A Hybrid Metaheuristic Bat Algorithm with Simulated Annealing for Node Localization in Wireless Sensor Network

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Abstract

Wireless Sensor Network has application laid its hands in various fields. Localization of nodes is the key technology of WSN. Among the various existing localization algorithms, Distance Vector Hop (DV-Hop) algorithm is the most commonly used localization algorithm. Routing exchange protocol is used to make the beacon information available for the unknown nodes. The information is used for calculating the co-ordinates of the neighbor nodes. Hence, the algorithm for localization of nodes is always found to be associated with an error. Thus to overcome the error occurring in traditional node localization algorithm in Wireless Sensor Network, a novel metaheuristic BAT with Simulated Anhelaing is proposed in this paper. The error in localization is significantly reduced and thereby increasing the overall performance of locating the nodes is improved. The simulation results prove the performance efficiency of the proposed novel metaheuristic algorithm for optimization of a WSN.

Keywords:- location algorithm, DV-Hop, metaheuristic, BAT, Simulated Annealing, WSN

NTRODUCTION

As WSN has become one of the fastest and reliable method in data collection and processing, it has a wide range of applications. In areas where humans cannot reach, the wireless sensor nodes are deployed through aircraft to study and monitor the environmental changes[1]. In general, the WSN nodes are deployed randomly in the monitoring area and the data about the environment is collected by the nodes[2]. In these cases, the location of the deployed nodes is found to be critical. It is highly impossible to manually install a GPS receiving device for every sensor node which is limited by cost, power and scalability. In such environments, the location information is highly missing which plays a critical role in the overall WSN performance[3]. Therefore, the localization technology plays a key role in wireless sensor network. The data collected by the nodes is transmitted to the destination node or monitor node through multi hopping. As the wireless sensor network is found to be self-organized, the nodes can identify or know the information about its neighbor nodes by its own[4-6]. The nodes in the wireless network are found to be stronger than common nodes in a communication connection. The data collected by the nodes are to the Base Station (BS) through multiple hopping technique[7]. In general, the nodes in a wireless sensor network are divided into two types as unknown nodes and the Beacon node. Generally, the unknown nodes does not know its location information whereas the Beacon nodes know its location information through the GPS device deployed with it. The localization algorithms are divided into two types as follows.

- Distance based
- Distance free

some of the distance based localization algorithms are Time of Arrival (TOA), Time Difference of Arrival (TDOA), Received Signal Strength Indicator (RSSI) and Angle of Arrival (AOA) etc., Approximate triangle point test, DV-HOP, MAP and Amorphous algorithm are distance or range free localization algorithm[8]. The distance based localization algorithm has to know the actual distance between the deployed nodes to know the location of the adjacent nodes in the network. Hence location awareness is significantly important in high level and confidential applications like military, underwater communication etc., Thus localization is found to be the

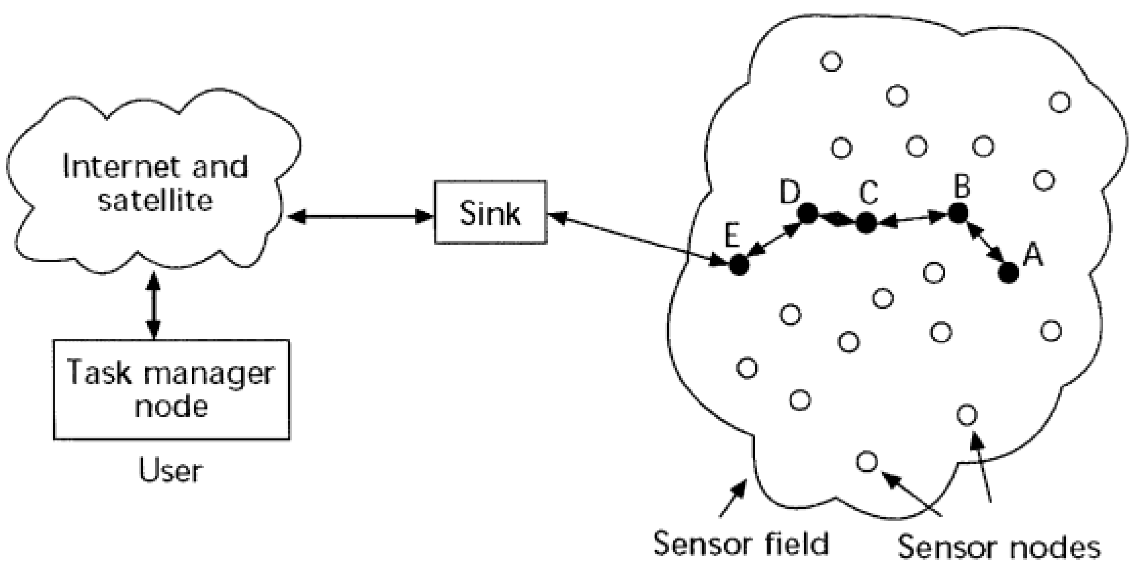

Figure 1: A WSN architecture

fundamental problem in making the availability of the geographic location of the sensor nodes. Based on the feature of the signals used for communication, the geometric approaches used for position estimation are Triangulation, Multilateralation or Trilateralation. Distance based localization techniques provide high accuracy but they are not cost effective[9-10].

