

Localization of WSN Using CDPSO with CRB Algorithm

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Abstract – Localization is the procedure of count on location of node position. In WSN, sensors deployed randomly and found the location of nodes is difficult. In this network, the nodes, knowing their location is important for indoor applications. In this application, the signals are affected by various factors such as noise, multipath, LOS etc. This impact on inaccurate location information of node, which leads to finding path to the destination node, is difficult. Localization system consists of three stages: Measurement of distance, Calculation of Position, Applying localization algorithm. Various methods will be implemented in each phase of localization procedure to improve the performance. In this paper, CDPSO algorithm with CRB for localization of cooperative WSN is proposed. Simulation tests have been conducted with various conditions. Comparisons made between proposed algorithm and existing algorithms like PSO, LMS, RLS and GPS algorithm in terms of position accuracy, CDF, complexity and MSE. From the comparison results it is noticed that proposed technique performs better than other algorithms. The proposed solution selects the best reference nodes using CRB and applying localization algorithms

Keywords – Localization, CDPS, PSO, CRB, CDF, Matlab.

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1. INTRODUCTION

Wireless Sensor Network (WSN) is a technology that led a revolution in the society which is needed in the day to day life of an individual. WSN is a collection of connected sensors. These sensors absorb the information from natural world and forward the data from source node to sink node. WSN is preferred in different applications, example supervision of agriculture, army, disaster management and hospitals.

Localization algorithms are primarily divided into approximate and definite localization respectively (Blumenthal et al 2005). The exact location is dependent on correct distance or angle measurements between sensor nodes that do not know their own position and nodes with localization systems preinstalled. These approaches promote high location determination accuracy, but contribute to detailed measurements and partially elevated network traffic. Through using knowledge of the absolute positions of a few sensors and inter-sensor measurements such as distance and bearing measurements, sensor network localization algorithms approximate the locations of sensors with

initially unknown location information. Anchors are named sensors with known positioning information and their positions can be accessed by using a GPS or by mounting anchors with known coordinates at points.

Location of a node is significant important in the several applications like routing, target tracking and monitoring etc. Localization methods will be extensively divided in to categories. 1. Range based and Range free localization methods. 2. Centralized and Distributed localization methods. 3. Anchor free and Anchor based methods.

• Range based and Range free localization algorithm

In range based approach, the sensor nodes estimate the location of nodes using Received Signal Strength (RSS), Time of Arrival (TOA) and Time Difference of Arrival (TDOA). In range based methodology extra hardware is required to find RSS, TOA and TDOA of signals. In RSS method, the distance will be measured depends on received signal power, which can be given as input for localization algorithm. In TOA method, the distance

can be measured based signal time. Based on difference between arrivals of signals, distance from agent node to anchor node can be found in TDOA method. time localization process different signals like Radio frequency (RF), Infrared (IR) and Ultra Wide Band (UWB) signals are used for estimation of location of node. In range free localization methods nodes estimate the location of nodes based on connection and hop count. Accuracy is the main limitation of this method.

• **Centralized and Distributed localization algorithm**

In centralized localization algorithm, the central node collects location information from all other nodes in network and perform localization task. In other techniques, all nodes in network execute algorithms and computes location information. Distributed localization algorithms are less complex in comparison with centralized localization algorithms. Due to many advantages distributed localization algorithms are preferably used in cooperative WSN. Figure 1 gives the centralized and distributed localization approach.

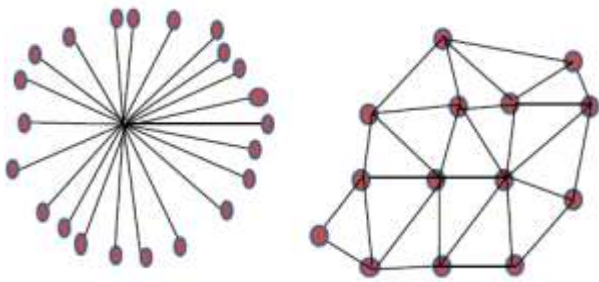


Figure 1 : Centralized and Distributed localization algorithm

• **Anchor free and Anchor based localization Algorithms**

The nodes which know their location by use of GPS are using known as anchor nodes. The main problem with this anchor node localization, GPS consume much energy and cannot detect location of nodes in indoor environment due to LOS.

