2) Record RSSI from each of reference node which mapped to its ID and stored inside database system.
- 3) Each ID is mapped to the corresponding coordinate in the indoor local map environment.
- 4) Track the devices coordinate by continuously scanning the RSSI value runs during online stage.
- 5) Get the several closest RSSI value from reference node coordinate with devices RSSI
- 6) Compared and applied several classification methods using certain algorithms to get an ideal estimation of devices coordinate.
- 7) Determine the best reference node point and get the final estimated coordinate of the device.

Although fingerprinting is much better than trilateration in term of accuracy, the mismatch problem between the offline and online localization stage including with a low utilization of its database to store related information are two major challenges for implementing fingerprinting approach for indoor localization [5].

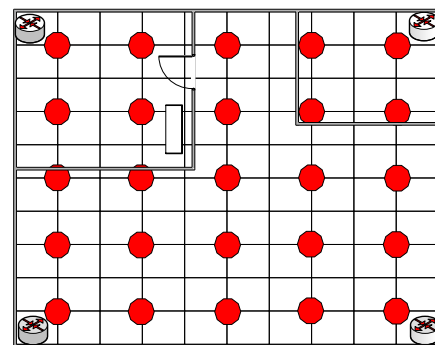


Fig. 2. Implementation of fingerprinting technique

Due to the dependency of RSS for location tracking, fingerprinting method usually estimates a distance by comparing the RSSI value of devices with the RSSI of reference node that firstly stored in the database of the system. The closest result of distance observed between those values is taken as final best estimated coordinate of the device. For fingerprinting technique, the tracking accuracy can be increased if and only if the gap distance

between the coordinate of nodes points is close to each other which will give more effectiveness to track device. Fig. 2 gives an illustration of fingerprinting technique.

From the above illustration, each of the circle objects represents the reference node in which RSSIs are captured and send to APs during the offline stage. Meanwhile, fingerprinting technique requires more implementation of APs in order to get better devices positioning and optimum accuracy result during the online stage.

Regardless of technique uses for tracking devices, these two has become and considered as the main choice due to its localization process. Table I briefly shows the features that these two techniques emphasize.

TABLE I. COMPARISON OF INDOOR POSITIONING SYSTEM TECHNIQUE

Characteristic	Scalability	Flexibility	Adaptability	Cost Efficiency / Effectiveness	Complexity	Deplorability	Accuracy
Trilateration	✓	✓	✓	✓	-	✓	-
Fingerprint	✓	✓	-	-	✓	✓	✓

Based on the features and characteristic of the techniques shows in Table I, each of it has its own capabilities and strength. As such the adaptability is related to how well does the technique works when it is implemented within the indoor environment. Due to the requirement of reference node and the related concerns of RSSI from the offline and online stage, fingerprinting is taking more process to adapt with the localization process which may result in a long run to detect device coordinate.

In term of cost, fingerprinting requires more and extra fund as the reference node is the main concern to this matter. A larger database may need to store related information of the reference node depending on how big the scale of fingerprinting technique ones want to develop. Due to this factor, fingerprinting is usually used in a specific place inside the building and not majorly implement within the whole building environment.

For the complexity of the two techniques, it relates to the initial setup and technique implementation including the localization process. Fingerprinting is harder to setup as much of information need to be observed and collect from the reference node point. Whereas trilateration get the APs to work together in locating the devices coordinate and show in the local map which seems much easier. Fortunately, the complexity contains in fingerprinting technique gives it an advantage for the accuracy in positioning devices on certain location. This is due to the help of the information of its reference node that enables a better positioning result.

These two techniques somehow have a great scalability where for trilateration it depends on the APs number and fingerprinting majorly depends on its reference node to estimate device position. The more number of these two

objects is used, the more scalable and wider can the localization process take places. In contrast, it gives both the flexibility and deplorability to add or remove numbers of APs and reference node depending on the scale of implementation needs to be developed.

### III. PROPOSED MODEL

The proposed technique is implemented based on the trilateration technique where it is combined with several algorithms to find whether the accuracy of observed result can be improved and the error rate can be minimized. The proposed technique is related to the implementation of Kalman Filter (KF) algorithm including Centroid Positioning (CP) which used to filter or manipulating the noise from the RSSI value and ensures the localization is processed within the triangle-shape formation of the setup APs.