DV-HOP Algorithm

The basic principle of DV-HOP method is that the maximum hop count of the Beacon node is first calculated by the unknown node. The average distance per hop is estimated followed by the multiplication of the ratio of the average hop by the minimum number of hops[11-13]. Finally, the estimated distance between the Beacon node and the unknown node is obtained.

Some of the problems identified with the existing DV-HOP algorithms are listed below.

- Less accuracy in localization of Beacons.
- Less rate of coverage in a sparse environment.

Figure 2 shows the configuration of nodes in wireless sensor network using traditional DV-Hop technique.

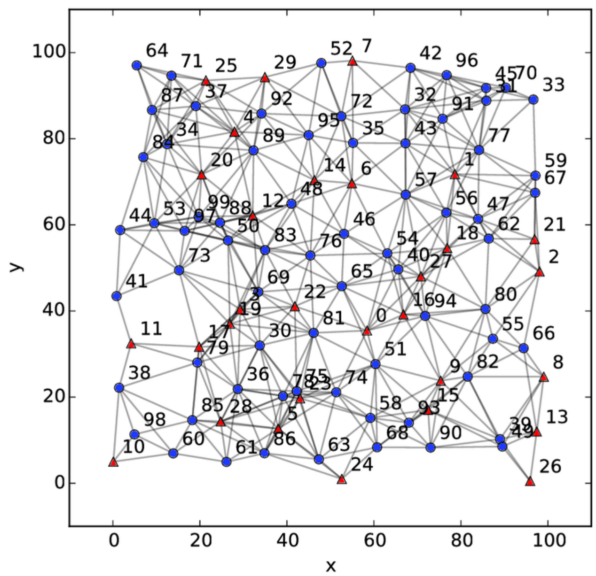

Figure 2: WSN configuration using DV-HOP algorithm

As the first step, a beacon is flooded throughout the entire wireless sensor network by every anchor nodes[14]. To identify the location of anchor node, its hop count value is initialized to one. The minimum hop count value is maintained by all the beacon receiving node. Beacon with the higher hop count value to a particular anchor node is identified as the stale node and is then ignored[15]. The other nodes which are not found as stale nodes are flooded forward in the network. The hop count values of these nodes are incremented at all intermediate hops. Through this technique, all the nodes in the entire network finds a path with minimal hop count to its anchor node. Figure 3 shows the implementation of DV-HOP algorithm in a WSN [16-20].

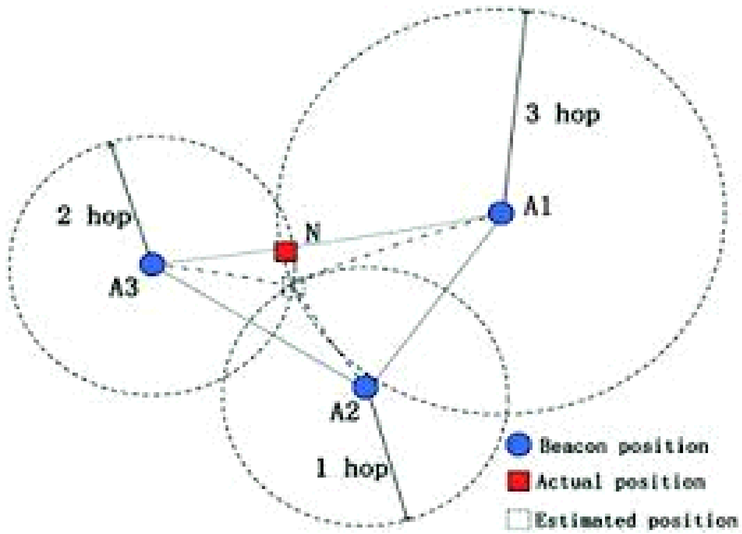

Figure 3: Implementation of DV-HOP algorithm in a WSN

Once the hop count is estimated by an anchor node, the second step is to estimate the average length for one single hop[21]. As the single hop length is estimated it is then flooded through the entire network. Once all the nodes in the network receive the hop size, they hop size is multiplied by its hop count value. By this way the physical distance between the unfold node and the anchor node is estimated. The formula used for calculating the average hop size[19] is the below given formula.

$$HopSize_i = \frac{\sum_{i \neq j} \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2}}{\sum_{i \neq j} h_i}$$

Where,
x_i, y_i – co-ordinates of the anchor node *i*
x_j, y_j – co-ordinates of the anchor node *j*
h_{ij} – the number of hops between the beacon node *i* and the beacon node *j*

The hop size is broadcasted by each anchor node in the network using the controlled flooding technique. All the nodes in the entire network receive this hop size message and all the unknown nodes in the network stores the first hop size message it receives. Simultaneously, the hop size message is broadcasted by the unknown node to its neighbor nodes[22-23]. This identifies the nodes that receives more number of hop size messages from the beacon node are the nodes nearer to the beacon node. As the end of this broadcast of hop size message and technique, all the unknown nodes compute their distance from the beacon node based on the number of hops between them[24-25].

It is assumed that
(x_{ij}, y_{jj}) – the unknown node at D location
(x_i y_i) – be the known location of the anchor node *i*.

