Velocity Based Contour Algorithm For Lost Target Recovery In Wireless Sensor Network

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Abstract— Target tracking in a WSN is an important issue and it requires a lot of energy. Poor prediction mechanisms can cause tracking issues including target loss, which is a serious problem in surveillance applications. Good algorithms for target prediction can save network energy and track the target effectively. In this work, Recovery of lost target is improved in terms of energy efficiency by taking into consideration geometrical shapes (circle, contour) and velocity of target. Kalman filter based prediction algorithm is taken as reference. The impact of various algorithms on sensor network energy consumption is studied in this paper. Performances of fixed circle, fixed contour and velocity-based circle are evaluated and compared based on energy efficiency. The simulation results demonstrate a numerical analysis of recovery techniques when it comes to recovery energy and target loss instances and will be able to improve the overall performamce.

Keywords- Target tracking, prediction algorithm, Wireless Sensor Network (WSN), Kalman filter, recovering a lost target, circle-based recovery method, contour-based recovery method

I. Introduction

Wireless Sensor Networks (WSNs) are widely used for collection of data. The tracking a target and recover a lost target are most challenging application of WSN. Target tracking is used to secure an area from harmful objects in real world / surveillance applications. It is used to reduce prevent intruder/ terrorist attacks all over the world. In the case of unlike event detection, tracking necessitates ongoing observation. To reduce processing power and energy consumption, the tracking and recovery algorithm should have fewer computations and be energy efficient. Changing the state of sensor nodes from active to sleep saves a significant amount of energy. To design target tracking and lost target recovery mechanism, initially to save energy, all sensor nodes are kept in sleep mode and predicts moving object trajectories in advance using soft computing techniques. During traverse awakening the nodes when the target is likely to transverse their sensing areas. System should be able to track a moving non-cooperative point target/object in spite of limited sensing coverage of each sensor. For the current work, Kalman filter approach has been used for target tracking [1]. Due to imprecise prediction, network hole, failure of nodes, failure of communication, atmospheric influences, noise, and other factors; tracking algorithm may be subject to target loss, and a target may remain unnoticed for a period of time. Recovery of target initiated if it’s got undetected while transverse while saving network energy[2]. This study compares and contrasts the performance of different loss target recovery methods. When it comes to the number of lost target occurrences, the amount of energy spent in monitoring a target, energy required in recovering a lost target, number of activated nodes and different strategies are compared.

II. Related work

Based on the trilateration method three Active nodes calculate the distance from the target and using a prediction algorithm, predict the target position. Based on the predicted location, sleeping nodes near the location that is predicted by tracking algorithm are awakened to track the target to save the energy. Thus, better prediction algorithm saves the node energy. To save energy, nodes that are not nearby are considered inactive and are put into a sleep state.

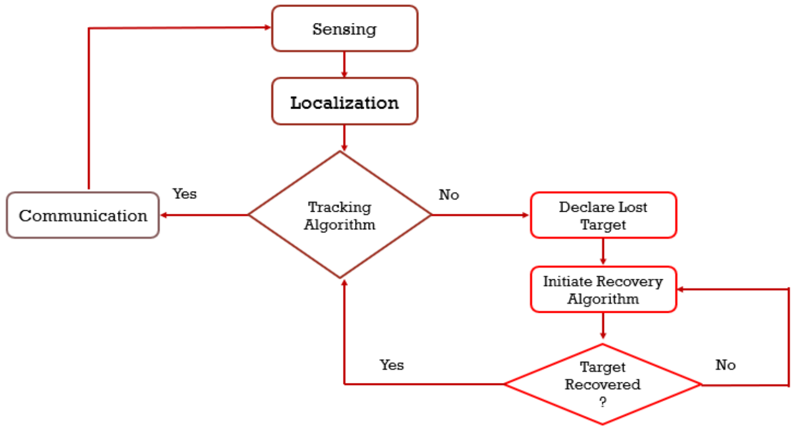

Figure 1: Flow chart of Target tracking and recovery of lost target

The recovery mechanism for lost target is a crucial feature of any target tracking application. It should relocate a target on time, if the target tracking algorithm fails. The target could be lost for a variety of reasons, as detailed below [3, 4].