#### A. Kalman Filter

Kalman Filter (KF) is basically algorithm contain a series of measurement where it enables a prediction of uncertain information for a dynamic system [13]. Typically the use of KF is suitable for a system that engages with an entities or element that continuously change over time. KF implementations are widely adopted to ensure the true value of certain information and entities. As such, the KF is also being used to filter signal processing as the signal obviously being affected by noise and fluctuation occurs during the transmission process.

In order to implement the KF mechanism to any of system model, two-step processes that refer to the prediction and estimation-correction are both used to measure including observe changes of information for any entities that need to be evaluated. The KF is used to find the optimum value and state that can reduce any uncertainty for further uses of any process [14]. For the prediction step, KF filter used the current state of an entity to produce certain estimation along with their uncertainties for the next state. Once the outcome is captured from prediction stage, it is estimated and corrected by updating the outcome using weighted average, where the more weight been given, the higher its certainty. This process will iterate over time until it meets the end of the process. The given equations below are best describes the situation.

$$\hat{x}_{\bar{k}} = \hat{x}_{k-1} \quad (1)$$

$$P_{\bar{k}} = P_{k-1} \quad (2)$$

where  $\hat{x}_{\bar{k}}$  is the prior estimate state,  $\hat{x}_{k-1}$  is the estimated state on the previous outcome,  $P_{\bar{k}}$  is the prior error covariance and  $P_{k-1}$  is the previous error covariance.

To relate with the system,  $\hat{x}_{\bar{k}}$  is referring to the state of the RSSI value and  $P_{\bar{k}}$  is covariance of error which is correlation between one state to another. By means, every state of the RSSI is affected by time (y-axis) to signal

strength or distance (x-axis) which determines what will be the possible RSSI state gain. In the meantime, the RSSI state itself is affected and influenced with a noise. This can be more understand from the following equation.

$$z_k = x_k + v_k \quad (3)$$

where  $z_k$  is the measurement value,  $x_k$  is the state value and  $v_k$  is the measurement noise.

The measurement value is referring to the RSSI value gain of the devices to the APs. In term of measurement noise, it depends on the environment as noise is working and exists independently and on its own. By mean, to determine and estimate the best position of devices during the tracking processes, it depends on how well prediction is made to the noise value as it will give better results of devices final positions.

The use of KF gives a good expectation and result for estimating the state value without the noise. Unfortunately, the process noise is hard to conceptualize which as it is statistically independent. This noise processing and the state condition are both considered to be Gaussian. In order to get the best true value of the state, noise parameter is usually estimated where the better estimation is conducted, the better result without noise is produced. As noise within the state lives independently, observation and changes can be done to ensure the best state is produced.

To update and give correction to the state, the following equations are used and upon finishing the process, it will iterate back from the prediction until there're no more measurement value exist.

$$K_k = \frac{P_{\bar{k}}}{P_{\bar{k}} + R} \quad (4)$$

$$\hat{x}_k = \hat{x}_{\bar{k}} + K_k(z_k - \hat{x}_{\bar{k}}) \quad (5)$$

$$P_k = (1 - K_k) P_{\bar{k}} \quad (6)$$

where  $K_k$  is the Kalman gain,  $R$  is estimated noise in the environment,  $\hat{x}_k$  is the estimate  $x$  at certain state and  $P_k$  is update state value and covariance [13].

The Kalman gain is used to tell on how much will the states estimated to change prior to the given value or state which directly refers to RSSI. Hence using equation (6) ensures that any signal can be processed out from the state and signal value. In fact, the result can be used to get more precise information on certain events where noise exists within the state or parameter.

With the implementation of KF, observation on RSSI value is managed but still depends on the Wi-Fi Analyzer application in order to get related information. It uses it to calculate the coordinate by using Trilateration method. The following equation is the basic calculation to determine RSSI value.

$$RSSI = 10^n * \log_{10}(d) + A \quad (7)$$

where, RSSI is signal in -dBm,  $d$  is distance estimation in meter,  $n$  is path loss exponent and  $A$  is RSSI value at 1 meter.

Next, the captured RSSI value is converted into the distance which is going to be used to trilaterate the position in locating the device. It can be converted into distance ( $r$ ) by using the following equation.

$$r_i = 10^{((27.55 - (20 * \log_{10}(f)) + s) / 20)} \quad (8)$$

where,  $r$  is distance in meter,  $f$  is frequency in MHz,  $s$  is signal level in -dBm and  $i$  equal to 1,2,3...

