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Hybrid Filter Scheme for Optimizing Indoor Mobile Cooperative Tracking System

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Abstract

The precise indoor tracking system using Xbee signal strength protocol has become a potential research to the WSN applications. The main aspects for the success tracking system is accuracy performance based on location estimation. The improvement of location estimation is complicated issue, especially using RSSI with low accuracy due to the signal attenuation from multipath effect at indoor propagation. Hence, many existing research typically focused on specific methods for providing improvement schemes at tracking system area. Then, we propose hybrid filter schemes, including extended gradient filter (EGF) for filtering noise signal based distance modification, and modified extended Kalman filter (MIEKF) will be combined with trilateration for filtering the error position estimation. Using mobile cooperative tracking scenario refers to our previous work, the proposed hybrid filter scheme which is called modified iterated extended gradient Kalman filter (MIEGKF) can optimize the error estimation around 41.28% reduction with 0.63 meters MSE (mean square error) value.

Keywords: hybrid filter, mobile cooperative tracking, MIEGKF, MSE, RSSI

1. Introduction

Many mobile applications of wireless sensor network (WSN) have the requirement on the location knowledge of human or devices. These applications have recently a lot of attention due to a wide range of potential implementations especially in the field of target tracking. Target tracking is the process which estimates target directly with some coordinate system as the reference. The target position can be specified as absolute coordinates consisting of (latitute, longitude) or (x, y) coordinates [1]. The target tracking can be viewed as a sequential localization which is requiring real-time mechanism in location estimation process [2]. Target tracking as the part of localization system can be applied to various domain such as enviromental monitoring, smart building, location service and rescue, showing the trajectory of the object or human in tracking system, human interfacing and network configuration [3, 4].

Depending on environment, target tracking are categorized into two types, indoor and outdoor. In outdoor environment still can be detected accurately by global positioning system (GPS) module for showing the location information. Due to the small-scale of the indoor environment, GPS signal is too faint to provide suffcient accuracy [5]. Compared with open outdoor environments, indoor environments are more complicated in terms of layout, topology and spatial constrains [6]. As a result, the wireless signal will be influenced by propagation effect such as shadowing, multipath fading, additive noise and some obstacles or materials of the building at indoor environments [6, 7]. There are several numbers of general measurement which have been developed with different kinds of target tracking methods without wireless signal strength, such as AOA (angle of arrival), TDOA (time difference of arrival) and TOA (time of arrival) [3, 6–8]. TOA and AOA have more accurate estimation compared to the other measurement scheme. On the other hand, these method require high cost hardware which can make difficult implementation due to the potentially high number of nodes required for covering a huge area. Therefore, signal strength based methods which generally employ measurements of RSSI (received signal strength indicator), provided by many wireless network devices that have inexpensive cost and easy implementation, is a good solution for target tracking [3, 9]. However, RSSI value is easily affected by various factors such as temperature changes, reflection of sound waves and some presence of something that can block the signal

transmission. Even at the fixed location, RSSI values are very fluctuate according to its error and noise component in it [10, 11].

Indoor RSSI based target tracking has become popular mechanism, but its instability and unpredictability characteristic can be affected to the location estimation accuracy [12]. To cope this problem, filtering scheme is applied to detect and eleminate outlier data of RSSI for improving its data quality. The filtering scheme built a forecasting model on the history data and then used it to predict the future values [13]. Since the accuracy is the key indicator to evaluate the performance of tracking system, many kinds of filtering algorithm used to improve the accuracy and provide low complexity. Bayesian filtering includes Kalman filter (KF), extended Kalman filter (EKF), sigma-point Kalman filter, particle filter (PF) and hidden Markov models are powerfull probabilistic tools that can estimate dynamic system state from noisy measurements. In addition, refers to research in [6] all kinds of bayessian filtering technique still fail to completely eliminate the uncentainty location estimation especially in RSSI based measurements. The hybrid schemes through fusing multiple algorithm can combine the other advantages of each algorithm.

Many researchers have been tried for combining several algorithms to obtain high precision result. Combination unscented PF (UPF) algorithm with particle swarm optimation (PSO) can improve the precision of the intrusion localization based on TOA signal measurements [14]. PF algorithm also can be combined with the other algorithm, such as fingerprinting fo Indoor localization and tracking system [15]. The large iterations number requirement up to 50 iterations in UPF and PSO combination will be influenced to the computation time performance. Median filter scheme which is followed by distance error elemination algorithm have been proposed in [8]. This scheme is applied at indoor localization by using Wi-fi access point, have low complexity compared to another filter scheme. However according to the MSE value result, it is only achieved 2.96 meters much higher error than using KF algorithms and its derivatives ie: UKF, EKF, IEKF. KF works on prediction-correction model applied for linear and time-variant or time invariants system [16]. While according to the error analysis result based on the simulated and real-time RSSI measurements in [11], extended gradient filter (EGF) performs better than KF algorithm. The prediction process of EGF algorithm is extracted the most often RSSI measurents received. While, the random distribution data of RSSI measurement have non-linear characteristic. EKF can be applied in non-linear system which is quite suitable for target tracking especially using RSSI measurements [7, 12, 17, 18]. When EKF compared to the other bayessian filtering algorithm such as PF algorithm, EKF has low memory requirement and low complexity [18].