(1) Network Hole: A network hole is an area of a network that is not covered by the network. Because sensor nodes are distributed at random, network holes are formed.
(2) Failure of nodes: Tiny sensor nodes are located in a remote location with limited access. Normally, their batteries cannot be recharged. Battery depletion is a common cause of node failure. Furthermore, node failure might be caused by physical damage.
(3) Target localization error: Improper node position results in erroneous target localization. The loss of a target is caused by erroneous target position assessment.
(4) A rapid change in velocity: If the target's velocity changes abruptly, the target may lose track of it and go undetected by sensor nodes.
(5) Error due to poor prediction: The prediction method aids in the activation of nodes that are closest to the target site. However, incorrect prediction may cause the tracking mechanism to activate the incorrect group of sensor nodes. As a result, a real target position cannot be obtained, and the target is lost.

The majority of the research in the literature has gone into developing an accurate tracking mechanism [5]. Because clustering-based network architecture saves energy by reduces transmission distance between nodes, most tracking algorithms assume it. Target identification, sensing, localization, prediction, and communication are all part of the tracking framework [6].

The rest of the paper is organized as follows. Section III presents brief summary of Kalman based target tracking algorithm. Section IV details proposed various algorithms implemented for recovery of lost target. Section V describes simulation set up, typical scenario and performance of various algorithms for recovery. Finally Section VI concludes the paper.

III. KALMAN FILTER BASED TARGET TRACKING

Kalman filter is generally utilized in target tracking applications. It uses prior information to forecast the target's next location, estimates based on current data inaccuracy, and performs a correction to the predicted state. It entails a straightforward calculation to predicting the future state. The Kalman filter gives better results for target motion that is linear but fails when the target moves non - linear. As a result, with Kalman-based tracking systems, the possibility of target loss is significant [7, 8].

The Kalman Filter's function can be explained in the following steps. (a) First one is prediction state and second one is update state. The prediction step at k^{th} instance takes the estimate from its previous time step $k\text{-}1^{th}$ to construct an estimate for the current time step. (b) Update step is the second step in which current time step measurements are used to modify and improve the prediction of the predict step.

Prediction state:

$$\overline{y_k} = Mx_{k-1} + N\widehat{u_{k-1}} + w_{k-1} \quad (1)$$

$$\overline{P_k} = MP_{k-1}M_k^T + Q_k \quad (2)$$

Update State:

$$K_k = \overline{P_k}H_k^T(H_k\overline{P_k}H_k^T + R_k)^- \quad (3)$$

$$\widehat{y_k} = \overline{y_k} + K_k(z_k - H_k\overline{y_k}) \quad (4)$$

$$P_k = (I - K_kH_k)P_k^- \quad (5)$$

Where,
Kalman gain matrix is K, while the identity matrix is I. (I_{4X4}).
Estimate of the state vector is shown by the superscript "^ " above.

Equation (1), The state variable and its process covariance matrix of the following time step k can be predicted using the initial state variable y_{k-1} and its process covariance matrix I. With the use of measurements at time step k, these estimations can be revised further.

A target relocation and communication procedure are part of the recovery framework. A clustering-based distributed tracking approach that uses a RADAR beam for recovery is suggested in paper [12]. When a target is lost, the sensor nodes that were tracking it switch from normal to high beam. Second-level recovery is started if it fails. The search zone is expanded at the second step of recovery. It's difficult to use a RADAR beam in small sensor nodes, and it will take extra energy in addition to recovery energy. All nodes within a radius (r1) distance circle are activated. Or else, the pth stage of recuperation will begin, with the new circle radius set to (2p - 3).

IV. ALGORITHMS FOR LOST TARGET RECOVERY

The recovery algorithm as reported in [13], using target kinematics, anticipate the next target location. To retrieve a lost target, it wakes up the senor nodes in a predefined sequence. This method wakes number of nodes in large number, causing the network to consume more energy. Kalman filter for target tracking algorithm is implemented.