In this localization process anchor nodes broadcast beacon signal and estimate location of unknown nodes using RSS. Nodes with known position is termed as anchor nodes, nodes without knowing their position is known as agent nodes. All the anchor nodes do not find the position of nodes with accuracy. Hence, CRB is used to select the best reference nodes with high accuracy. Localization algorithms can be used to find location of nodes using reference nodes which already know their position. Categorization of localization algorithms can be two types: 1) Centralized 2) Distributed.

In centralized localization algorithm, central node calculates node location and passes the information

to other nodes. Disadvantage of this method is more complexity. Centralized algorithms are generally not scalable so it is unfeasible for large WSN. In distributed localization algorithms, every node computes its position and hence complexity is reduced. Distributed algorithms are scalable so it is fit for large networks. Distributed PSO localization algorithm is proposed to find accurate node location. Proposed solution perform better in comparison with other algorithms like PSO, RLS algorithm, LMS algorithm and GPS in terms of position accuracy, latency and complexity.

2. COOPERATIVE LOCALIZATION

In non-cooperative location estimation anchor nodes find location of agent node. Agent nodes do not participate in localization process because communication does not exist between agent nodes. Main drawback of this approach is that more anchor nodes or long distance transmissions are required. Cooperative localization method gets the location information from anchor nodes and agent nodes, hence long range transmissions are not required.

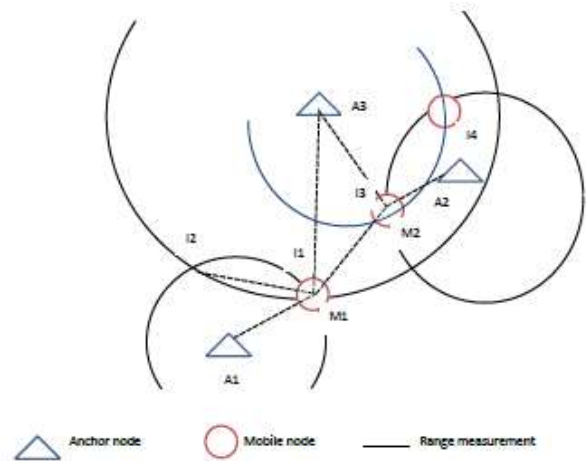


Figure 1: Cooperative network

To solve the problem of a less number of reliable anchor nodes it could be helpful to get the mobile nodes cooperate for localization. Figure 1 gives the manner in which two mobile nodes get advantage from cooperation. Mobile node M1 is connected with anchor node A1, A3 and mobile node M2 is connected with anchor nodes A2 and A3. Generally in range based localization both mobile node M1 and M2 cannot fix their locations openly. Mobile node M1 might be positioned in either intersection of I1 or I2 whereas mobile node M2 might be in I3 or I4. In a cooperative WSN, nodes cooperates with each other and find the distance between them. This distance information is useful to find location of M1 in I1 and M2 in I3. Exchange of information between the nodes is required in cooperative localization. As shown in Figure 3.1, mobile node M1 sends its possible position coordinates of I1 and I2 to mobile node M2 that would then be able to determine its position

apparently using the inter distance of the two mobile nodes. The position of M2 should then be returned to M1 assisting it, as well determine its position. Cooperative localization can compromise augmented accuracy and coverage. The positioning accuracy is extremely enhanced by sharing location coordinates between agents. Cooperative localization method enhance location accuracy, but increases the complexity of computations. In cooperative localization some agent nodes give inaccurate location information which gives poor location results. In this research, CRB is used to discard inaccurate location information from the agent nodes and select the agent nodes which gives accurate location information as anchor nodes. In the thesis the nodes nearer to the agent are consider as anchor nodes. However, the closest neighbors may not correspond to the best links as positioning it also depends on the geometric configuration of the agent and its neighbors. So selecting that anchor nodes to determine position of node is a big task. In use the CRB to select those anchors that which would give the best positioning accuracy is proposed. Distributed PSO localization algorithm with CRB is proposed to find accurate node location.