It is assumed that the distance between the anchor node *i* to the unknown nodes as d_i and the formula to calculate the same is given below.

$$\begin{cases} (x-x_1)^2 + (y-y_1)^2 = d_1^2 \\ (x-x_2)^2 + (y-y_2)^2 = d_2^2 \\ \vdots \\ (x-x_i)^2 + (y-y_i)^2 = d_i^2 \end{cases}$$

The following formula is used to compute the distance of the co-ordinate D.

$$A = -2 \times \begin{bmatrix} x_1 - x_n & y_1 - y_n \\ x_2 - x_n & y_2 - y_n \\ \vdots & \vdots \\ x_{n-1} - x_n & y_{n-1} - y_n \end{bmatrix}$$

$$B = \begin{bmatrix} d_1^2 - d_n^2 - x_1^2 + x_n^2 - y_1^2 + y_n^2 \\ d_2^2 - d_n^2 - x_2^2 + x_n^2 - y_2^2 + y_n^2 \\ \vdots \\ d_{n-1}^2 - d_n^2 - x_{n-1}^2 + x_n^2 - y_{n-1}^2 + y_n^2 \end{bmatrix}$$

$$P = \begin{bmatrix} x \\ y \end{bmatrix}$$

where $P = (A^T A)^{-1} A^T B$

Proposed hybrid metaheuristic BAT algorithm with simulated annealing

As sensor nodes in a WSN are randomly deployed it is very difficult to precisely find out the distance between the nodes and location of each node in WSN field. Any discrepancy in these details can cause significant performance degradation in many applications.

BAT algorithm

Bat Algorithm is a type of meta heuristic searching algorithm. The following rules are the framework of BAT algorithm,

- Echolocation is use to sense the distance of the target.
- Signals are transmitted randomly with varying frequency and it is adjusted automatically proximity. The pseudocode for conventional BAT algorithm is given below.

Pseudo code for bat algorithm

1. Objective function $f(x), x = (x_1, \ldots \ldots \ldots x_d)^T$
2. Initialize the bat population $x_i (i = 1,2,3 \ldots\ldots n) and\ v_i$
3. Define Pulse frequency $f_i\ at\ x_i$,
4. Initialize the rates r_i and the loudness A_i
5. While (t< Max number of iterations)
6. Generate new solutions by adjusting frequency and updating velocities and locations/solutions according to equation (1), (2) and (3).
7. If $(rand > r_i)$
8. Select a solution among the best solutions
9. Generate a local solution around the selected best solution
10. End if
11. Generate a new solution by flying randomly
12. If $(rand < A_i) \& f(x_i < f(x^*))$
13. Accept the new solutions
14. Increase r_i and reduce A_i
15. End if
16. Rank the bats and find the current best x^*
17. End while
18. Post process results and visualization

Simulated Annealing Algorithm

The goal of SA algorithm is to to start with intense and then reduce the intensity of search. The pseudocode for a basic SA algorithm is given below.

S1 = An initial solution is set
T = An initial temperature is set
REPEAT
REPEAT
S2 = Neighbour of the node S1 is identified
UNTIL a criteria is established by the node S2
ΔE = obj(S2) – obj(S1)
IF (ΔE > 0) THEN // Noe S2 is chosen as better than node S1
S1 = S2
ELSE with probability EXP(ΔE/ T)
S1 = S2
END IF
Decrease T

UNTIL the stop criteria
End
Instead of the best movement, a random movement is chosen in SA algorithm. If this chosen movement is found to improve the search, then it is accepted else, the probability of movement is taken as 1. This probability is found to reduce with a decrease in temperature. Inappropriate search movements occur with an increase in temperature and it gets reduced with a reduction in temperature. The value of temperature is multiplied by a coefficient value ranging between 0 and 1. Local optimality problem is encountered with a decrease in temperature. So a value near to 1 is chosen say 0.998.
Steps involved in getting start of a SA algorithm and its preparation is discussed below.

Getting Started and Preparation:
The problem information is first identified and the various adjusting parameters are obtained.
1. An answer near to the current answer is identified which satisfy the set criteria.
2. Answer obtained is evaluated.
    2.1 If the newly identified neighbor is better than the existing, go to a NA (New Answer).
    2.2 The probability > random number, go to a NA else step 1.
3. Update the problem parameters and algorithm. Got to step 1.

In the first step, the number of sensors is need to be identified for the user. As a request is raised by a user, a binary path solution is randomly generated. In SA algorithm, an Optimized path solution is created from the primary path. Two indexes are randomly chosen for a neighbor node. The indexes represent sensor nodes which are prone to change. Dijkstra algorithm is used for identifying the relay nodes in identifying the path between the BS and the destination node. The overall energy optimization of the nodes of the path established is reduced thereby adding a value of 1 to the network lifetime. The loop is continued until the desire value of optimization is reached. Table 1 shows the values used for simulation of network. Figure 4 shows the flowchart of a Simulate Annealing algorithm

Table 1: Simulation values

Parameter	Value
Network Size	500 * 500 m
SNodes Location	Uniform Distribution
Nodes Location	Uniform Distribution
Nodes Initial Energy	0.1 J
Super Node Initial Energy	0.5 J
Communication Range	90 m
Sensing Range	60 m
Number of Nodes	300
Number of SNodes	25
Number of Target	20
Elect	50 nJ/bit