For loss target recovery, Figure 2 shows implementation simple with Fixed Circle. In a circular based approach, recovery algorithm activates all nodes that are in range of first radius that is R1. As soon as target lost is reported, algorithm selects first stage radius R1 based on current velocity of the target. If target is not recovered it activates all nodes into bigger radius R2. Radius R2 is considered double the radius R1. It activates more number of nodes and hence more energy is used during this iteration of target recovery. If target still fails to be recovered; in subsequent iterations Radius R's are increased.
Prediction of target movement by considering contour shape covers less area as compared to circle as shown in Figure 3. In this case less number of nodes are activated and less energy is being used in target recovery. However, is the motion of target is not captured properly target may get lost further. More energy and times can be saved if velocity in addition to contour is taken in consideration. Velocity based circle and velocity based contour algorithm are also analyzed in this work.

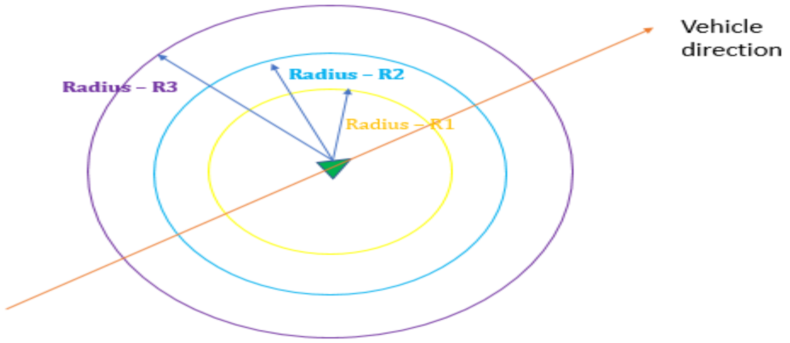

Figure 2: Conceptual diagram of Fixed Circle based recovery of lost target

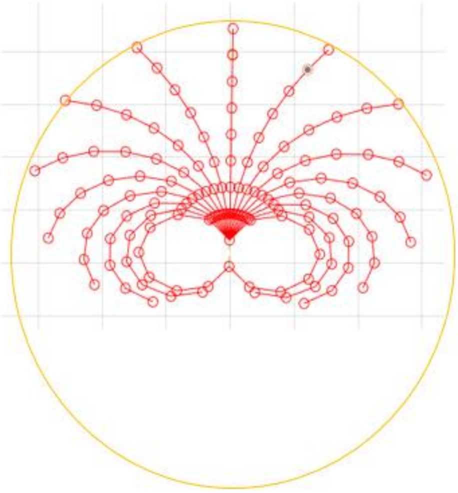

Figure 3 : C Conceptual diagram of ontour based recovery of lost target

V. **SIMULATION RESULTS**

As mentioned earlier, in this studies Kalman filter is taken as tracking algorithm and various recovery algorithms were simulated in MATLAB scenario. Simulated target trajectories are shown in Figure 4. The experimental setup consists of 600 nodes distributed at random in a 100mX100m zone. All sensor nodes have a communication range of 20 meters. Sensor nodes identify the existence of the target as soon as it enters the field, and the target tracking procedure begins. The network parameters utilized in simulations are listed in Table 1. Table 2 displays the energy model and the amount of energy used by each sensor node process [17]. Figure 4 depicts a clustered WSN. Total of 24 clusters are formed using static clustering. It depicts a section of each cluster that contains member nodes. Cluster Heads (CH) with their identities (ID) are also highlights for each cluster.

Parameter	**Value**
Area	100 x 100 m^2
No. of Nodes	930
Nodes' Initial Energy	2 Joules
Target Speed	0-10 m^2
Range of Sensing	10 meters
Range of communication	20 meters

Table 1: WSN parameters used for target recovery algorithm

Parameter	**Value**
Sensing Energy	9.6 x 10^{-3} J/Second
Processing Energy	4.0 x 10^{-9} J/Second
Receiving Energy	0.88 x 10^{-3} J/Byte
Transmission Energy	5.76 x 10^{-3} J/Byte
Sleep Energy	0.33 x 10^{-3} J /Second
Size of message	64 Byte
Size of Instruction	1000

Table 2: Energy Consumption Parameters.