In this paper we propose hybrid filter scheme for optimizing the target tracking based RSSI measurement. Combining EGF algorithm for filtering and predicting the RSSI measurement with the EKF algorithm for reducing the error location estimation from trilateration algorithm, can provide a multilayered conceptual framework of improvement schemes at the target tracking system. IEKF (iterated extended Kalman filter) as the EKF refinement based on its local iteration will be processed data from the previous output of EKF algorithm as the IEKF input calculation. The iterations of IEKF should be stopped when there is no significant change to the data [19]. Due to the computation time impact from the increasing of iterations numbers, the role of iterations of IEKF can be modified based on selection process. Modified IEKF which have been proposed in [7] utilize selection process to the average result of each iteration and choosing the best result for all iterations. Modified IEKF can be reduced the fluctuative data of estimation result which will make complicated process in determining the maximum number iterations of IEKF. Adopted Modified IEKF from [7] and combined with EGF to the mobile cooperative tracking scenario from [9] will be produced significant reduction in error estimation based RSSI measurement. The contribution of this paper is to propose optimization design system for mobile cooperative tracking scenario that used EGF algorithm to filter noise of RSSI measurement and modified IEKF (MIEKF) to reduce error estimation output from trilateration algorithm as initial estimation.

To apply hybrid filter scheme, the three anchor nodes (ANs) as the transmitter are sending RSSI via Xbee S2 PRO module to the unknown node (UN) as the target. The original RSSI measurement values will be converted to the distance using pathloss exponent (PLE) value which have been modelled before in offline phase. Using cluster-based PLE areas for complex indoor environment can be minimized propagation effect problem which have various PLE value [20]. Three nearest distance are used for initial estimation using trilateration

algorithm. After that, UN send the data frame involve location estimation coordinate (X, Y), distance estimation, and original RSSI measurement to the server by the gateway node (GN). At the first step, server will be filtered the original RSSI based on distance estimation using EGF algorithm. Initial estimation process as well as process at UN will be calculated again in server, using filtered RSSI. The lowest error estimation result will be selected as the input data of MIEKF. The final output of MIEKF is the passed route of the UN at building. This layered scheme in optimizing the accuracy performance of indoor tracking system has low processing time due to the complex process is occured at server. MIEGKF algorithm is not loaded the capacity of the sensor node. To evaluate the performance of MIEGKF, mobile cooperative tracking scenario will be simulated using RSSI data measurement in a realistic condition. The experimental result show that proposed hybrid filter scheme MIEGKF algorithm has better performance in accuracy of tracking system and stability data of RSSI measurement than MIEKF algorithm. Although MIEGKF require a little more computation time compared than MIEKF algorithm.

2. Proposed Hybrid Filter Scheme

In this system, we propose filter scheme using multilayered algorithm for improving the accuracy reqruitment in indoor tracking system. The multilayered algorithm contain trilateration, EGF algorithm, and MIEKF algorithm which are called as modified iterated extended gradient Kalman Filter (MIEGKF) algorithm. UN as the target node will move followed by RSSI data reception from the AN. After receiving the RSSI data from three AN, UN will be converted the RSSI become the distances and also calculated using trilateration algorithm for getting the estimated location (XTRI1, YTRI1). UN node send its estimated location to the server with some other data such as all RSSI from each AN, and also the distances conversion.

The complicated calculation algorithm required high computation time will be occured at Server. EGF algorithm will be processed at server using some additional parameter from UN. According to the previous research in [10], EGF is filtered the RSSI based the time observation. While in this proposed system, EGF is filtered the RSSI based the estimated distance which have been calculated before in UN. The parameter calculation at (10-15) will be modified using RSSI based distance observation. Due to the main parameter still remain RSSI measurements, the observed initialization at (9) will be same and only modified based on distance function. The time-stamp at (10) should be modified into distance function as follows:

$$d = [d_1, d_2, d_3, \dots, d_n] \tag{1}$$

The deviation ratio between the RSSI measurement and its estimated distance can be written using this following equation:

$$\overline{R_n} = k . \sum_{i=1}^n R_i \rightarrow R_i = \frac{\Delta rssi_i}{\Delta d_i} = \frac{rssi_i - rssi_{i-1}}{d_i - d_{i-1}} \tag{2}$$

k is the window size representation which should be between zero and one. If the value of k is nearly zero, the filtering process will be not processed. An optimal value of k specifially for this system that was adopted from previous research in [5] can be determined using this following calculation:

$$k = \frac{0.3 * RSSI_0 - RSSI_i}{\max(d)} \tag{3}$$

The value of 0.3 is obtained from learning process based on simulation for getting the appropriate number in reliability of RSSI measurents. $RSSI_0$ is the RSSI data measurement at 1 meter distance as the reference parameter from $RSSI_i$ at certain distance. $RSSI_0$ in this system is -44 dBm in line of sight condition (LOS) between UN and AN. According to the average deviation ratio calculation at (26), the predicted RSSI value can be derived as:

$$RSSI_{predicted} = (k . \sum_{i=1}^n R_i * \Delta d_i) + rssi_{i-1} \tag{4}$$

The final result of EGF algorithm is the filtered RSSI measurement that used standard deviation rule as shown at (10, 11). The filtered RSSI will be processed again for having estimated distance calculation and also estimated position using trilateration algorithm (XTRI2, YTRI). As shown at Figure 1, the estimated position from trilateration algorithm will be compared and selected the lowest error estimation using average value approach that was used before in modified IEKF algorithm [7]. The output from this reselection process will be optimized again based on error output analysis using IEKF algorithm including its modification. The part of optimization using MIEKF is adopted our previous research in [7]. Using simulation process based on data measurement and realistic scenario in mobile cooperative tracking, this hybrid filter is achieved the accuracy improvement due to two parts involve RSSI data measurements and its estimated location have been repaired using MIEGKF algorithm. The result of the MIEGKF will be presented at the next section of result and analysis.
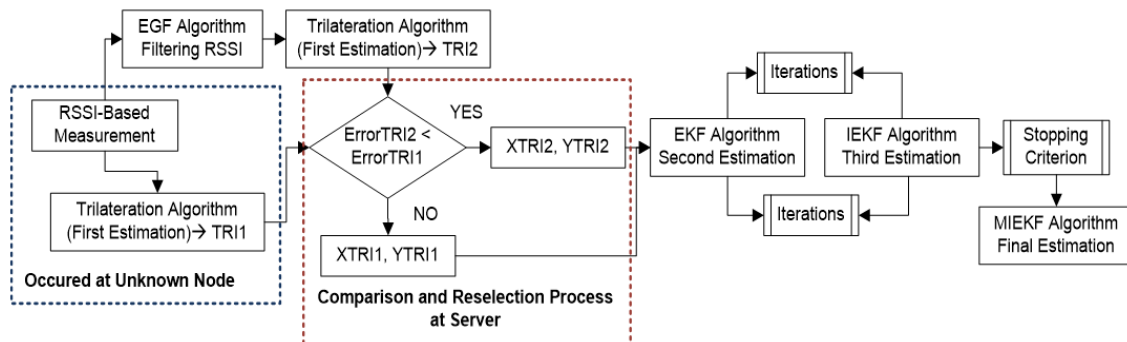

