Self-Organized Hybrid Wireless Sensor Network for Finding Randomly Moving Target in Unknown Environment

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ABSTRACT

Unknown target search, in an unknown environment, is a complex problem in Wireless Sensor Network (WSN). It does not have a linear solution when target’s location and searching space is unknown. For the past few years, many researchers have invented novel techniques for finding a target using either Static Sensor Node (SSN) or Mobile Sensor Node (MSN) in WSN i.e. Hybrid WSN. But there is a lack of research to find a solution using hybrid WSN. In the current research, the problem has been addressed mostly using non-biological techniques. Due to its complexity and having a non-linear solution, Bio-inspired techniques are most suited to solve the problem. This paper proposes a solution for searching of randomly moving target in unknown area using only Mobile sensor nodes and combination of both Static and Mobile sensor nodes. In proposed technique coverage area is determined and compared. To perform the work, novel algorithms like MSNs Movement Prediction Algorithm (MMPA), Leader Selection Algorithm (LSA), Leader’s Movement Prediction Algorithm (LMPA) and follower algorithm are implemented. Simulation results validate the effectiveness of proposed work. Through the result, it is shown that proposed hybrid WSN approach with less number of sensor nodes (combination of Static and Mobile sensor nodes) finds target faster than only MSN approach.

A. PSO - Particle Swarm Optimization

Self-organization is one of the important features of Swarm Intelligence (SI). Self-organization is a nonlinear distributed system which cannot have a linear solution and is not controlled by any single particle. It is a continuous process in which particles interact with each other locally [6], [7].

Initially, self-organized systems are predictable, but after some iteration or some time instances, these may be predictable, neutral or unpredictable.

There are mainly five features:

- Positive feedback
- Negative feedback
- Amplification
- Multiple iterations
- Balance of exploitation & exploration

The system has positive and negative feedback in which positive feedback inspires for the creation of convenient structure while negative feedback neutralizes the positive feedback [8],[9],[10].

Multiple iterations are required to reach to the goal. All particles find their own best position (i.e. Local best position). Among the local best positions of all particles, a best position is chosen (i.e. global best position) and all particles use best global position for next movement.

I. INTRODUCTION

Wireless Sensor Networks have gained worldwide attention due to its potential applications in area surveillance such as disaster monitoring, animal monitoring, underwater monitoring etc. [1],[2]. Different sensors have their own physical properties like temperature, moisture, smoke, light, odor, etc. As per the demands of application specific sensors are recommended to be used. The main challenges in WSN are its low bandwidth, memory limitation, and processing power. Researchers need to consider these limitations of WSN to provide a solution. In recent work, very few researchers focused on hybrid WSN due to communication hurdle between SSN to MSN.

Numbers of computations are required in analytical optimization methods. The number of computations depends on the size of the problem. If problem size increases, then computations also increase exponentially. Bio-inspired optimization techniques can be another alternative to analytical optimization. It is more efficient for the increased problem size or when the problem is complex [3],[4],[5].

The objectives of the paper are a) to simulate random moving target searching in an unknown environment, with minimum sensor nodes in hybrid WSN (SSN and MSN), b) to efficiently use, PSO (Particle Swarm Optimization) technique to achieve group movements of MSNs for target searching c) to compare area coverage of all approaches.

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B. PSO Algorithm

Generally, PSO performs searching operations using swarm particles. To get the optimal position each move in the direction to their best local position (pbest) and best global position (gbest) [11], [12], [13].

\[
pbest(i, k-1) = \arg \min_{k=1,2...,t} [f(P_i^k(k))],
\]

\[
gbest(k-1) = \arg \min_{i=1,2...N, k=1,2...t} [f(P_i^k(k))]
\]

Where \( t \) is number of iterations and \( N \) is the total number of particles (i.e. swarm size).