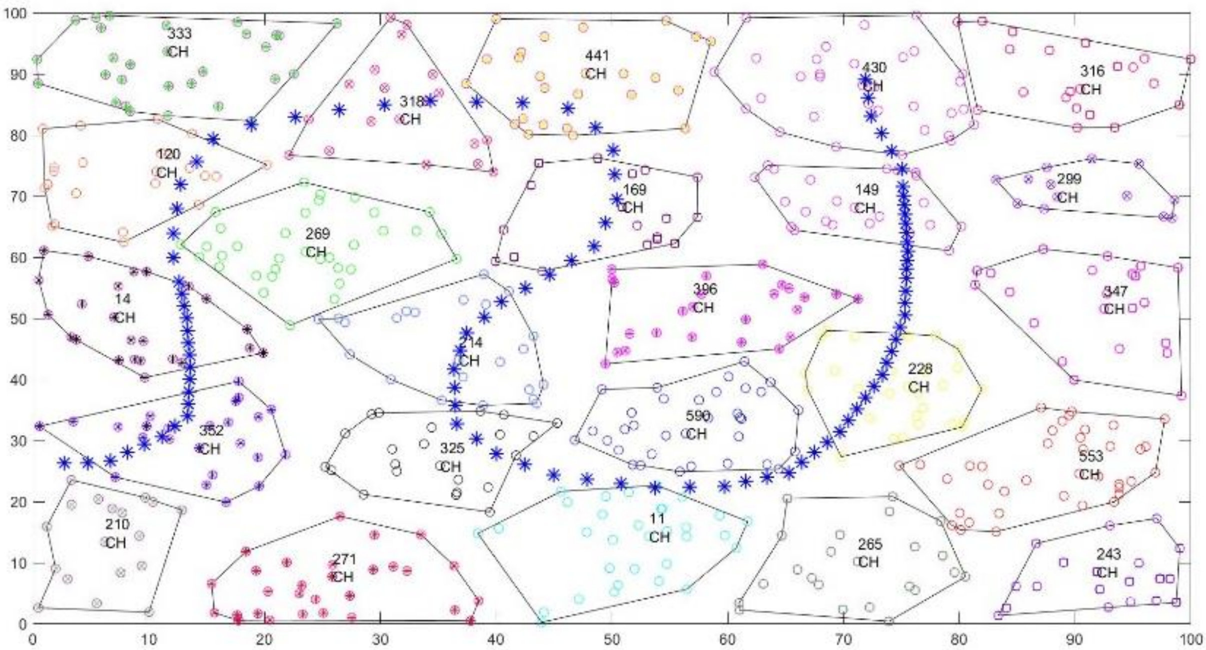

Figure 4 : Typical case scenario of Sensor Network with nodes pus Cluster head and their IDs

Figure 5 demonstrates Fixed circle recovery method used for Typical case presented in Figure 5. Similarly; Figure 6 shows Velocity based circle recovery method , Figure7 shows Fixed contour recovery method and Figure 8 shows Velocity based contour recovery method scenarios.

In the event of a Tracking algorithm based on Kalman filters, the target instances are lost. In this scenario, the target is believed to be travelling at a slow speed ranging from zero to five meters per second and can go across the sensor network in any linear or non-linear pathway. A non-linear trajectory cannot be tracked using the Kalman filter.