Figure 1. Proposed hybrid filter scheme

3. Research Method

There are severals adopted algorithm in this paper. Those are trilateration algorithm which is computes the location target by using distance between target and transmitter node, EGF algorithm for eliminating the outlier data of RSSI measurements, and also MIEKF algorithm for improving the   location target estimation from trilateration based on iterations role arrangement. Combining EGF and MIEKF algorithm become a hybrid filter scheme will be improved two main aspect parameters, those are stability data of RSSI measurements that can be influenced to the accuracy performance of this mobile tracking system.

3.1. Trilateration Algorithm

Trilateration algorithm refers to the calculation process which estimates the target location by using the distances from three fixed position of the anchor nodes (AN) as the transmitter. The distances are deducted from RSSI measurements between the target or unknown node (UN) with the AN. As shown at Figure 1, there are three fixed AN coordinate assumption (X_{AN1} ,Y_{AN1}), (X_{AN2} ,Y_{AN2}), (X_{AN3} ,Y_{AN3}), and there is estimated target UN (X_{UN} ,Y_{UN}), at the point intersection of ANs. The distance *(d)* between UN and AN d_i *(i= 1, 2, 3)* can be determined using the following (5) [1]:

$$d_i = \sqrt{(X_{UN} - X_{AN_i})^2 + (Y_{UN} - Y_{AN_i})^2} \text{ , for i = 1,2,3,...,n} \tag{5}$$

Each AN and UN coordinate will be subtitued to the (5), then each distance result from (5) will be substracted with the other part as shown to this following equation:

$$d_n{}^2 - d_{n-i}{}^2 = 2X_{UN}\left(X_{AN_{n-i}} - X_{AN_n}\right) + X_{AN_n}{}^2 - X_{AN_{n-i}}{}^2 + 2Y_{UN}\left(Y_{AN_{n-i}} - Y_{AN_n}\right)$$
$$+Y_{AN_n}{}^2 - Y_{AN_{in-1}}{}^2 \tag{6}$$

let assume, new variables $V_{i\,(1,2,3...,n)}$ for simplifying some quadratic part at (6) as follow:

$$V_{i=1,2,3,\dots,n} = \frac{\left(X_{AN_n}{}^2 - X_{AN_{n-i}}{}^2\right) + \left(Y_{AN_n}{}^2 - Y_{AN_{n-i}}{}^2\right) + \left(d_n{}^2 - d_{n-i}{}^2\right)}{2} \tag{7}$$

according to the (5-7), the estimated position of UN (X_{UN}, Y_{UN}) can be calculated using this following formula respectively [7, 20]:

$$X_{UN} = \frac{V_{n-i}(Y_{AN_{n-i}} - Y_{AN_n}) - V_i(Y_{AN_i} - Y_{AN_{n-i}})}{(X_{AN_i} - X_{AN_{n-i}})(Y_{AN_n} - Y_{AN_{n-i}}) - (X_{AN_n} - X_{AN_{n-i}})(Y_{AN_i} - Y_{AN_{n-i}})}$$

$$Y_{UN} = \frac{V_{n-i}(X_{AN_{n-i}} - X_{AN_n}) - V_i(X_{AN_i} - X_{AN_{n-i}})}{(Y_{AN_i} - Y_{AN_{n-i}})(X_{AN_n} - X_{AN_{n-i}}) - (Y_{AN_n} - Y_{AN_{n-i}})(X_{AN_i} - X_{AN_{n-i}})} \tag{8}$$

In ideal condition of trilateration algorithm, three circles will intersect at only one point. However, in reality, the estimated distance contain noise due to the RSSI measurements as ilustrated at Figure 2. Therefore the estimated position of UN become the unique point of intersection. In that case, it requires the other technique to refine the output of trilateration and also filter the noise from RSSI data measument for getting the target node with minimum position estimation error.
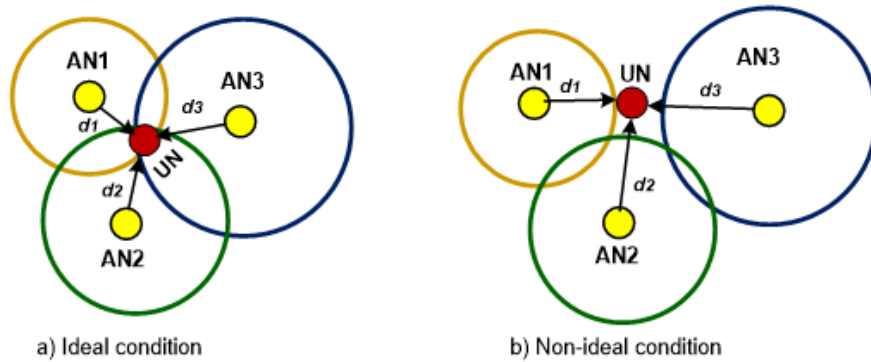