3. CDPZO LOCALIZATION WITH CRB ALGORITHM (CDPZO-CRB)

Here, implementation of CDPZO with CRB is explained. Proposed solution consists of two parts 1. Selection of optimum references 2.Distributed PSO localization. First, we have explains optimum selection of references, then we have explains CDPZO with CRB localization algorithm. The flowchart for the implementation of CDPZO with CRB is shown in figure 3.2.

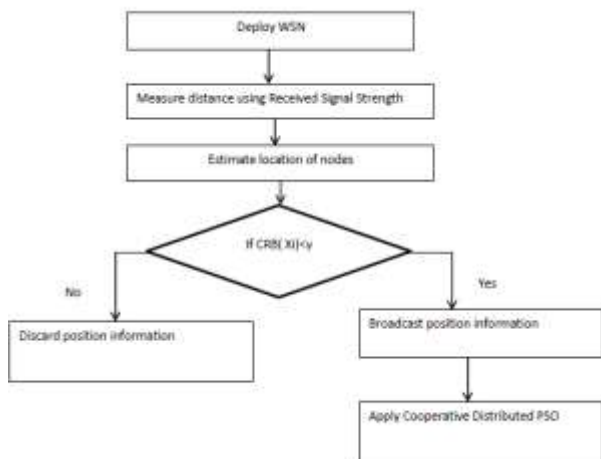


Figure 2: Flow chart for proposed method

3.1 Optimum Selection of References Using CRB

In cooperative WSN, every node communicated with all other nodes. Every node is involved in the process of estimation. Here CRLB is calculated to estimate the set of nodes which gives lower bound,

least localization error. In this process, unknown nodes initiates the localization process and agents in the communication range responds to that process by estimating the locations. All the nodes do not give accurate location due to noise. So, selection of nodes which gives accurate locations is important criteria. In this research, CRB is used to select the nodes which gives lower bound and minimum variance of error.

The use the CRB on localization error for the selection is proposed. Every agent node compares its localization accuracy with all other agents using available global knowledge. This method is known as global-crlb algorithm. This algorithm selects optimal subsets according to the following equation 3.1 and 3.2. Steps for the CRB is given below.

1. Consider location of node as x_i ; and Fisher Information Matrix (FIM) is given as below

$$F(X_i) = -E\left(\frac{\partial^2 \Delta(X_i)}{\partial X_i^2}\right) \dots\dots\dots(3.1)$$

2. CRB is calculated by taking inverse of FIM

$$CRB(x_i) = trace[F(x_i)]^{-1} \dots\dots\dots(3.2)$$

3. According to CRB theorem the variance of CRB must be at least greater than Inverse of FIM
4. If $CRB(x_i) < y$ (Threshold value) is selected as reference node
5. If $CRB(x_i) > y$ (Threshold value) then discard the information from that particular anchor

PSO is considered as swarm intelligence algorithm, works on social movement of group of birds and fish school. Solution of PSO called as particles. PSO algorithm complexity is less hence implementation is easy with good convergence which is viable for localization of WSN. PSO algorithm implemented for localization of WSN with high accuracy and less complexity. Proposed objective function evaluates the fitness of particles. It attempts to localize more unknown nodes in a high accurate search space. The updated particles position can be mathematically modeled according the following equations 3.3 and 3.4.

$$V_i^{k+1} = w \times V_i^k + c_1 \times r_1 (p_{best} - x_{ik}) + c_2 \times r_2 (g_{best} - x_{ik}) \dots\dots\dots(3.3)$$

$$X_i^{k+1} = X_i^k + V_i^k \dots\dots\dots(3.4)$$

Where X_{ik} = current position of node i at iteration k

V_{ik} = velocity of node

C_1, C_2 = acceleration constants

r_1, r_2 = uniformly distributed random numbers in the range of (0, 1)

w = Inertia weight

Flow chart for CDPSO localization algorithm is shown in figure 3.3.