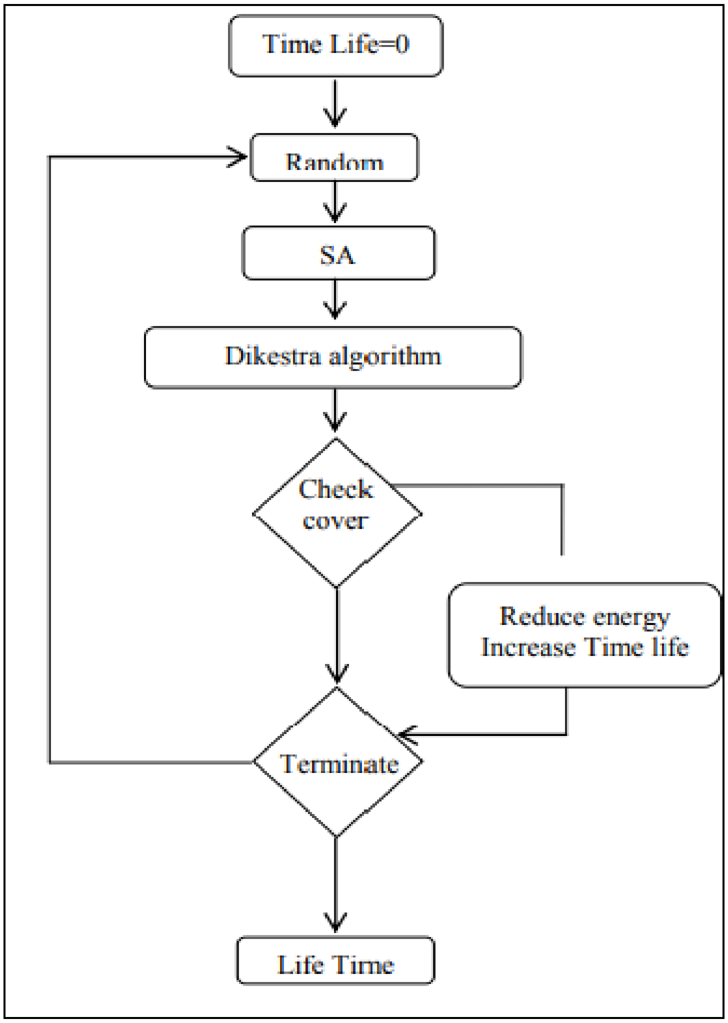

Figure 4: Flowchart for SA algorithm

Proposed BAT with Simulated Annealing algorithm

Some of the complexities identified in optimizing a WSN are

- Node position
- Data collection
- Power consumption of node i.e real time
- Node distance and its mobility in real time network
- Accuracy vs Complexity with increase in network scalability
- Propagation error with increased Node density

SIMULATION RESULTS

The network area considered is 1000m radius. In a conventional DVHOP algorithm, the error in obtaining the position of the neighbor nodes and latency is increased.

The performance metrics parameters considered and the results are obtained by using DVHOP and the proposed BAT with SA algorithms. There is a randomness found in anchor shift with respect to latency. The node distribution map is shown in figure 5.

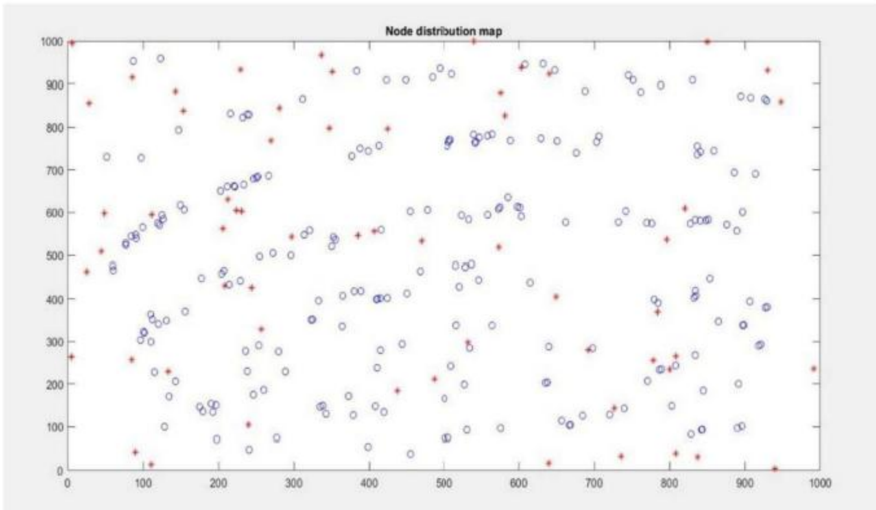

Figure 5: Node distribution map

The errors obtained in positioning the nodes in the network using DV-Hop algorithm is shown in figure 6 and neighbor relationship diagram using DV-Hop algorithm is shown in figure 7.