Each particle in the swarm decides the movement by an objective function

\[
f(x_1, x_2, ..., x_n) \text{ where } f : \mathbb{R}^n \rightarrow \mathbb{R}
\]

The fitness of particle is calculated from its \( pbest \) position in the searching area. The particle where \( pbest \) is closer to the \( gbest \) have lower cost and vice versa. PSO determines minimization of a fitness function. After each iteration, the position of a particle and its velocity are modified to achieve lower cost or higher fitness value. The notations used in PSO are shown in Table I.

| Symbol | Meaning |
|--------|---------|
| \( c_1 \) | Self-confidence factor |
| \( c_2 \) | Swarm confidence factor |
| \( rand1 \) & \( rand2 \) | Random numbers |
| \( \omega \) | Inertia weight |
| \( X_i \) | Particle’s position |
| \( V_i \) | Particle’s velocity |
| \( k, k-1 \) | Current and previous iterations respectively (movement of particle) |
| \( pbest_i \) | Particles best position |
| \( gbest \) | Swarm’s best position |
| \( P_i \) | Position of agents in the solution space |
| \( t \) | Total number of iterations |
| \( d \) | Dimensions of solution space |

Velocity and position of every particle are modified after \( k \) iteration and is shown as:

\[
V_i^d(k) = \omega V_i^d(k-1) + c_1 rand1_i^d(k) (pbest_i^d - X_i^d) + c_2 rand2_i^d(k) (gbest_i^d - X_i^d)
\]

\[
X_i^d(k) = X_i^d(k-1) + V_i^d(k)
\]

Here \( rand1 \) & \( rand2 \) are random numbers in the range \([0,1] \) for good coverage. \( \omega \) is \( 0.2 < \omega < 1.2 \) an inertia weight manipulates the trade-off between exploitation & exploration abilities of the object. Flowchart of PSO is shown in Fig. 1.

C. Global Positioning System (GPS) with Real Time Kinematic (RTK)

GPS is a location receiving device used worldwide. At least four GPS Satellites and a GPS receiver are required to get the location of objects in 2-D space. But its accuracy is 5 meters to 100 meters and precision is 5 meters to more than 20 meters. So use of GPS is not possible in proposed work. It needs more accuracy and precision.

More accurate position can be calculated using Real Time Kinematic (RTK) [14], [15]. Its accuracy is up to 2 centimeters. It consists of one GPS base station and multiple rovers. Setup positions are shown in Fig. 2. GPS base station is positioned on known location. It takes measurements from satellites in view and sends it with its known position to the rovers. Rover receiver also collects measurement from satellite in view, and process it with the base station information. Rover calculates their locations with relative to the base station.
and less amount of communication computations. Because each sensor
SSN. The proposed algorithm requires fewer communication resources
Matlab simulation is carried out to support the proposed work.

algorithms are proposed to move coverage MSN near to moved MSN.
using a V oronoi diagram. For NCON problem ECST & ECST-H
algorithm and TV Greedy algorithm. (Target based V oronoi Greedy
algorithm) in which Basic algorithm selects one MSN for one target,
problems are studied: choosing route link and staying time on the route

Communication with Satellite

Satellite

Communication with
GPS Base Station

GPS Base Station

Fig. 2. Real Time Kinematic (RTK) setup.

Equipments of RTK are costlier hence GPS less technique can be
used to get the position of sensor nodes. The proposed work is simulation
based so not much focused on how to get locations of sensor nodes.

The rest of the paper is organized as follows: A literature survey is
explained in section II. In the section III proposed work with algorithms
are introduced and explained in detail. Results analysis is given in
section IV and in section V conclusion and future scope is given.

II. LITERATURE SURVEY

In recent years, several researchers proposed new techniques to
find the object. Most of the techniques are SSN based and very few
are MSN and hybrid based. Bio-inspired optimization strategies are
also implemented to optimize the performance of their work [16],[17].
Some of the techniques are now discussed.

Zhuofan Liao et al [18] proposed algorithms to solve MSN
deployment ( MSD) problem. Multiple MSN & Multiple Static Targets
are considered in the system. The study focuses on overall energy
consumption by minimizing MSN’s movement to track the target &
Network connectivity. MSD is divided into two subproblems 1. TCOV
(Target Coverage) and 2. NCON (Network Connectivity) problems.
TCOV problem is solved using two Heuristic algorithms- Basic
algorithm and TV Greedy algorithm. (Target based Voronoi Greedy
algorithm) in which Basic algorithm selects one MSN for one target,
and TV-Greedy algorithm minimizes the total number of movements
using a Voronoi diagram. For NCON problem ECST & ECST-H
algorithms are proposed to move coverage MSN near to moved MSN.
So that moved MSN will be able to communicate with sink node.
Matlab simulation is carried out to support the proposed work.

In dynamic transportation system, Ning Zhu. et al [19] proposed a
system which is used for collecting traffic information by MSN. Two
problems are studied: choosing route link and staying time on the route
link. To tackle these problems Ant Colony builds the route for MSN and
Particle Swarm Optimization (PSO) determines the stay time on each
route link. The proposed work is studied analytically and proved that
MSNs are more effective than SSN in transport network surveillance.