$$d \sim N[\hat{d}_i, (\hat{d}_i\delta)^2]$$

$$\text{where } \delta > 0 \dots\dots(3.6)$$

The distributions of ranging error d ; of different nodes are given in equation 3.7.

$$\sum_{i=1}^M d_i \sim \prod_{i=1}^M N[\hat{d}_i, (\hat{d}_i\delta)^2] \dots\dots(3.7)$$

The following equation 3.8 with distribution of ranging error is used to improve the location accuracy

$$1/M \sum_{i=1}^M \frac{\sqrt{(x-x_i)^2 + (y-y_i)^2} - \hat{d}_i}{(\hat{d}_i\delta)^2} \dots\dots(3.8)$$

3.2 Simulation Results and Analysis

► Simulation Setup

The proposed solution CDPSO with CRB is simulated and tested using MATLAB. 100 agent nodes are randomly placed and 13 anchor nodes with familiar locations are placed in the field of 500m X 500m. The transmission range of every node in one hop is 20 m. Standard deviation of measurement is 1% of measured distance. Figure 4 shows MATLAB-based GUI tool for the calculation of the CRB and localization. CRB is calculated and displayed on GUI by giving the lower bound on the 2-c ellipse. The threshold parameters R_y , is set for the stop limit. The parameters used are $R_r=0.08$ (conservative approach) and the $R_r, =0.05$ (aggressive approach). Table 3.1 shows simulation parameters and values.

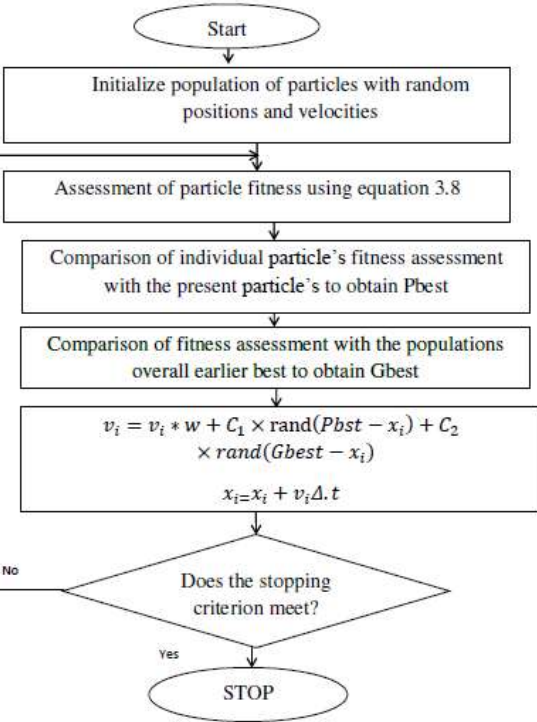


Figure 3: Cooperative Distributed PSO Localization flowchart

Coordinates of unfamiliar node U is (x, y) and i_{th} anchor node location is given as (x_i, y_i) which is denoted as A_i . be the d_i is the distance assessed from unknown node U and anchor node A_i is given by equation 3.5.

$$1/M \sum_{i=1}^M \sqrt{(x-x_i)^2 + (y-y_i)^2} - \hat{d}_i \quad (3.5)$$

$f(x,y)$ is the localization function which works based on range based measurement technique. The above localization objective function will not take into account the probability distribution of range fault. The localization functions f is defined as all the range-based localization techniques with PSO use the objective function as which will not take into account probabilistic distribution of ranging fault. Normal distribution functions of distance between unknown node U and anchor A is given in equation 3.6.