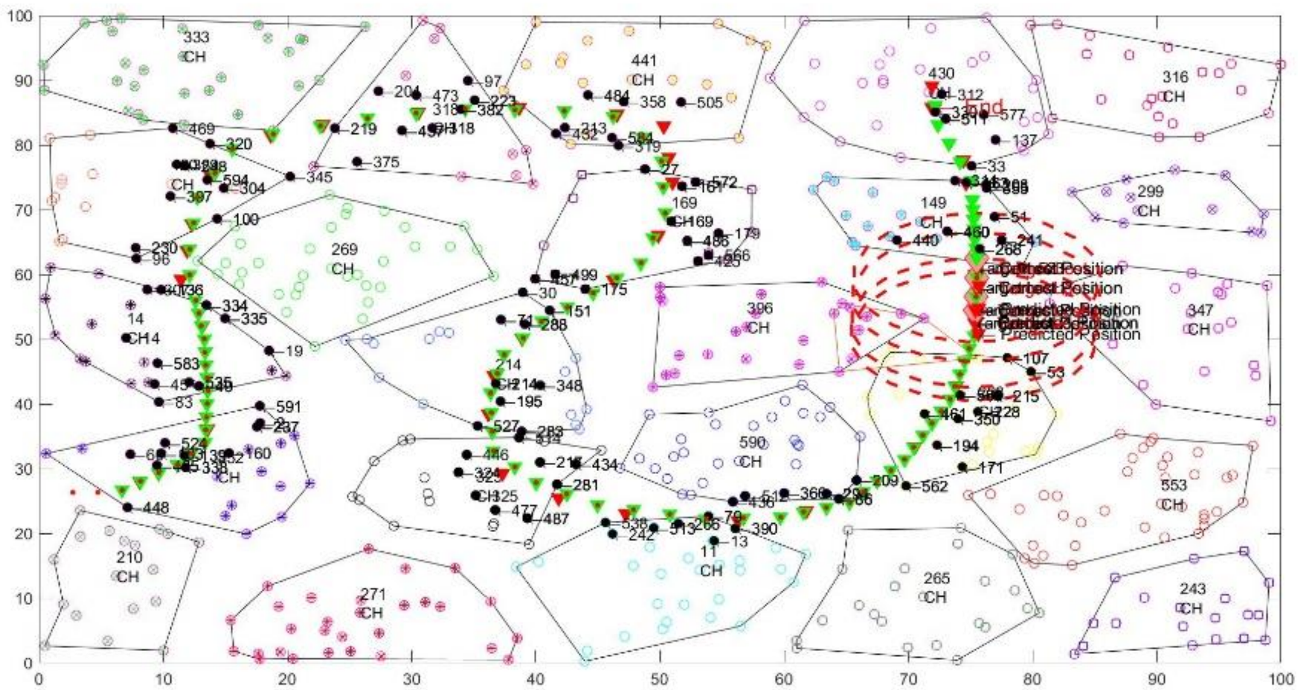

Figure 5 : Fixed circle recovery method for Typical case scenario

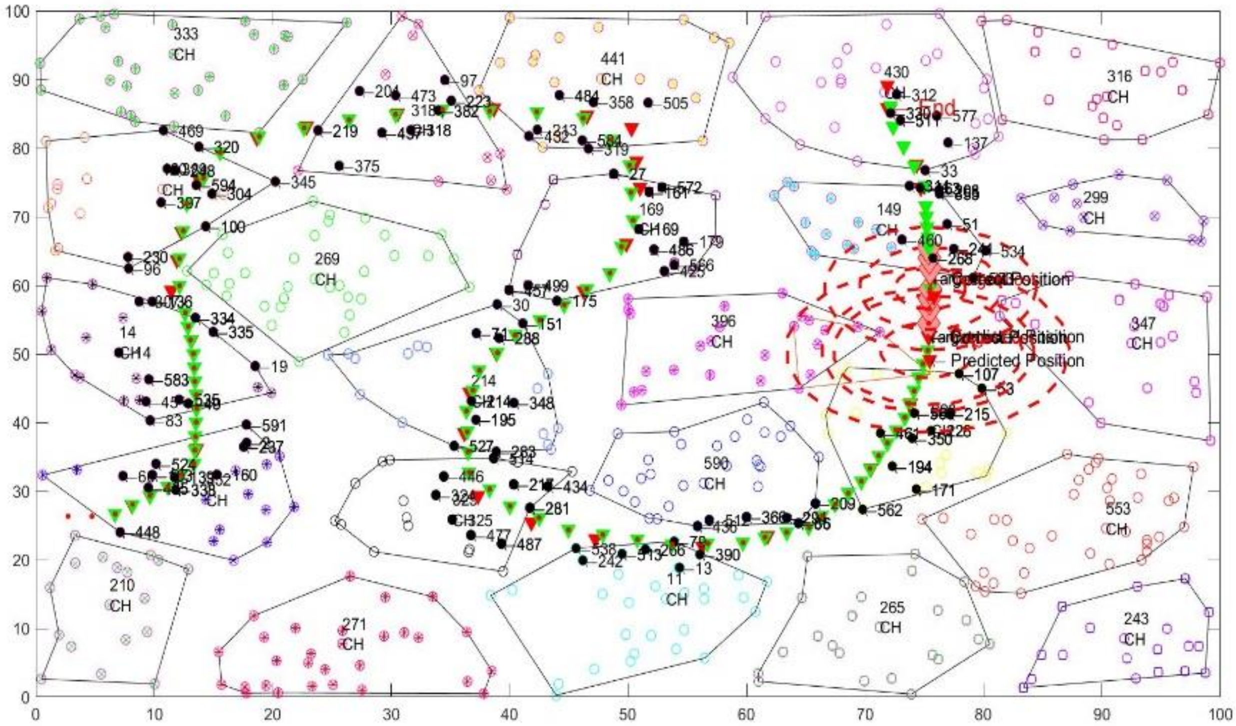