Figure 2. Trilateration algorithm illustration

3.2. Extended Gradient Filter (EGF)

In order to use RSSI measurement for indoor object tracking, there are some factors which can affect to the data, such as signal attenuation, multi-path effects, device manufacturing faults, temperature, effect of human bodies, physical objects and etc. Due to this influence, signal becomes weak and sometimes produces instability data. Extended gradient filter (EGF) is one from various approaches for minimizing the effects of noise in RSSI measurements. EGF algorithm is used to predict RSSI measurements when there is disconnection between AN and UN. Therefore, the movement of the UN as the target can make increase and decrease the RSSI values from AN. EGF algorithm is suitable for uniform speed of the moving object which is appropriate to this proposed system, there is not speed variable for the target movement. In mobile cooperative tracking scenario, the movement of an object is assumed in uniform speed. According to that condition, the RSSI value for each position of the UN movement will be different. To observe the change of RSSI measurement values, RSSI values observed at time t_i represent as follows [5]:

$$rssi = [rssi_1, rssi_2, rssi_3, \dots, rssi_n], \text{ in dBm unit} \tag{9}$$

The time-stamps t_i of the range time for RSSI measurements, for i =1,2,3, ..., n can be written as follows:

$$t = [t_1, t_2, t_3, \dots, t_n] \tag{10}$$

then, the RSSI measuments ratio of change (R_i) based on its time will be also varying as shown to this following (11):

$$R_i = \frac{\Delta rssi_i}{\Delta t_i} = \frac{rssi_i - rssi_{i-1}}{t_i - t_{i-1}} \tag{11}$$

Window size of EGF algorithm denotes as *k* number of used measurements for calculating the previous ratio of change. The ratio of change average at window size of *k* can be calculated as follows [5,10]:

$$\overline{R_n} = \frac{1}{k} \sum_{i=n-k}^{n-1} R_i \tag{12}$$

having this average rate value representation, the nth as the predicted RSSI value can be derived as:

$$RSSI_{predicted} = \left(\frac{1}{k} \sum_{i=n-k}^{n-1} R_i * \Delta t_i \right) + rssi_{n-1} \tag{13}$$

The future RSSI measurement at the next movement will be determined using prediction process. While the filtering process of EGF will be adopted the standard deviation (σ) rule to the predicted RSSI and previous RSSI value.

$$\sigma(RSSI_n, rssi_n) = \sqrt{\frac{1}{2}(RSSI_n - rssi_n)^2} \tag{14}$$

using (10), the filtered RSSI measurements can be obtained by the following (15):

$$RSSI_{filtered} = RSSI_n + \left(sign(RSSI_n - rssi_n) \right) * \sigma(RSSI_n, rssi_n) * \sigma(RSSI_n, rssi_n)^2 \tag{15}$$

Where *sign( )* represent as the positive or negative value of the difference between predicted *RSSI* and the current received RSSI measurement (*rssi).* The output of *sign* command will be followed the input condition, ie: input positif , output is 1, input negative output is -1 and if the input zero the output will also zero. The performance of EGF algorithm is only improving the RSSI data measurement which will be used for distance estimation phase and also location estimation using trilateration. However, the result of trilateration is still not good enough in accuracy level. The next following sub-section will be presented an description of the MIEKF algorithm for improving the accuracy level.

3.3. Modified Iterated Extended Kalman Filter (MIEKF)

There are three main steps of estimated position refinement at modified iterated extended Kalman filter (MIEKF) algorithm which is derivative algorithm from Kalman filter (KF). As shown at Figure 3, those are extended Kalman filter (EKF) as the improvement algorithm for the trilateration output, iterated EKF as the error reduction algorithm for EKF algorithm based on iteration numbers, and also modified IEKF for giving the limits number of iterations at IEKF algorithm.

EKF is one of bayessian algorithm that is usefull for non-linear applications as well as indoor tracking system. Data variation from RSSI measurement can give non-linear effect caused by indoor propagation losses. Due to the non-linear effect couldn't be measured, IEKF algorithm is also can be used for optimizing the accuracy improvement. IEKF algorithm can be improved the estimation output from EKF algorithm using its observation matrix equation which will be repeated for having iterations process until stopping criterion met. Stopping criterion is represented as the maximum number iterations of IEKF algorithm. However, the strongly non-linear effect of indoor tracking system can make the reduction of estimated error IEKF algorithm at each iteration will be different. According to this problem, IEKF algorithm required some modifications procedure based each iteration result. This modification is also able for minimizing the iterations number that can be increased the computation time.
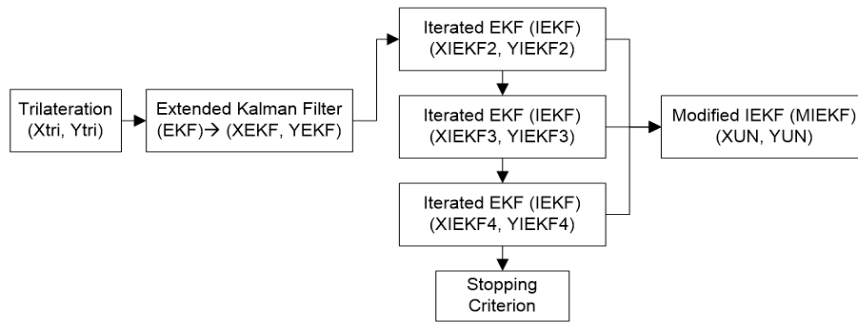
Figure 3. The main steps of MIEKF algorithm

The MIEKF algorithm as the EKF development will also be processed using three steps involves initialization state, update state and the predict state [1–3, 7, 8, 12, 17–19]. The initialization state variable referring to the trilateration output at (8), can be written as follows:

$$X_0 = [X_{tri} \ Y_{tri}] \tag{16}$$

Reffering to the trilateration algorithm, there are three nearest distance (d_1, d_2, d_3) of UN to the AN. Z_k as the observation data matrix is using distance estimation from the result of RSSI based measurement can be described as follows:

$$Z_k = [d_1 \ d_2 \ d_3] \tag{17}$$

The coordinate output from trilateration algorithm will be used for covariance matrix of MIEKF algorithm that is derived to this following (18):

$$P_0 = \begin{bmatrix} \sigma^2 X_{tri} & 0 & 0 \\ 0 & \sigma^2 Y_{tri} & 0 \\ 0 & 0 & 0 \end{bmatrix} \tag{18}$$