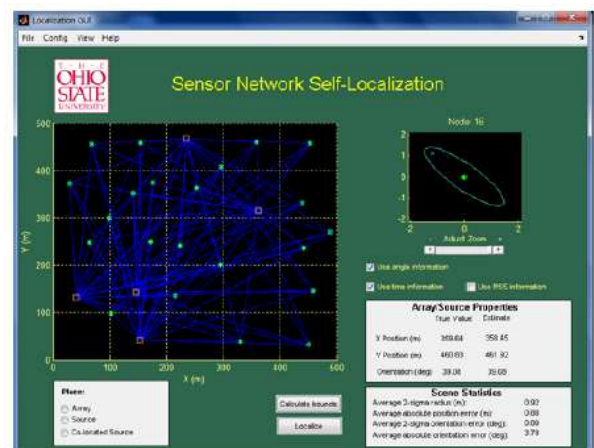


Figure 4: Simulation setup of cooperative WSN using Matlab based GUI Tool

Table 3.1: Simulation parameters

Parameter	Value
Network size	500mX500m
No.of anchor nodes	13
No.of agent nodes	100
Transmission range	20m
standard deviation (σ)	1% of measured distance
Initial energy (E_i)	5J
Transmission power (P_t)	2w
Threshold value (conservative approach)	0.08
Threshold value (aggressive approach)	0.05
Path loss exponent (α)	2

► **Performance Metrics**

Performance of the proposed method is measured by considering different scenarios and performance metrics. The performance metrics for analysis of results are defined below.

Cumulative Distribution Function (CDF): CDF is used to measure accuracy of localization algorithms. if localization algorithms are in comparison and their accuracies are almost same, in that case the system which reaches high probability have been considered as best system.

Complexity: Average number of transmissions needed to transmit the data from sender to receiver in specified intervals of time is known as complexity.

Root Mean Square Error (RMSE): Variation between the estimated position value and actual location value of localization algorithm. Equation 3.9 gives the formula to find RMSE value.

$$RMSE = 1/M \sqrt{\sum_{k=1}^m (x_k - \hat{x}_k)^2 + (y_k - \hat{y}_k)^2} \tag{3.9}$$

► **Results analysis**

The performance of proposed method Cooperative Distributed PSO algorithm is tested with different parameters and results are analyzed.

Figure 5 shows the graph plotted for number of anchors vs processing time. As the number of anchor nodes are increasing, processing time also increases for the reason that computational complexity, average delay also increases.

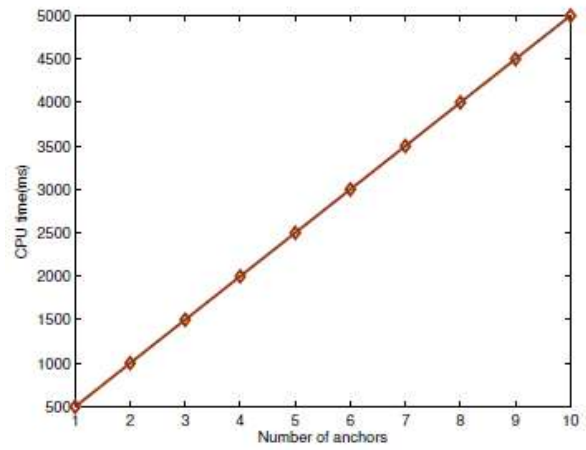


Figure 5: Number of anchors Vs processing time

Hence, CRB is used to select the optimum reference nodes.

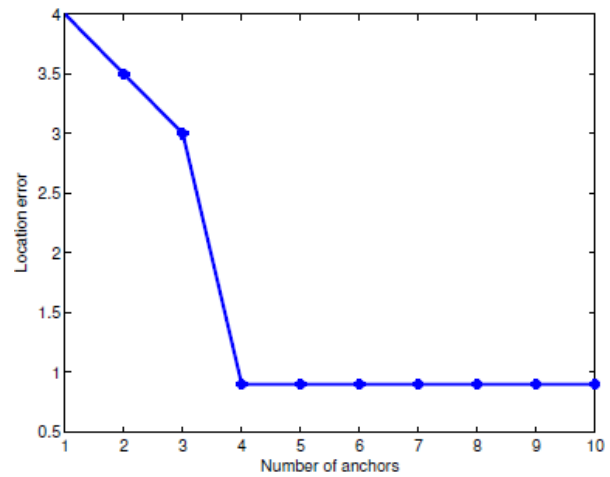


Figure 6: Number of anchor nodes vs. location error

Figure 6 shows graph plotted for number of anchor nodes vs. location error. Location error is decreased as number of anchor nodes are increasing. If anchor nodes are equal to 4 or exceeds location errors is minimum and constant.