### B. Centroid Positioning

Centroid Positioning (CP) algorithm is used whenever the coordinate of three related APs has been determined. CP algorithm is actually a simple and traditional method to estimate a certain position. In order to initiate the algorithm, information of the AP coordinates that placed within the environment is the only things that matter to which it will identify unknown coordinates of subject or device [15]. This algorithm principle indicates that the range of localization process will always occur inside the formation range created [16].

The center point is used as a reference model to determine the devices coordinate and measure the rate of accuracy during the localization process. CP algorithm will pinpoint the center of the triangle which produced from the link relation of AP1, AP2 and AP3 respectively. To determine the center of the triangle, assumed that AP1, AP2 and AP3 coordinates are set to ( $x_1, y_1$ ), ( $x_2, y_2$ ) and ( $x_3, y_3$ ). The center point of coordinate ( $x_N, y_N$ ) then is computed according to the following equation:

$$\begin{aligned} x_N &= \frac{x_1 + x_2 + x_3}{3} \\ y_N &= \frac{y_1 + y_2 + y_3}{3} \end{aligned} \quad (9)$$

where,  $x_1, y_1$  is the coordinate for AP1,  $x_2, y_2$  is the coordinate for AP2,  $x_3, y_3$  is the coordinate of AP3 and  $x_N, y_N$  is the center coordinate of triangle-shape formation.

CP algorithm is amended after trilateration process that uses KF algorithm has been computed. From the observed result produced from that process, the coordinate of that result is taken and combined together with the center point coordinate. A final coordinate is then computed and observation again is made to check whether improvement has been achieved or not. This allows new results of coordinate generated which the performance and accuracy can be analyzed whether it gives better solution for localization processes or not.

To improve the devices positioning during the online localization process, RSSI value is filtered using KF algorithm. The purpose of this new implemented technique is to manipulate, minimize and find the most optimum predicted noise value from the raw RSSI. KF algorithm implementation will ensure that the true state

of RSSI is captured and it visualizes an improved positioning of devices on the map.

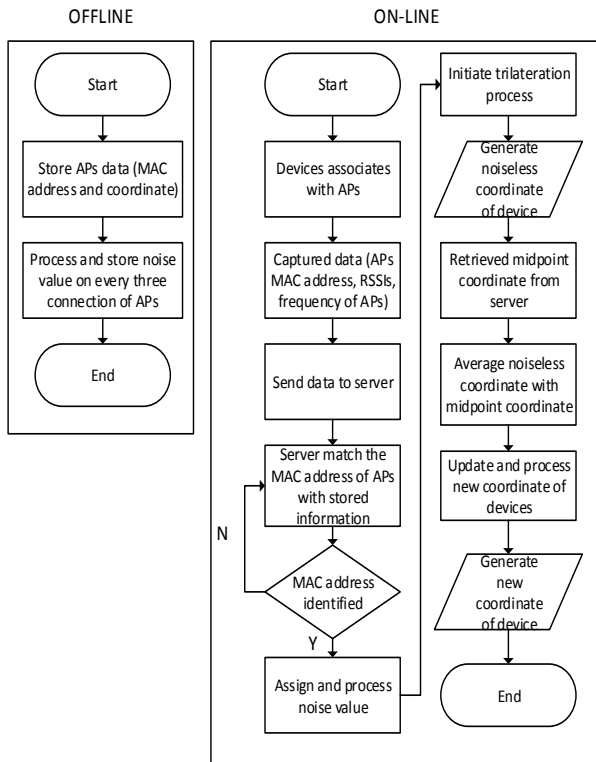


Fig. 3. Workflow of the new proposed system model

The newly improved result outcome then shows the final observed coordinate of the device which considered true it gives the best estimation of the location of the device although it may change over time due to obstacles and presence of noise. Fig. 3 describes the process of the newly proposed technique as a comparison to the previous system model. The steps in estimating the location of the device with an assistance of KF are described as follows:

- 1) APs coordinate and its MAC address need to be stored inside system database for the request and retrieval localization services.
- 2) Noise variable values have to be stored in the system database depending on the environment scale and correlation of APs that covers the range.
- 3) Mobile devices need to associate with three APs for the trilateration process.
- 4) The associated APs to devices first send data (APs MAC address, signal strength, the frequency of APs) to the server which data captured from third-party software running in the background.
- 5) Server process services by identifying APs MAC address and retrieve its coordinate.
- 6) Server allocated the noises value that based on linked- connection of APs used.
- 7) The system starts trilaterate these data to get the distance of devices from the associated APs.
- 8) Server again allocates the midpoint coordinate of the link-formed-shape relation of associated APs

to the system process. The observed result from the trilateration process is combined with the midpoint coordinate and observation is made after the result is averaged.

- 9) The improved coordinate is generated once the averaging process between the produced coordinate from trilateration and midpoint coordinate from the APs linked-formed is done. Device coordinate then is shown in the location map.

#### IV. RESULT AND DISCUSSION

An experiment to test the improved KF and CP algorithm is set up. The testbed is conducted with two separate environment setup and for each environment setup, the algorithms are verified and compared from one implementation to another. For the testing process regarding the uses of trilateration technique, it is divided into two phases, offline and online. In phase I, data collection regarding the APs information is conducted including its corresponding coordinate and MAC address which this information are stored offline in the database. In addition, as KF is related to the presence of noise, its value also been estimated and specifies which stored inside the database. Phase II engages with a real-time calculation between APs and application of user where trilateration began. Meanwhile, the environment setup where it used for the testing processes are as follows:

- 1) Area with less obstacle
- 2) Area with more obstacle

##### A. Kalman Filter Algorithm Implementation

On the first simulation testing, observation is made towards the RSSI value by using the KF algorithm in order to analyze whether the proposed technique manages to reduce error positioning rate from the normal trilateration process. Prior to starting the testing process, RSSIs is first captured and extracted using Wi-Fi Analyzer software and the values are stored inside the databases system model.

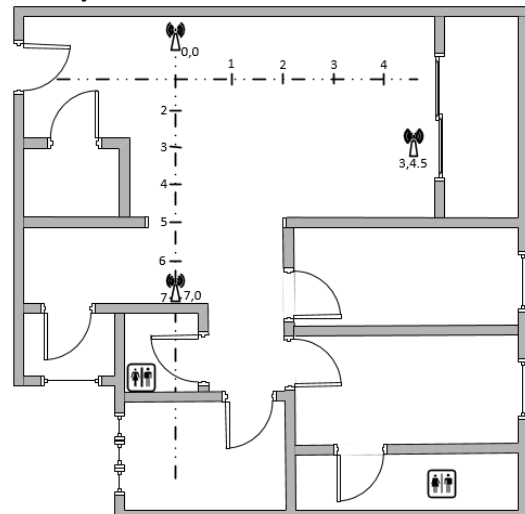


Fig. 4. Area with fewer obstacle layout

Assume that the test is first conducted in an area with fewer obstacles and followed with an area with more obstacle, the change and behaviour of RSSI are directly observed. Table II and Table III show data collection of RSSIs from three different APs which collected from different environment setup. In addition, Table II basically done in an area with fewer obstacles whereas Table III is done in an area with more obstacles. The layout and environment of the first testing are illustrated in Fig. 4 while Fig. 5 indicates the environment setup for an area with more obstacles.

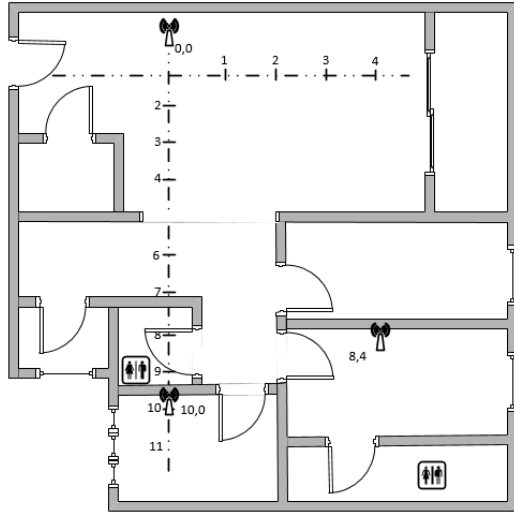


Fig. 5. Area with more obstacle layout

Placement of APs within the environment basically differentiates whether it is an area with fewer obstacles or more obstacles.