Each variable including initialization state and covariance matrix will be predicted to the next state using this following (19-20):

$$X_k = X_0{}^T * F \rightarrow F = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{19}$$

$$P_k = F * P_0 * F^T + P_0 \tag{20}$$

The predicted state output is the update data which should be multiplied with Kalman gain (K_k) as shown to this equation:

$$K_k = P_k . H_k{}^T . S_k{}^{-1} \tag{21}$$

H_k is the observation data matrix in update state, will be represented by jacobian matrix. This matrix is obtained from comparison data between coordinate output (X_{tri}, Y_{tri}) and estimated distance ($dist_{(i=1,2,3)}$) of trilateration algorithm.

$$H_k = \begin{bmatrix} \frac{X_{tri} - X_{AN1}}{dist_1} & \frac{Y_{tri} - Y_{AN1}}{dist_1} & 0 \\ \frac{X_{tri} - X_{AN2}}{dist_2} & \frac{Y_{tri} - Y_{AN2}}{dist_2} & 0 \\ \frac{X_{tri} - X_{AN3}}{dist_3} & \frac{Y_{tri} - Y_{AN3}}{dist_3} & 0 \end{bmatrix} \tag{22}$$

$$dist_{i=1,2,3} = \sqrt{(X_{tri} - X_{AN_i})^2 + (Y_{tri} - Y_{AN_i})^2}$$ (23)

Another covariance matrix is S_k which is calculated by combination of covariance matrix P_k with noise covariance of estimated distance R_k as follows:

$$S_k = H_k . P_k . H_k^T + R_k \rightarrow R_k = diag(\sigma^2 d_1 \quad \sigma^2 d_2 \quad \sigma^2 d_3)$$ (24)

then the update state including covariance matrix P_0 and observation matrix Y_k are derived as :

$$P_0 = (P_k - K_k * H_k) * P_k$$ (25)

$$Y_k = Z_k - h_k \rightarrow h_k = [dist_1 \quad dist_2 \quad dist_3]$$ (26)

the posterior state as the estimation result of EKF algorithm (X_{EKF}, Y_{EKF}) is represented as:

$$X_{k+1} = X_k + K_k . Y_k$$ (27)

The calculation based on eq.(17-27) are the steps of EKF algorithm. The IEKF algorithm can be applied based on EKF calculation by replacing the estimated output of EKF as the initial state of IEKF first iteration at i = 0. The equation of switching state vector at each iteration number can be derived as:

$$X_k{}^i = [X_{EKF_i} \quad Y_{EKF_i}]$$ (28)

As well as the other state parameters which is used trilateration algorithm should be replaced by the result of EKF algorithm. This process will be continously up to maximum number iterations founded. The maximum number iterations or stopping criterion is discovered from learning process the data of each iteration result, when there is not change in error reduction, the iteration process should be stopped. Unspesific covariance noise modelling system can make ustable reduction of IEKF for each iterations. Utilizing selection process for finding the best performance to the existing data with an average value approach is an idea from MIEKF algorithm. Using this scheme, the reduction will be always stable although each iteration is not constantly reduced [7].

4. Results and Discussion
In this section will be presented the design system of mobile cooperative tracking system and some procedure of RSSI measurement. The mobile cooperative tracking scenario is consist of network model deployement and also data frame data structure for having communication mechanishm between AN to UN or UN to the server. There are two main parameters for analyzing this hybrid filter scheme performance, those are the error estimation and the processing time requirement.

4.1. Measurement Phase
The measurement phase was implemented with signal transmission from Xbee-Pro (S2) module. Anchor node (AN) as the reference node was transmitted RSSI data to the unknown node (UN) as the target node. AN position is placed at 2.4 meters height, while the UN is placed at 0.9 meters height. There are 18 AN with seven meters separation and one UN that will be deployed at 3rd floor of applied postgraduate PENS building as the observation environment. The propagation characteristic of this building can be obtained from pathloss exponent (PLE) value and deviation standard. Those PLE value (*n*) based on RSSI measurement approach can be determined using this following (29) [20]:

$$n = \frac{RSSI_0 + RSSI_j}{-(10 \, log_{10} \, d_j)}$$ (29)

RSSI$_0$ as the data reference parameter will be measured at one meter distance among to the AN and UN. RSSI$_j$ are measured at LOS condition every 2 meters movement of UN in all hallways of the building. The movement distances of UN from AN are represented by d$_j$ at *j (1,2,3..n).* Adopted from [19], the PLE value that are used in sytem in range 0.89 to 1.79 for LOS condition and 2.01 to 5.09 in non-LOS condition. This PLE value calculation is occured in offline phase that can later be used in real-time scenario of tracking system. UN has been known before the PLE value for calculating the estimated distance.

$$d = 10^{-\left(\frac{RSSI_i + RSSI_0}{10 \cdot n}\right)}$$ (30)

While, in online phase of RSSI data measurement, we assume the point route of UN at building observation. There are 53 points route which will be passed by UN. At each point movement, the UN will be received three data RSSI from nearest AN. The distance of inter-point movement is two meters. After receiving the RSSI data, UN will be calculate the estimated distance (*d*) using PLE value parameter that will be subtitued to (30).This estimated distance will be used for trilateration parameter calculation. Each point route that haven't known before, can be shown at the server. The cooperative mechanishm in communication system between AN, UN, and server will be discussed at the next subsection.