Figure 7 represents the graph plotted between position error and CDF of different schemes in conservative approach ($R_r = 0.08$). The Distributed PSO algorithm with CRB is compared with other algorithms like GPS, LMS, RLS, and PSO in terms of CDF. The CDF of CDPSO with CRB gives better results in comparison with other algorithms. The proposed method discards the transmission of inaccurate location information of nodes, hence selects the nodes which gives accurate results as anchor nodes. In case of PSO the nodes which are in the transmission range of agent nodes with inaccurate location information are also used as anchor nodes. Hence the CDF of CDPSO is

degraded. In case of RLS, LMS due to less number of nodes which are pre-configured present in the localization process CDF is decreased. In case of GPS, performance is poor because of LOS and multipath effects.

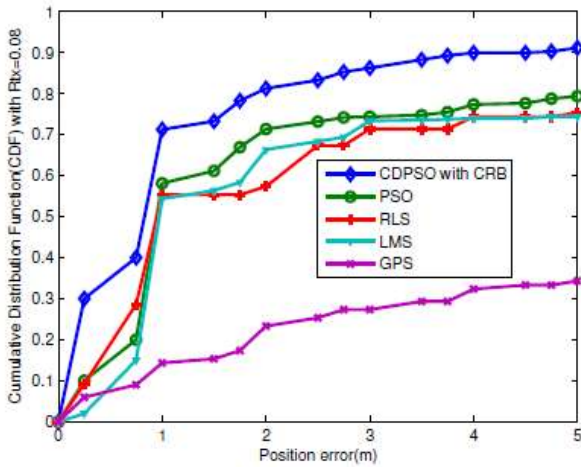


Figure 7: Performance comparisons of different censoring schemes in conservative approach

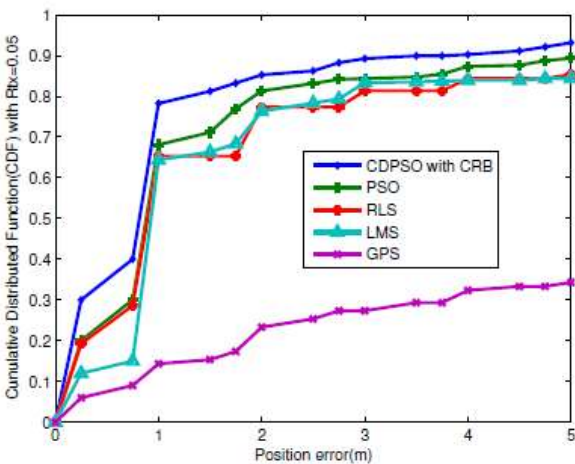


Figure 8: Performance comparisons of different censoring schemes in aggressive approach

Figure 8 represents the graph plotted between position error and CDF of different schemes in aggressive approach ($R_{Tx} = 0.05$). The CDPSO algorithm with CRB is compared with other algorithms like PSO, RLS, LMS and GPS. The CDF of CDPSO with CRB performs better in comparison with other algorithms because it selects the optimum references with high accuracy, discard location information from inaccurate nodes and localize the nodes using cooperative cooperative distributed PSO. In case of PSO, nodes with inaccurate location information also participate in the localization process. Hence CDF is degraded in comparison with other algorithms. Performance of RLS and LMS is poor because only pre-configured nodes are participated in localization process. The performance of GPS is least in comparison with other algorithms due to LOS, noise and multipath effects.