Dusade A. et al [20], proposed Moving Object Tracking using
Support Vector Machine (MOT-SVM) for finding a movable object by
SSN. The proposed algorithm requires fewer communication resources
and less amount of communication computations. Because each sensor
node needs to send one bit of information to the central processing unit
to indicate that a moving object is going far or coming near. Moving
target far from observing SSN indicates ‘-‘ and near indicates ‘+‘.
Observer SN calculates + and – using RSS (Received Signal Strength).
If RSS is less, it is going far & if RSS is more it is coming near.
Experimental analysis is carried out and compared with Aslam’s work
& shown MOTSVM performs well in terms of accuracy, precision, and
robustness to data errors.

Jia Wei Tang et al [21], proposed a technique to track moving objects
using image processing technique. UAV (Unmanned Aerial Vehicle)
with vision capability is used to detect the movement of objects.
FPGA (Field Programmable Gate Array Algorithm) is used to develop
the UAV. For motion estimation and object segmentation block (area
based) matching & RANSAC (Random Sample Consensus) algorithms
are used. The entire work is supported by self-experimentation and
analytical calculations.

Hamid Maboubi et al [22], [23], focused on problem of tracking
and monitoring a mobile target in the field with multiple obstacles for
an increasing network lifetime. MSN’s are located using relocation
technique. The proposed work finds near-optimal relocation strategy
for MSN. It also finds the energy efficient path to send information
from movable target to destination. The proposed technique is proved
by simulation result & shown network life time increases.

Enyang Xu. et al [24] proposed work for mobile target tracking by
MSN. MSN controller gets the location of MSN & Target continuously
by anchor nodes. After analysis of Time of Arrival (TOA), controller
guides movement to MSN. MSN navigation strategy, target
localization, MSN localization and joint target & MSN localization
are formulated & calculated. Based on Time of Arrival (TOA), convey
optimization algorithm is developed for localization. Cubic law is used
for routing MSN.

Yifan Cai et al [25], [26], proposed a couple of algorithms to
track the target in a totally unknown physical environment. Multiple
robots search the target cooperatively to get the parameter ranges of
cooperation method in multiple robots using a combination of HRL
and MAXQ algorithms.

All parameters which are required for cooperation are obtained
through learning approach and new tasks can be performed by
the multiple robots. With simulation study, it is studied and shown that
multiple robots in the unknown environment can search the target.
Summary of studied literature is shown in Table II. (Table II (a) &
Table II (b)).

III. PROPOSED WORK

Proposed technique shows self-organization Mobile Sensor Node
(MSN) and Static Sensor Node (SSN) to find the moving target (T)
using Particle Swarm Optimization (PSO). MSN & SSN are equipped
with Global Positioning System (GPS) which is used to tell their exact
location coordinates in two-dimensional spaces. Target is assumed
to be movable random. Without having visual sense and directional
guidance to MSN and SSN, using only location guidance, MSN tracks
the moving target.

The proposed system is heterogeneous, using both SSN and MSN in
the same system. SSNs have the capability to send their own locations
to all MSNs which are far away. If the target is in the searching range
(SR) of SSN then SSN sends its own location to all MSN.

MSN are low capability sensors having a movable trolley/vehicle
on which MSN’s are located. The trolley moves as per the signals are
given by MSN. It can move in only three directions Left (Lt), Straight
(St) and Right (Rt), from the current position. Left and right rotations
are exactly 45 degrees from the current position. Fig. 3 shows the
**TABLE II (a). Summary of Literature**