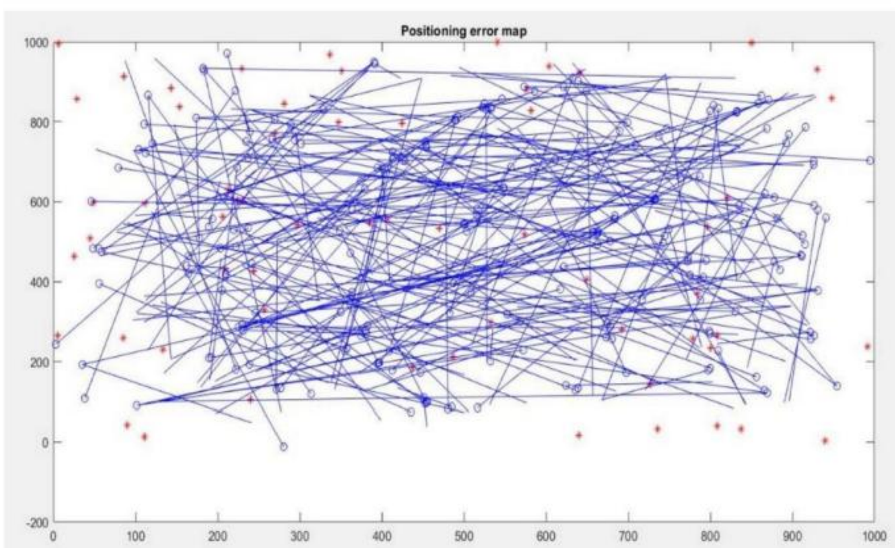

Figure 6: Positioning error map using Dv-Hop algorithm

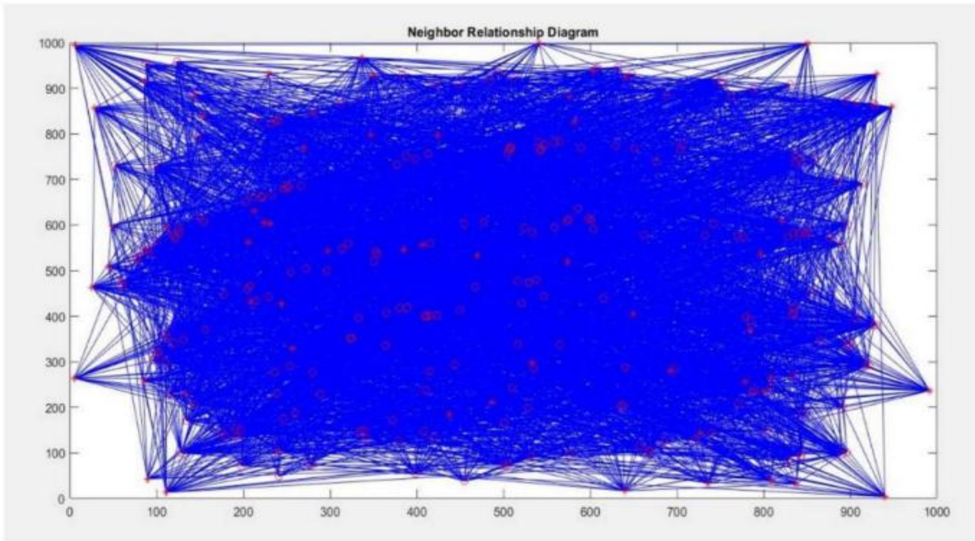

Figure 7: Neighbor relationship diagram using DV-Hop algorithm

Figure 8 shows the node distribution map obtained using proposed BAT-SA algorithm.

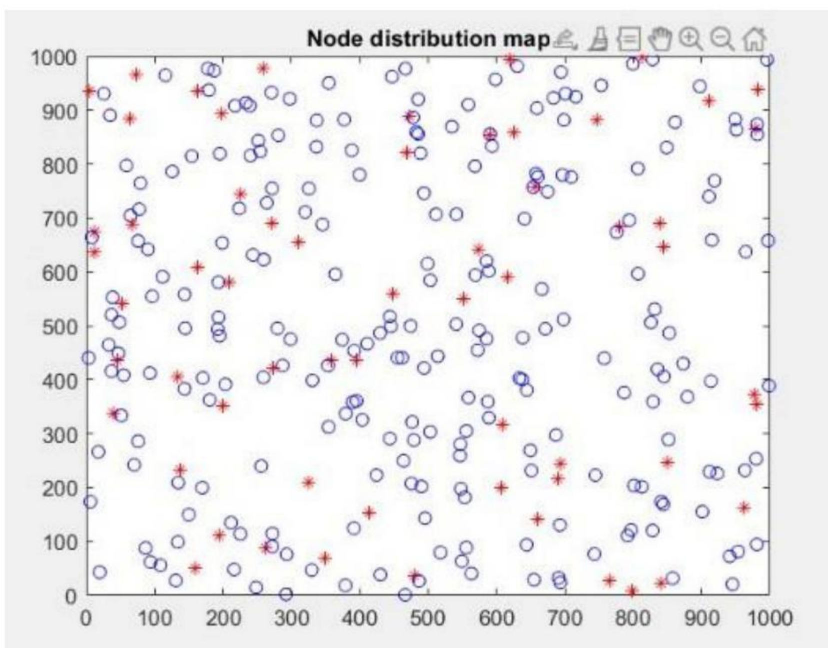

Figure 8: Node distribution map using BAT-SA algorithm

Figure 9 is the positioning error map using the proposed BAT-SA algorithm. When the positioning error is compared between the conventional DV-HOP and the propose BAT-SA algorithm, it is found to be significantly reduced in the propose algorithm.