4.2. Mobile Cooperative Tracking Scenario

The main concept of the mobile cooperative tracking scenario is allow UN will be served by another AN when it move continously. According to the measurement phase, the maximum range of AN could be served the UN is 7-10 meters. While in Xbee-Pro (S2) module spesification shows that it can transmit signal up to 60 meters. Due to the environment condition and stability data requirement in this system, the maximum coverage of UN is determined. This tracking system contain AN, UN, gateway node (GN) and also server for supporting the cooperative communication system.

One UN as the object tracking receive the RSSI from each AN and also send the data messages to the GN. The GN function is only receive the message from UN and forward it to the server. As ilustrated in Figure 4, server will be show the estimated result involve using trilateration and the estimated passed route using MIEGKF algorithm.
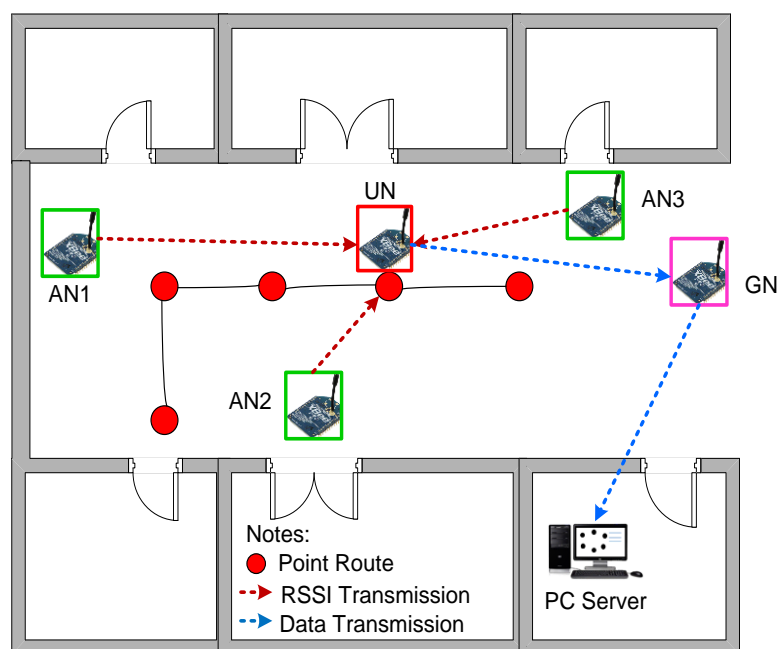

Figure 4. Communication mechanism of mobile cooperative tracking

Mobile cooperative tracking scenario starts from calculating the estimated position of the UN by trilateration algorithm. Each point route as the UN passed location was served by three nearest AN with 7-10 meters maximum range. When the UN move to the next point route, the AN will be served by others nearest AN. Because of many parameters number for having calculation in this system, there are two types data frame structure in data transmission of mobile cooperative tracking. i) data frame for sending message AN to the UN, ii) data frame from UN to GN or GN to the PC server. Each AN will be sent some parameter for initial estimation at UN, such as route number, AN coordinate, RSSI and area number for determining PLE value based on its database. All these parameter are required for trilateration algorithm calculation. Three AN are automatically send the data frame structure as in Figure 5 to the UN together using Xbee-S2 (Pro) as the communication protocol. UN receive the message directly and also separate each parameter from its separator "@". From all value parameters reception, UN calculate its position using trilateration and send its location information to the server with forwarding it via GN. As shown at Figure 6, UN will send some parameters ie: route number, temporary estimated location, each estimated distance from three nearest AN, and also area number. All coordinate position of AN don't send to the server because of server can check it to the its database according to the area number. Otherwise to the UN, at server the requirement data is more complete than UN due to its memory capacity. UN is only know the PLE value based its area number. While server can know everythings such as the served ANs and also their coordinate, and PLE value number. Therefore, in server will be occured complicated calculation using MIEGKF algorithm which is also initialized with trilateration algorithm again.

Route	S	X AN	S	Y AN	S	RSSI	S	Area
1	@	61.68	@	81.62	@	-47.0	@	1

Figure 5. Data frame structure from AN to the UN

Route	S	XTRI 1	S	YTRI 1	S	RSSI 1	S	D1	S	RSSI 2	S	D2	S	RSSI 3	S	D3	S	Area
1	@	61.68	@	81.62	@	-47.0	@	3.20	@	-48.6	@	3.98	@	-52.8	@	5.57	@	1

Figure 6. Data frame structure from UN to the GN or to the PC sever

4.3. Performance Analysis

The effectiveness of the proposed EGF algorithm for smoothing the RSSI data measuments is presented by comparing the original data of RSSI measurements with filtered RSSI data. Figure 7 respresents the distribution of RSSI measurement data based on distance modifications from 1-12 meters. The original RSSI data measurements show raw condition over the distance modification especially at 2-3.5 meters distance as indicated by uniform RSSI data at -47 dBm up to -53 dBm. After applying the EGF algorithm, the EGF smoothed well the raw RSSI measurent data. The smoother RSSI data can be approached to the ideal condition or log normal distribution of RSSI data based on distance modification.