### B. Centroid Positioning Algorithm Implementation

Whenever the observed results produced from the KF algorithm, CP algorithm is used where the process is carried out on top of the produced result of KF algorithm. CP algorithm basically starts its process once APs coordinates are determined. For an area with a fewer obstacle, CP algorithm calculate the center point of coordinate based on the APs coordinate which equals to (3.3, 1.5). Whereas in an area with more obstacle, the coordinate of AP1, AP2 and AP3 placed on (0, 0), (10, 0), and (8,4) respectively produced a center coordinate point of (6.1,3). Using the center coordinate point, the observed coordinate of KF is taken and averaged together with the center coordinate. The result is then observed which can be seen on Table II and Table III.

TABLE II: RSSI DATA COLLECTION ON FIRST TESTING

Actual Co-ordinate = 4,2	Test 1 (Area with less obstacle)					
Access Point	AP1 (0,0)		AP2 (7,0)		AP3 (3,4.5)	
Noise	Process = 0.0001			Measurement = 0.1		
RSSI (dBm)	Center point coordinate (x,y) = 3.3,1.5					
	Nor-mal	KF	Nor-mal	KF	Nor-mal	KF
	-48	-44	-58	-49	-64	-54
	-48	-46	-58	-49	-64	-54
	-48	-46	-59	-50	-63	-55

	-48	-47	-59	-51	-63	-55
	-48	-47	-60	-51	-63	-55
	-48	-47	-60	-52	-63	-56
	-48	-47	-57	-52	-63	-56
	-48	-47	-57	-53	-63	-56
	-48	-47	-57	-53	-63	-57
	-48	-48	-57	-53	-63	-57
Average	-48	-46.4	-58.2	-51.3	-63.2	-55.4
Rounding Up	-48	-46	-58	-51	-63	-55
Distance (r)	1.39 ≈ 1.4	1.10 ≈ 1.1	4.41 ≈ 4.4	1.97 ≈ 2.0	7.85 ≈ 7.9	3.12 ≈ 3.1
Devices Coordinate (x,y)	Normal Trilateration 2.2,-4.9		KF 3.3,0.1		KF + Centroid 3.2,0.8	
Error Rate (x,y)	1.8,6.9		0.7,1.9		0.8,1.2	
Distance Differences	7.13m		2.02m		1.44m	
Accuracy Percentage	29.7%		79.9%		85.6%	

TABLE III: RSSI DATA COLLECTION ON SECOND TESTING

Actual Coordinate = 6.5,3	Test 2 (Area with more obstacle)					
Access Point	AP1 (0,0)		AP2 (10,0)		AP3 (8,4)	
Noise	Process = 0.001			Measurement = 0.1		
RSSI (dBm)	Center point coordinate (x,y) = 6.1,3					
	Normal	KF	Normal	KF	Normal	KF
	-65	-59	-68	-64	-51	-64
	-64	-61	-66	-64	-51	-63
	-64	-62	-67	-64	-52	-62
	-64	-63	-67	-65	-53	-61
	-64	-63	-67	-65	-53	-60
	-64	-63	-67	-65	-52	-59
	-63	-63	-66	-65	-52	-59
	-64	-63	-66	-65	-51	-58
	-63	-63	-66	-65	-52	-57
	-63	-63	-67	-66	-53	-57
Average	-63.8	-62.3	-66.7	-64.8	-52.0	-60.0
Rounding Up	-64	-62	-67	-65	-52	-60
Distance (r)	8.81 ≈ 8.8	7.00 ≈ 7	12.44 ≈ 12.4	8.81 ≈ 8.8	2.21 ≈ 2.2	5.56 ≈ 5.6
Devices Coordinate (x,y)	Normal Trilateration 1.1,16.8		KF 3.6,5.1		KF + Centroid 4.8,3.2	
Error Rate (x,y)	5.4,13.8		2.9,2.1		1.7,0.2	
Distance Differences	14.82m		3.58m		1.71m	
Accuracy Percentage	-48.2% (≤0%)		64.2%		82.9%	

During the testing process, RSSIs is being measured for multiple times where RSSIs of devices from every AP are captured for ten consecutive times. The reasons RSSI are captured several times are to summarize and get the most optimum value of RSSI as to trilaterate and estimate the device location. As the algorithm is being tested one by one, comparisons between algorithms are generated in order to evaluate and validate which algorithm process gives a higher performance to the implemented trilateration technique. In the first testing process, the signal level noise is defined which shown in Table II.