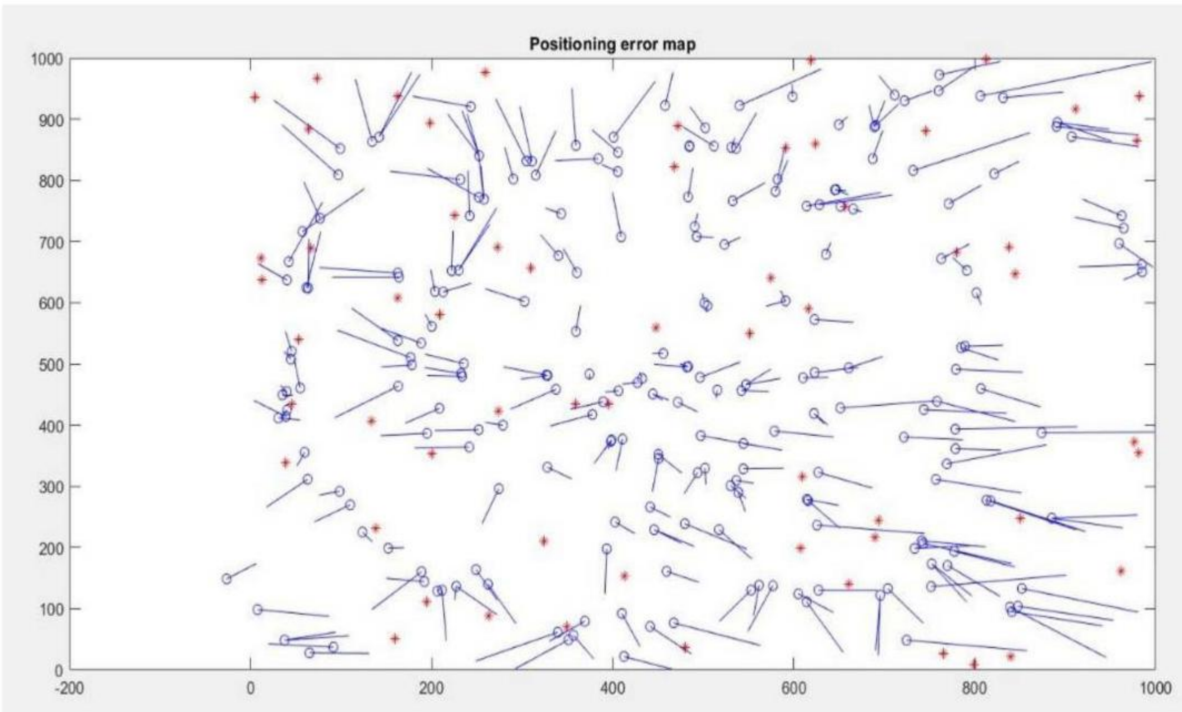

Figure 9: Positioning error map using the BAT-SA algorithm

Similarly, figure 10 shows the neighbor relationship diagram of the proposed algorithm.

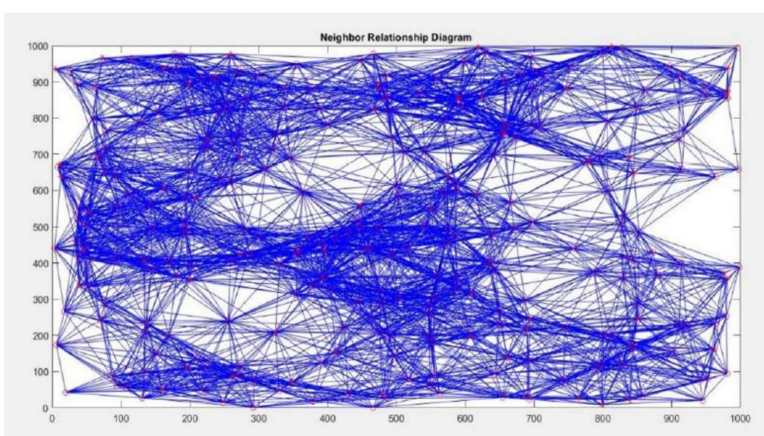

Figure 10: Neighbor relationship diagram of BAT-SA algorithm

The convergence of node is achieved by using the Cos function of BAT with SA algorithm. After finding out the Cos function, the neighbor relationship diagrams are compared. The simulated results are compared in figure 11 as follows.

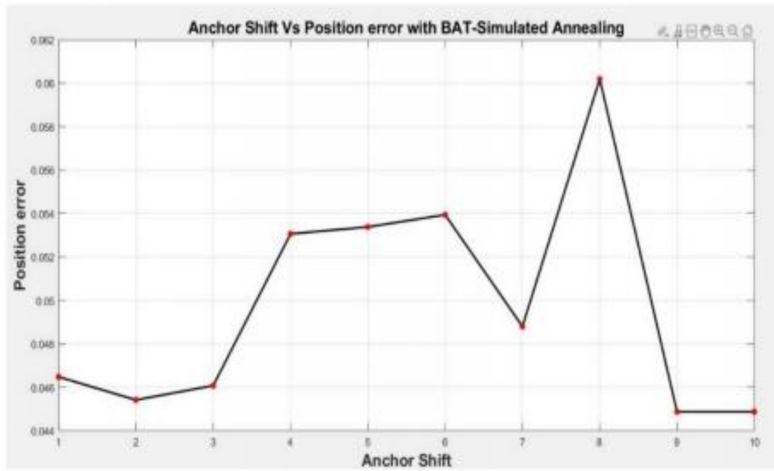

Figure 11: Anchor shift Vs Position error using BAT- SA

Figure 12 shows the results plotted for anchor shift against latency using BAT-SA algorithm.