On the other hand the smoother RSSI data has more small variations, which is due to the its inability to loosing the noise effect and removing the outlier data. This small variations can influence to the estimated distance calculation. Estimated distance parameter is important value for having trilateration. Figure 8 show that using EGF algorithm for minimizing the signal variations is achieved lower error estimated position than using conventional trilateration. According error analysis using cummulative distribution (CDF) graphic at Figure 8, Adding EGF smoother can reduce error significantly at CDF 0.1 up to 0.9 which have estimated error lower than 4 meters. While conventional trilateration have estimated error at the range of 1 meters up to 5 meters at thats CDF range. Overall the average of estimated error using EGF smoother is only 1.57 meters which is smaller than conventional trilateration at 2.08 meters.
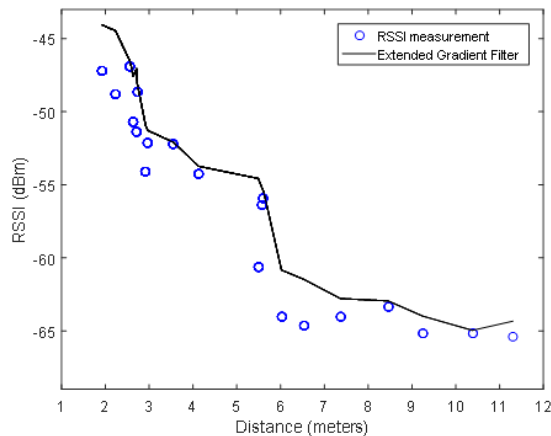
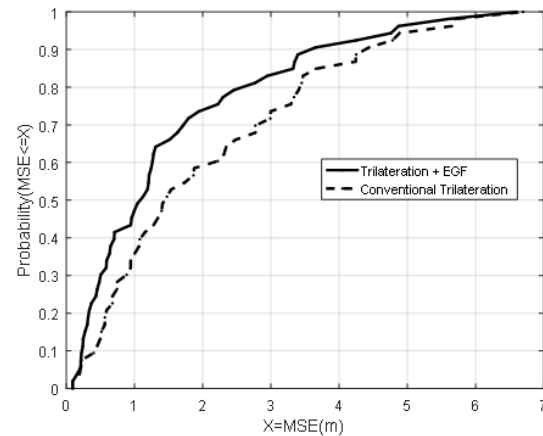Figure 7. RSSI smoother using EGF algorithm

Figure 8. Error CDF graph comparison at trilateration implementation

The reduction at trilateration algorithm after combined with EGF smoother, will be also affected to the MIEKF algorithm. The MSE comparison at Figure 9 shows that MIEGKF algorithm is the better algorithm which has lowest error estimation at the range of 0.018 meters up to 2.44 meter. Whereas, the MIEKF without EGF algorithm is achieved MSE at 0.065 meter until 2.43 meters. Although at the range of MSE comparison between MIEGKF and MIEKF have small difference, in MSE average value calculation MIEGKF still achieve the smallest error at 0.63 meter as listed at Table 1.

Table 1. Performance Analysis of Hybrid Filter Scheme

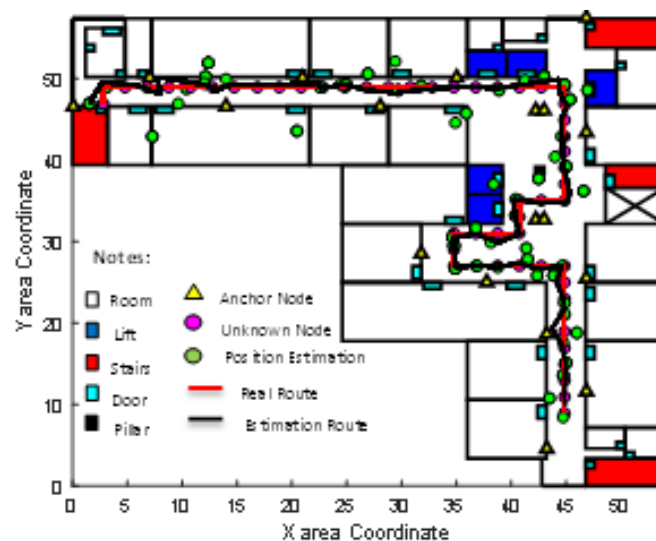|	Error Estimation Average (meters)		Processing Time (seconds)	
	Single Filter Scheme	Hybrid Filter Scheme	Single Filter Scheme	Hybrid Filter Scheme
TRI	2.08 m	1.57 m	0.075 s	0.156 s
IEKF-1	1.30 m	1.29 m	0.156 s	0.209 s
IEKF-2	1.19 m	1.04 m	0.191 s	0.254 s
IEKF-3	1.13 m	0.97 m	0.237 s	0.301 s
IEKF-4	1.10 m	0.99 m	0.281 s	0.341 s
Modified IEKF	0.88 m	0.63 m	0.303 s	0.362 s

Figure 8. Estimated route from MIEGKF implementation
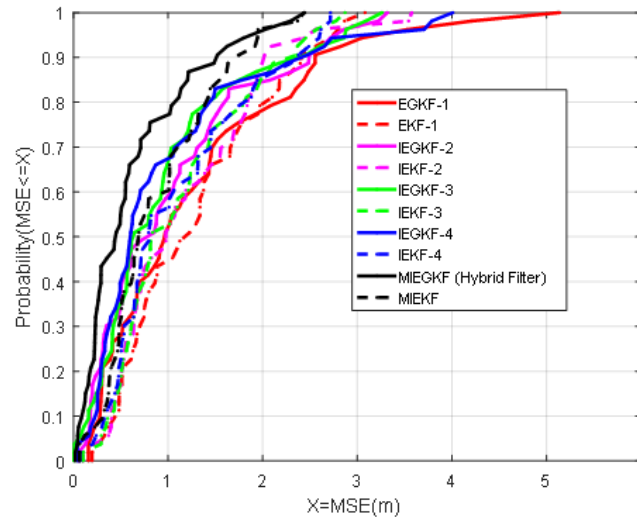
Figure 9. Error CDF graph comparison at MIEGKF implmentation

According to the performance of MIEGF algorithm which has lowest estimated error, it was used for showing the passed route of UN. In this simulation was ilustrated the real sketch of observation building including the AN deployment, route assumption, and also the estimated result implementation. As shown at Figure 8, there are 53 points route of UN that have been estimated using trilateration algorithm and also linearized using MIEGKF algorithm.