| Sr. No. | Year & Author | Problem Identified | Algorithm used | Outcomes |
|---------|---------------|--------------------|----------------|----------|
| 1       | 2015- Zhuofan Liao and others | MSN Deployment (MSD) | TCOV-(Heuristic Algorithm) - Basic Algorithm, TV Greedy Algorithm - Target Based Voronoi Greedy Algorithm, NCON (Approximate Algorithm) - ECST – Euclidian Minimum Spanning, ECST-H – ECST- Hungarian | Controls on the movement of MSN, Prolong the network lifetime |
| 2       | 2014- Ning Zhu and others | Mobile sensor’s use in the transportation system to collect traffic information | Hybrid two-stage algorithm based on PSO and ACO | MSN’s are better traffic information collector than SSN |
| 3       | 2013- Dusade A. and others | Moving object tracking in WSN | MOT SVM- Moving Object Tracking using Support Vector Machine | Out performs than Aslam’s work in terms of accuracy, precision, and robustness to data errors |
| 4       | 2016- Jia Wei Tang and others | Real Time moving object detection | FPGA Algorithm- Field Programmable Gate Array Algorithm, Block Matching Algorithm, RANSAC- Random Sample Consensus Algorithm | Tracking of Moving Objects |
| 5       | 2016- Hamid Mahboubi and others | The problem of tracking and monitoring a moving target in a field with an obstacle | Residual Energy based Voronoi Diagram | Prolong the lifetime of the network |
| 6       | 2013- Enyang Xu and others | Track Mobile target by MSN | TOA- Time of Arrival Cubic Law | Target follower MSN with good performance |
| 7       | 2013- Yifan Cai and others | Target searching in unknown environment | HRL- Hierarchical reinforcement Learning, MAXQ | Target Searching in unknown Environment |

**TABLE II (b). Summary of Literature (Continued as of Table II (a))**

| Sr. No. | Proposed work compared with | SSN/MSN/ Hybrid | GPS | Stochastic Algorithm | Target | Network | Control | Simulation/Execution |
|---------|----------------------------|-----------------|-----|----------------------|--------|---------|---------|----------------------|
| 1       | None                       | MSN             | No  | No                   | Static (Multiple) | MSN     | Centralized | Simulation-Matlab    |
| 2       | Self’s analytical results  | MSN             | No  | PSO and ACO          | No- collect traffic information | Transport System | Distributed | Analytical study (Numerical Experiment) |
| 3       | Aslam’s Work               | SSN             | No  | No                   | One – Movable | Binary Sensor Network | Centralized | Not Mentioned         |
| 4       | NO                         | UAV/MSN – Unmanned Aerial Network | No  | No                   | Movable | Real Time Network | Centralized | Experimental/ Analytic |
| 5       | NO/ Simulation study compared analytically | MSN             | No  | No                   | Movable | MSN with obstacle | Centralized | Not mentioned         |
| 6       | Analytical study           | MSN             | No  | No                   | Movable - multiple | MSN     | Centralized | Not mentioned         |
| 7       | NO                         | Robots/ Unknown Environment | No  | No                   | Multiple | Unknown Environment | Distributed | Not Mentioned         |
possible rotations from the current position. There are 8 possible initial positions of MSN and each position has its relative left, straight and right rotations for movement.

A. Topology Formation by MSN

All MSNs together form a swarm. MSN moves randomly to search the target, but it must be in the range of at least one MSN’s CR. Initially MSNs are located in such a way that they will not share each other’s SR. Any two MSNs are a 2SR distance away from each other. If two MSNs are sharing SR, then same space will be searched by these two MSNs. By using this initial condition, the search space is increased.

Fig. 5 shows the possible minimum and maximum distance between two MSN. Fig. 5 (a) shows MSNs are sharing other’s SR. In such case, the same area will be searched by multiple MSNs and is wastage of time. Fig. 5 (b) shows the minimum distance between two MSN i.e. 2SR. So that it will search in the unsearched area. Fig. 5 (c) shows the maximum distance between two MSN i.e. CR to communicate with each other. If distance is increased than CR then sensors will not be able to communicate with each other.

B. Basic Flow of Systems

Initially, SSNs are placed randomly in the searching space. Target (T) is also placed randomly and is movable. It moves randomly and is not GPS equipped. Swarm of MSNs is placed at any random place or at the border of searching space. MSNs move randomly by swarm technique. While moving randomly if T found, then the mission is complete, else searching process continues.
Fig. 5 (c) shows worst case scenario of sensors (maximum distance between two sensors).

Due to the movement of T, if it comes in the SR of any SSN then SSN broadcasts its own location coordinates and a message saying ‘Target is found’ to all MSNs. Once location and message received by all MSNs, all MSNs calculate its own distance $\text{Dist}_i$ from sender SSN using Euclidean distance \cite{30}, \cite{31}.

$$\text{dist}_i = d_i + n_i$$  \hspace{1cm} (6)

Where $d_i$ is distance between SSN and MSN and $n_i$ is Gaussian additive noise, which has random value uniformly distributed in the range \cite{32}:

$$d_i \neq d_i(P_n / 100)$$  \hspace{1cm} (7)

$P_n$ is a percentage noise. Accurate calculation of distance depends on the value of $P_n$.

$$d_i = \sqrt{(x - x_i)^2 + (y - y_i)^2}$$  \hspace{1cm} (8)

Where $(x, y)$ are coordinates of SSN and $(x_i, y_i)$ are coordinates of particles.