By capturing the raw RSSIs from each APs that consist of noise, the signal is filtered and produced a more smooth result where AP1, AP2 and AP3 signals is



equivalent to -46, -51 and -55. This signal level is then converted into distance measurement and location is estimated to devices coordinate on map shown in Figure 6. To verify whether noise plays a major role to the observed result, second testing is executed where APs position change in a place with lots of boundaries such as walls and door. When moving the position, RSSIs data of the APs are measured for a few second before it is extracted. This is to ensure the RSSIs data have been updated based on devices location and distance between devices to APs. Then, the same processes are repeated by capturing ten consecutive RSSIs value from AP1, AP2 and AP3 for before three implemented algorithm is executed. Then the signals are measured which gives the value of RSSIs from AP1, AP2 and AP3 in the second testing equivalent to -62, -65 and -60. This information is used to find coordinate of device and results are portrayed in Fig. 7.

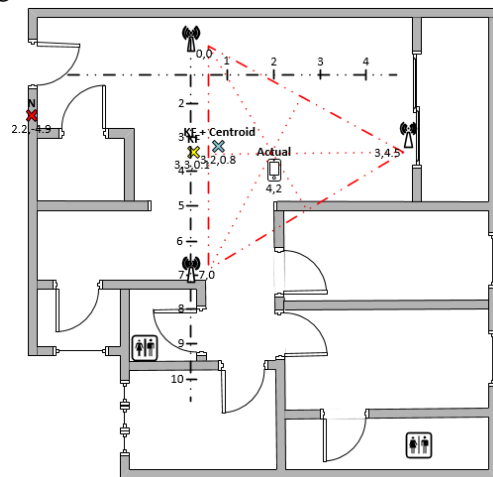


Fig. 6. Result of the coordinate produced from different algorithm in area with fewer obstacles

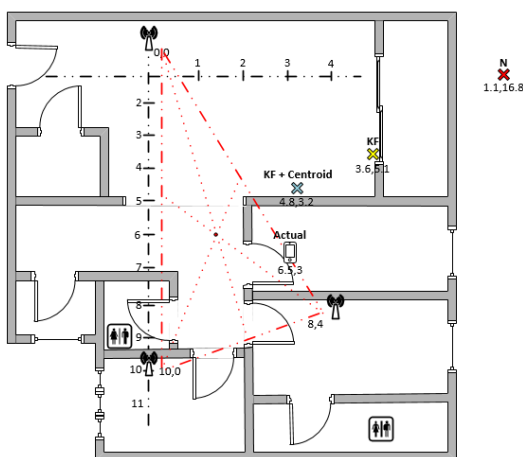


Fig. 7. Result of the coordinate produced from different algorithm in area with more obstacles

The “X” or cross mark in both Fig. 8 and Fig. 9 illustrate the result that based on the different algorithm used. The red “X” mark indicates the result if a normal trilateration is used without any algorithm implementation. Whereas yellow and blue represent

observed result captured when KF algorithm and combination of KF and CP algorithm are implemented in the trilateration process respectively.

## V. CONCLUSION

By using the KF algorithm where noise value is manipulated to the existing system model, it is shown that the error accuracy can be reduced compared to normal trilateration process. In fact, when KF and CP algorithms are combined together, the accuracy level achieved a greater result. In terms of the accuracy percentage on the implemented algorithms, it basically been determined based on distance differences between the actual locations of the device to the observed coordinate result. The smallest margin difference of distance between actual and observed coordinate, the higher accuracy percentage it has.

Since the purpose of KF is to measure the change of RSSI behaviour by minimizing noise, the performance of the existing system model is increased. In addition, the use of CP algorithm that been put on top of KF algorithm is to ensure that any localization process always resides within the triangle-shaped formation of related APs. The experiment shows that by combining both KF and CP algorithm, accuracy level can be increased and minimized error rate produce which gives a better result on the indoor location tracking system.

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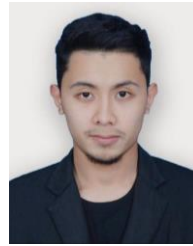
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