In otherwise adding EGF algorithm for filtering the RSSI data measurements can increase the computation time. It proves from processing time measurement at server that used Toshiba satelite Core i7 M840 as the laptop spesification and Matlab type R2016a as the simulator tools, without EGF algorithm was took up around 0.08 seconds faster than adding EGF. Without adding EGF filter which was only take single filter in estimated position, was achieved better performance in processing time than the error performance. The difference processing time 0.059 seconds between MIEGF with MIEKF algorithm was not significantly influence the performance result. Moreover this algorithm is occured to the server that have larger capacity than small device of node.

5. Conclusion

In this paper, we propose optimization mechanism for mobile cooperative tracking system using hybrid filter scheme. There are two filtering process in this system. EGF algorithm as the initial filter is smoothing the outlier data from RSSI measurement based its distance modifications. The output of EGF algorithm are smoother RSSI measurement data which have low variation than without it. The smoother RSSI data is effectively for using estimated position calculation. The initial repairment at RSSI data are influenced to the next process calculation in tracking system. The comparative analysis show that MIEGKF as the hybrid filter could decrease around 0.2 times better than single filter scheme of MIEKF algorithm. Although it was only required arround 0.07 s additional time for processing time. The future work of this paper will be focused at adaptive environment system for multi objects tracking system.

References
[1]   Subhan F, Hasbullah H, Ashraf K. Kalman filter-based hybrid indoor position estimation technique in bluetooth networks. *International Journal of Navigation Observation. Hindawi Publishing Corporation.* 2013; 2013.
[2]   Mahfouz S, Mourad-Chehade F, Honeine P, Farah J, Snoussi H. Target Tracking Using Machine Learning and Kalman Filter in Wireless Sensor Networks. *Sensors Journal*, *IEEE*. 2014; 14(10): 3715–3725.
[3]   El Madani B, Yao AP, Lyhyaoui A. Combining Kalman Filtering with ZigBee Protocol to Improve Localization in Wireless Sensor Network. *ISRN Sensor Networks. Hindawi Publishing Coorporation.*

2013; 2013: 1–7.

[4]   Cheng L, Wu C, Zhang Y, Wu H, Li M, Maple C. A survey of localization in wireless sensor network. *International Journal of Distributed Sensor Networks. Hindawi Publishing Coorporation.* 2012; 2012.

[5]   Joana HS, Kim W. A fusion approach of RSSI and LQI for indoor localization system using adaptive smoothers. *Journal of Computer Networks and Communication. Hindawi Publishing Coorporation.* 2012; 2012.

[6]   Shang J, Hu X, Gu F, Wang D, Yu S. Improvement schemes for indoor mobile location estimation: A survey. *Mathematical Problem in Engineering. Hindawi Publishing Coorporation.* 2015; 2015.

[7]   Ainul RD, Kristalina P, Sudarsono A. Modified Iterated Extended Kalman Filter for Mobile Cooperative Tracking System. *International Journal on Advanced Science Engineering Information Technology.* 2017; 7(3): 980-992.

[8]   Helhel S, Kocakusak A. Improved Indoor Location Systems in a Controlled Environments. *TELKOMNIKA Telecommunication Computing Electronics and Control.* 2016; 14(2): 748–756.

[9]   [9] A RD, Kristalina P, Sudarsono A. SWOT : Secure Wireless Object Tracking with Key Renewal Mechanism for Indoor Wireless Sensor Network. *International Journal on Advanced Science Engineering Information Technology.* 2018; 8(2): 520–531.

[10]   Subhan F, Ahmed S, Ashraf K. Extended Gradient Predictor and Filter for Signal Prediction and Filtering in Communication Holes.*Wireless Personal Communications.* 2015; 83(1): 297-314.

[11]   Lee JG, Kim BK, Jang SB, Yeon SH, Ko YW. Accuracy enhancement of RSSI-based distance estimation by applying Gaussian filter. *Indian Journal of Science and Technology.* 2016; 9(20).

[12]   Moragrega A. Received signal strength – based indoor localization using a robust interacting multiple model – extended Kalman filter algorithm. *International Journal of Distributed Sensor Network.* 2017; 13(8): 1-16.

[13]   Yu Y, Zhu Y, Li S, Wan D. Time series outlier detection based on sliding window prediction. *Mathematical Problems In Engineering. Hindawi Publishing Coorporation.* 2014; 2014.

[14]   Zhang H, Jiang X, Li C. Unscented Particle Filtering Algorithm for Optical-fiber Sensing Intrusion Localization Based on Particle Swarm Optimization. *TELKOMNIKA Telecommunication Electronics and COntrol.* 2015; 13(1): 349-356.

[15]   Shu Y, Huang Y, Zhang J, Coue P, Cheng P, Chen J, et al. Gradient-Based Fingerprinting for Indoor Localization and Tracking. *IEEE Transactions on Industrial Electronics.* 2016; 63(4): 2424–2433.

[16]   Amin SNAM, Ahmad H, Mohamed MR, Saari MM, Aliman O. Kalman filter estimation of impedance parameters for medium transmission line. *TELKOMNIKA Telecommunication Computing Electronics and Control.* 2018; 16(2): 900–908.

[17]   Chen P, Ma H, Gao S, Huang Y. Modified Extended Kalman Filtering for Tracking with Insufficient and Intermittent Observations. *Mathematical Problem in Engineering.Hindawi Publishing Coorporation.* 2015; 2015.

[18]   Khan R, Khan SU, Khan S, Khan MUA. Localization performance evaluation of extended kalman filter in wireless sensors network. *Procedia Computer Science.* Elsevier Masson SAS. 2014; 32: 117–124.

[19]   Havlík J, Straka O. Performance evaluation of iterated extended Kalman filter with variable step-length. *Journal of Physics Conference Series.* 2015; 659(1).

[20]   A RD, Kristalina P, Sudarsono *A. Cluster-Based PLE Areas for Mobile Cooperative Localization in Indoor Wireless Sensor Network.* ICITEE. 2016.