All MSNs share their calculated distance from Sender SSN (SSSN) to each other. The MSN which is closer to SSSN will be selected as a Leader and others will be followers. Leader MSN (LMSN) will decide its direction to reach to SSSN and move step by step towards SSN. Other MSN will not waste their energy for deciding the direction and path. They will just follow the LMSN. At every step, All MSNs calculate their current distance from SSSN and share it to all MSNs. If any Follower MSN (FMSN) is closer to SSSN than LMSN, it will be selected as a new LMSN and former will be FMSN. In such fashion, MSNs travel to SSN, without knowing directions and any manual interaction. Once all MSNs reach to SSN, they start searching again with their random search.

C. Proposed Algorithms

To search the target, four algorithms are proposed which are as follows:

1. MSN’s Movement Prediction Algorithm (MMPA) for searching (T)

2. Leader Selection Algorithm (LSA)

3. Leader’s Movement Predication Algorithm (LMPA) for traveling towards SSSN is shown in Fig. 8.

4. Follower’s Algorithm (FA) is shown in Fig. 9.

D. Algorithms

1. MSN’s Movement Prediction Algorithm (MMPA) for searching (T)

   \begin{itemize}
   \item Start
   \item Initialize Previous Location = 0
   \item Current Location = Current Location of MSN
   \item MSN broadcasts it’s location to it’s neighbor MSN
   \item MSN stores other broadcasted locations
   \item Choose MSN as a neighbour which satisfies swarm criteria
   \item Calculate next prediction move in same direction
   \item Move 4 times left or right to change MSN to backward direction
   \item Does predicted move satisfy swarm criteria?
   \item Previous location = current location
   \item Take a random rotation either left, right or straight and move accordingly (But swarm criteria should be satisfied)
   \item Update current location = current location of MSN
   \item Search Target
   \item Is Target found?
   \item No
   \item Send “Target Found” message to all MSNs
   \item Stop
   \end{itemize}

Fig. 6. MMPA Flowchart.

2. Leader Selection Algorithm (LSA)

   \begin{itemize}
   \item Start
   \item SSN searches target continuously
   \item Is target in Searching Range of SSN?
   \item No
   \item Yes
   \item SSN Broadcasts “Target found” Message & its locations to MSN
   \item MSN Calculates their distance from Sender SSN
   \item Smallest distance from Sender SSN, will be Leader MSN
   \item Stop
   \end{itemize}

Fig. 7. LSA Flowchart.
3. Leader’s Movement Predication Algorithm (LMPA) for traveling towards SSSN

![LMPA Flowchart](image)

```
Start

LMSN Calculates the SSNDist (distance from SSSN)

Predict to move LMSN left, straight, and right direction and calculate predicted distance from SSSN PLt, PSt, PRt respectively

Lowest = find lowest predicted distance form PLt, PSt, PRt

Move MSN in backward direction

No

If (Lowest < SSNDist)?

Yes

Move MSN to lowest distanced direction

Is SSNDist <= SR or SSSN?

No

Stop

Yes

Fig. 8. LMPA Flowchart.
```

4. Follower’s Algorithm

![FA Flowchart](image)

```
Start

Calculate next prediction move in same direction

Is predicted movement’s distance greater than previously calculated distance of Sender SSN to MSN?

No

Move 4 times left or right to change MSN to backward direction

Predict next move (i.e. left, right and straight)

Calculate distance form Sender SSN

Move left, right or straight as per smallest distance calculated form Sender SSN to MSN

Follow LSA to find Leader

Stop

Fig. 9. FA Flowchart.
```

IV. RESULTS AND DISCUSSIONS

Matlab 7.0 simulator is used for the experiment. Due to the random movement of MSNs and T, the number of iterations/steps cannot be predicted. A number of times simulation is executed and tested for finding the T. The assumed parameters with respective values for the simulation are given in Table III.