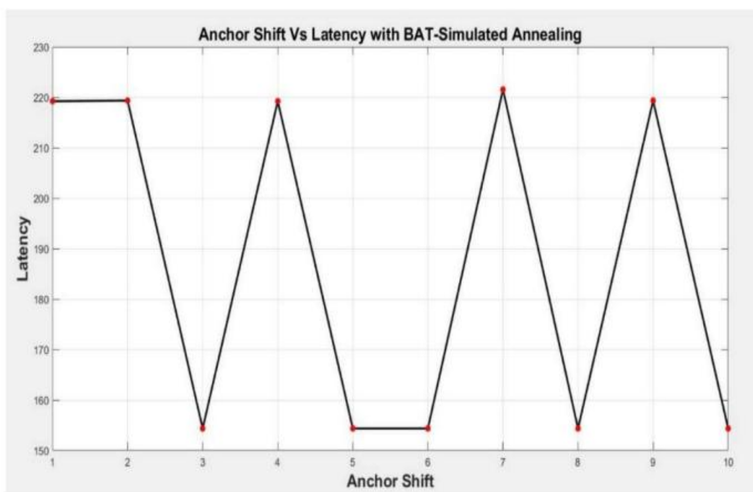

Figure 12: Anchor shift Vs latency using BAT- SA

The Position error is found to increase with an increase in number of iterations and is depicted in figure 13.

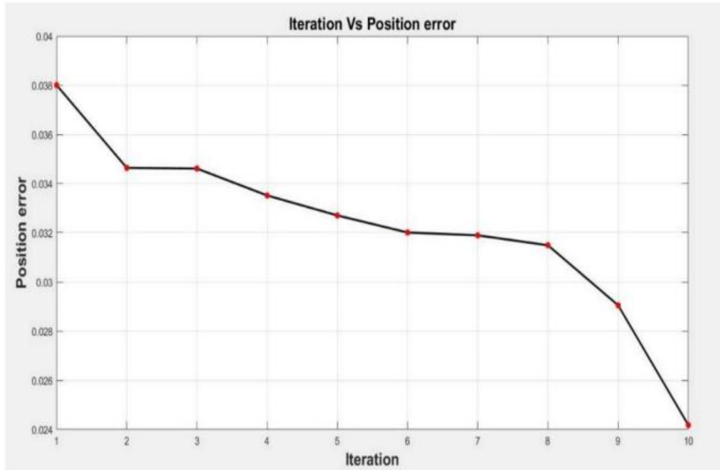

Figure 13: Iteration Vs Position error

The latency is found to increase with decrease in the number of iterations and is shown in figure 14.

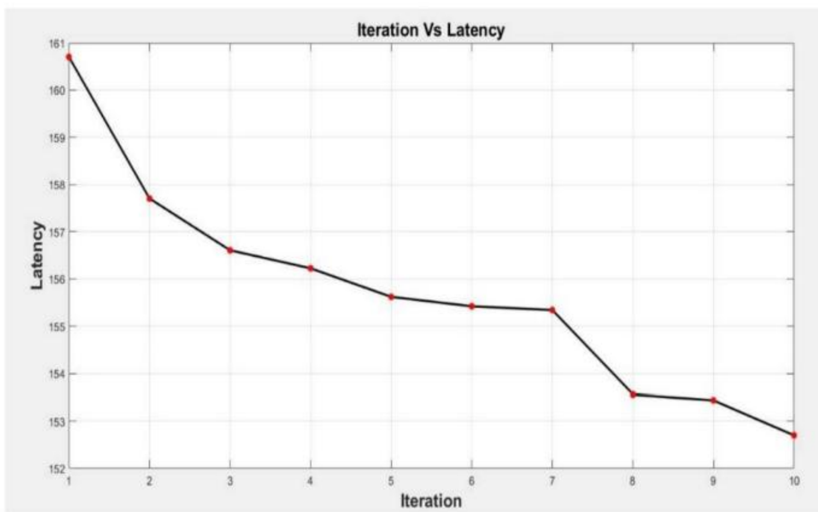

Figure 14: Iteration Vs Latency

The error in positioning the neighbor nodes increases with and increases in the range of communication. Figure 15 shows the results for position error with respect to communication radius error.

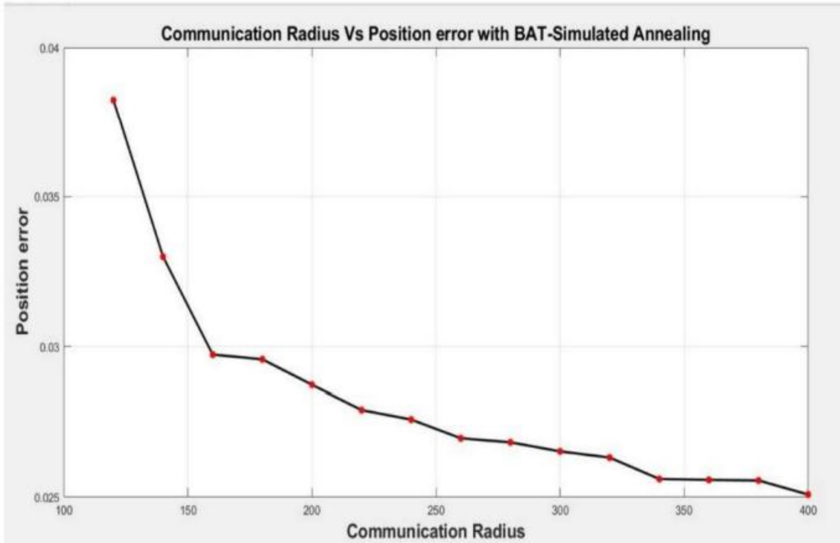

Figure 15: Communication radius Vs Position error

The latency also increases due to the increase in communication range and is shown in figure 16.