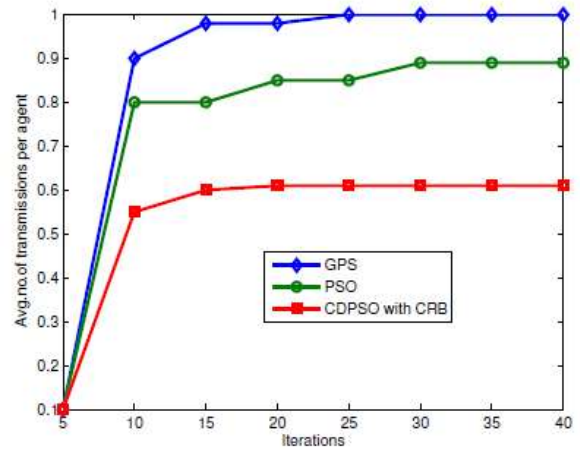


Figure 9: Comparison of different algorithms for average number of transmissions with respect to no. of iterations

Figure 9 gives diagram plotted between number of iterations Vs average number of transmissions per agent. The complexity of CDPSO with CRB is least because more number of inaccurate nodes are discarded. Hence, least number of nodes participated in localization process and complexity is reduced. The complexity of PSO is more because every node in the transmission range participate as reference node in localization process. Hence, average number of transmissions to localize particular agent node is also increased. In case of GPS signals are affected by noise, multipath effects and more computational complexity.

Figure 10 represents the graph plotted between number of iterations Vs MSE of location. The CDPSO algorithm with CRB compared with other algorithms PSO, RLS algorithm, LMS algorithm and GPS. Performance of CDPSO algorithm with CRB performs better in comparison with other algorithms because nodes with accurate information only participates in localization process. In case of PSO inaccurate nodes also participate in localization process, hence the performance is degraded. Performance of LMS and RLS algorithm is poor because least number of references participate in localization and SNR is low for LMS algorithm.

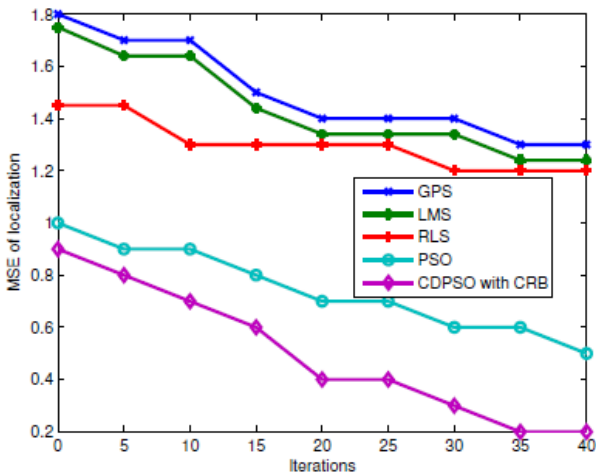


Figure 10: Comparisons of different algorithms for Mean square error of localization with respect to number of iterations

In case of GPS, signals are affected by noise and multipath effects leads to more MSE in comparison with other algorithms.

4. CONCLUSION

In this paper, CDPSO algorithm with CRB for localization of cooperative WSN is proposed. Simulation tests have been conducted with various conditions. Comparisons made between proposed algorithm and existing algorithms like PSO, LMS, RLS and GPS algorithm in terms of position accuracy, CDF, complexity and MSE. From the comparison results it is noticed that proposed technique performs better than other algorithms. The proposed solution selects the best reference nodes using CRB and applying localization algorithms. To find the exact node position, the cooperative distributed PSO algorithm with CRB (CDPSO-CRB) is suggested. In this paper, the CDPSO-CRB implementation details are given. Using anchor nodes, this algorithm finds the precise node location. To estimate minimal variance and discard incorrect connections, CRB is used. In contrast to other algorithm places, the advantage of the proposed approach is precision and less complexity. The CRB (CDPSO-CRB) cooperative distributed PSO algorithm provides an average mean square error of 0.5 m.

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