SSNs are placed in searching space in such a way that whole area is covered. Searching space is divided into four quadrants and four SSNs are placed at the center of each quadrant (SSN1- (2.5, 2.5), SSN2-(2.5, 7.5), SSN3-(7.5, 2.5) and SSN4-(7.5, 7.5)) and fifth SSN is placed at the center of searching space (SSN5-(5, 5)). MSNs are placed at left-lower corner of searching the space (MSN1-(0.3, 0.9) and MSN2- (0.3, 0.3)). While moving, MSNs maintain at least 2SR distance from each other and will be in the CR of other MSN. T is placed randomly in searching space. The speed of T is same as speed of MSNs. If the T is in the SR of any MSN then it is assumed that T is found.

In the simulation, the movement of the target is shown in red colored dots, movement of MSN1 is shown in blue colored dots and movement of MSN2 is shown in green colored dots. Blue circles and pink circles indicate the SR and CR of the respective sensor. In SSN, CR is not visible for the sake of visibility of MSN’s and T’s movement but it is same as CR of SSN.

Simulations readings are observed after every 100 iterations or T comes in SR of any SSN or MSN. It is assumed that if T moves in SR of any MSN, then searching mission gets completed and it shows a total number of iterations required to find the T.

A number of times simulation is executed and some of the cases are discussed here as an example.

**A. Case 1: Target found by MSNs only**

Fig. 10 (a) shows the initial placement of sensors and T. T moves randomly in searching space as iteration increases. The path and area covered are shown in the red colored tail of T. At the same time MSNs also move using PSO technique to find the T. MSNs maintain the atleast 2SR distance and atmost 1 CR distance from each other. MSNs movements are shown in blue and green colored tail of MSN1 and MSN2 respectively. While moving, MSN found T in their SR at 68th iteration and is shown in Fig. 10 (b).

**TABLE III. PARAMETERS AND VALUES**

| Sr. No. | Parameter                          | Value          |
|---------|------------------------------------|----------------|
| 1       | Searching Space                    | 10 X 10 (Obstacle free) |
| 2       | Total Number of MSNs:              | 2              |
| 3       | Total Number of SSNs:              | 5              |
| 4       | Total Number of Target (T):        | 1              |
| 5       | Location of T:                     | Unknown        |
| 6       | Communication Range (CR) of sensors: | 1.2            |
| 7       | Searching Range (SR) of sensors:   | 0.3            |
| 8       | Targets Initial Position:          | Random         |
| 9       | MSNs and Target Movement:          | Random         |
| 10      | The speed of Target:               | Same as MSN    |
| 11      | GPS enabled Sensors                | Yes            |
| 12      | Maximum Iterations                 | 1000           |

[a](image) Searching Space

(a) Initialization
B. Case 2: T is Found by MSN with the Help of SSN 4

Fig. 11 (a) shows the initial localization of sensors and T where T is located near the SSN4. After one iteration, T moves in the SR of SSN4, which is shown in Fig. 11 (b). Once T is found by SSN4, it broadcasts ‘T Found’ message and SSN4’s location to MSNs. MSNs stops the searching and switch into the leader-follower mode and reaches to CR of SSN4. It is shown in Fig. 11 (c). While MSNs move towards SSN4, T moves randomly in another location. Once MSNs reaches in the CR of SSN4, MSNs switch their mode in searching mode and search the T as a random search strategy.

Fig. 11 (d) and 11 (e) show the movements of the sensor and T after 100th and 200th iterations respectively. T is found in 228th iteration by MSNs and is shown in Fig. 11 (f).
C. Case 3: T is Found by MSN with the Help of SSN5

Fig. 12 (a), (b), (c) and (d) are shown as explained in case 2. Instead of SSN4, T appears in SR of SSN5. T is found in the 28th iteration of MSNs.

D. Case 4: Involvement of Multiple SSNs

Sometimes T moves into the bigger area. Before coming all MSNs near to the SSSN, T moves far away from its found location. Once MSNs reaches to SSN, it searches T by random search. So MSNs are not able to find T near to SSN. After 123rd iteration, T is found by SSN2 so MSNs need to move towards SSN2. It is shown in Fig. 13 (a), (b), (c) and (d). Fig. 7 (e) shows T is found in 254th iterations by MSN near to SSN2. Even though T is traveling more distance in a straight way, MSNs are succeeded to find T.
(d) Target is found by SSN2 in 198 Iterations

(e) Target found by MSN in 254 Iterations

Fig. 13. Movement of MSNs and T.