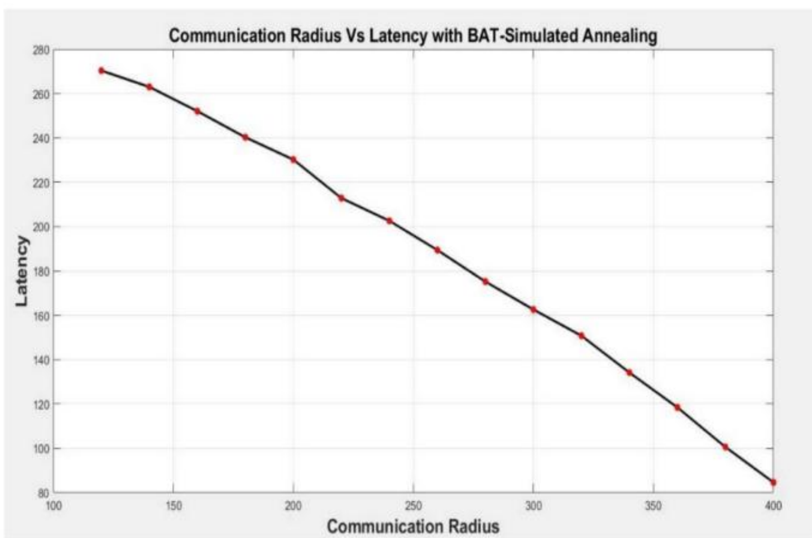

Figure 16: Communication range Vs Latency

The position error and latency is found to increase with an increase in the network area and figure 17 shows the same.

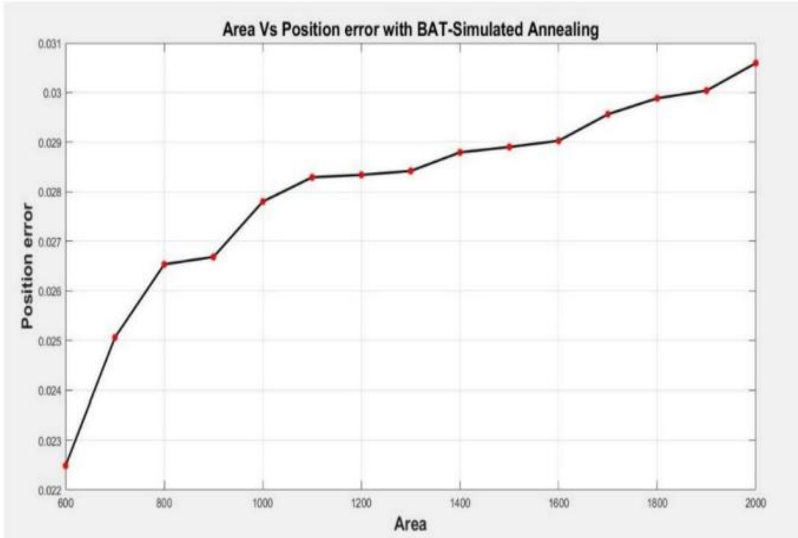

Figure 17: Area Vs Position error

As the area of the network increases, the latency is also increasing and is obtained from the simulated result which is shown in figure 18.

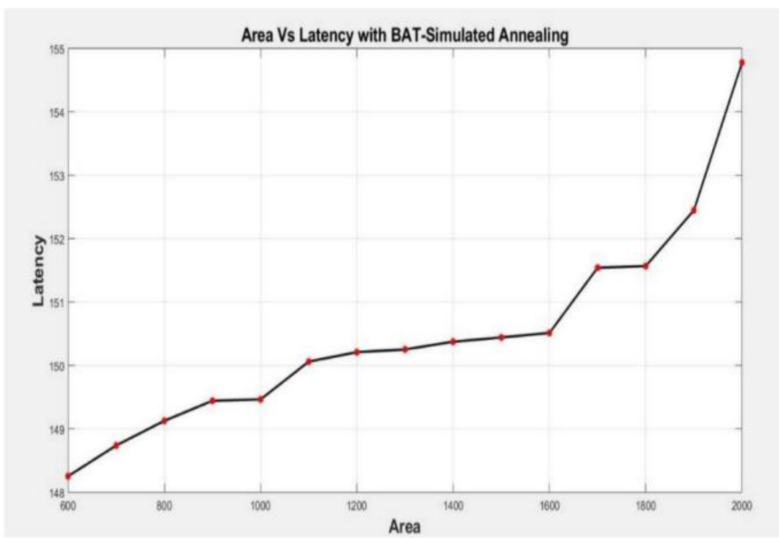

Figure 18: Area Vs Latency

CONCLUSION AND FUTURE WORK

The conventional BAT algorithm than DVHOP has good accuracy since it provides minimal localization error. The convergence or the computing rate and the success rate of the proposed BAT with SA algorithm is found to have better performance than the conventional DVHOP algorithm. From the simulated results obtained, it is proved that the computing time is also reduced with an increase in the scalability of the network area. The position and latency is also increased. Area Vs the position and latency is significantly reduced in the propose algorithm than the conventional DVHOP. The simulation results also shows the consistency of the proposed algorithm. Thus the overall system performance is increased and the WSN is significantly optimized by using the proposed metaheuristic BAT-SA algorithm. The hybridization of other metaheuristic algorithms can be featured as the future work.

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