E. Case 5: Worst Case

Sometimes T does not come in SR of any SSN or MSN then it requires more number of iterations. It works like only MSNs are in the network searching for T. Fig. 14 (from the figure (a) to figure (k)) shows that in 1523rd iteration T is found by MSN.
Comparison Between the Networks with Only MSNs and Hybrid WSN

To show the effectiveness of hybrid WSN, two types of simulations are performed. The first type of simulation consists of only MSNs which are placed on the test bed. And in the second type, both SSNs and MSNs are placed.

If the size of searching space is small then both scenarios work well, but if the size of searching space is large then the simulation with only MSNs requires more number of iterations to find T as compared to hybrid WSN. The total number of iterations required for both scenarios is shown in Table IV and Fig. 15. To find the T, 10 simulations are carried out of each scenario and numbers of iterations are sorted in ascending order. Average number of iterations in SSN is only 10 but to transmit data to base station it require more energy. Only 572.9 average iterations are required for Hybrid WSN and are far less than only MSN scenario.

| Sr. No. | Only SSNs (Dense Deployment) | Only MSNs (Number of Iterations) | Hybrid WSN (Number of Iterations) |
|---------|-----------------------------|-------------------------------|-----------------------------------|
| 1       | 1                           | 52                            | 28                                |
| 2       | 1                           | 168                           | 68                                |
| 3       | 1                           | 1,021                         | 228                               |
| 4       | 1                           | 1,021                         | 254                               |
| 5       | 1                           | 1,224                         | 452                               |
| 6       | 1                           | 1,335                         | 622                               |
| 7       | 1                           | 1,512                         | 784                               |
| 8       | 1                           | 1,627                         | 772                               |
| 9       | 1                           | 1,651                         | 998                               |
| 10      | 1                           | 1,724                         | 1,523                             |
| Average | 10                          | 1133.5                        | 572.9                             |
In Hybrid approach, if more number of SSNs are placed then the number of iterations reduces.

**G. Coverage Comparison of Searching Space**

To cover the complete searching space (10 X 10) by sensors range, more number of SSNs need to deploy. The number of SSNs needed to cover area depends upon the SR of sensors. If SR=0.3 in same searching space the 289 (17 X 17) SSNs are needed.

**1) Degree of coverage**

The degree of coverage can be the ratio of entire searching space and area covered by all sensors and coverage area can be area covered by all sensors through their SR [18]. In Only SSN approach when SR=0.3, the area coverage, and the coverage degree are 86.7 and 1.15 respectively. In only MSN approach area coverage, and the coverage degree are 0.6 and 166.67 respectively. This approach requires more time to search T.

In the proposed technique SR is 0.3 and number of sensors are only 7 (2 MSNs and 5 SSNs). The coverage area and the coverage degree of proposed work are 2.1 and 47.62 respectively, which is shown in Table V and Fig. 16. Even though proposed work has less coverage area than SSN approach and larger cover area than MSNs approach, it requires less energy than other approaches for searching T.

**Table V. Coverage Area and Coverage Degree**

| Example           | Searching Space | Number of Sensors | SR  | Coverage Area | Coverage Degree |
|-------------------|-----------------|-------------------|-----|---------------|-----------------|
| Only SSNs         | 10 X 10         | 289 (SSNs)        | 0.3 | 86.7          | 1.15            |
| Only MSNs         | 10 X 10         | 2 (MSNs)          | 0.3 | 0.6           | 166.67          |
| Proposed work     | 10 X 10         | 7 (2 MSNs + 5 SSNs) | 0.3 | 2.1           | 47.62           |

Fig. 16. Coverage Area Comparison.

**Randomly moving target is efficiently found by novel proposed technique. MSNs are allowed to move in only three random directions. Without control of third parties, MSNs move autonomously and find target successfully. A novel concept of hybrid WSN is implemented to find the target. SSNs and MSNs are utilized together to achieve objectives. If more number of SSNs & MSNs are deployed, then searching time reduces tremendously. A PSO technique in hybrid WSN is effectively implemented to find the unknown target in an unknown environment. Results show that hybrid WSN performs better than only MSNs in the network.**

It is proved that using less number of sensors, target finding can be done effectively so due to less number of sensors utilized in the network, equipment cost and its maintenance cost is reduced.

Obstacle free environment is assumed for simulation. Single target is assumed and its speed is assumed same as MSNs speed. But in real case target’s speed may be lower or higher than MSNs speed. In future work, it is planned to consider obstacles in searching space with multiple targets and lower or higher speed of target than MSNs.

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