Figure 6: Velocity based circle recovery method for Typical case scenario

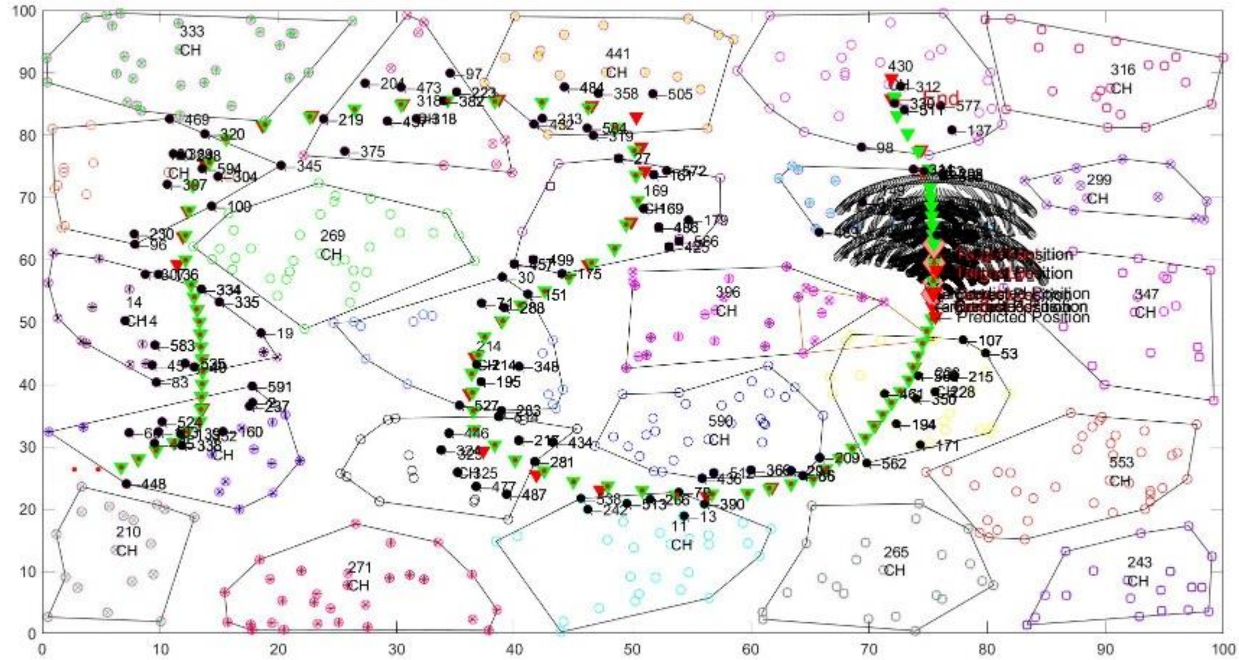

Figure 7 : Fixed contour recovery method for Typical case scenario

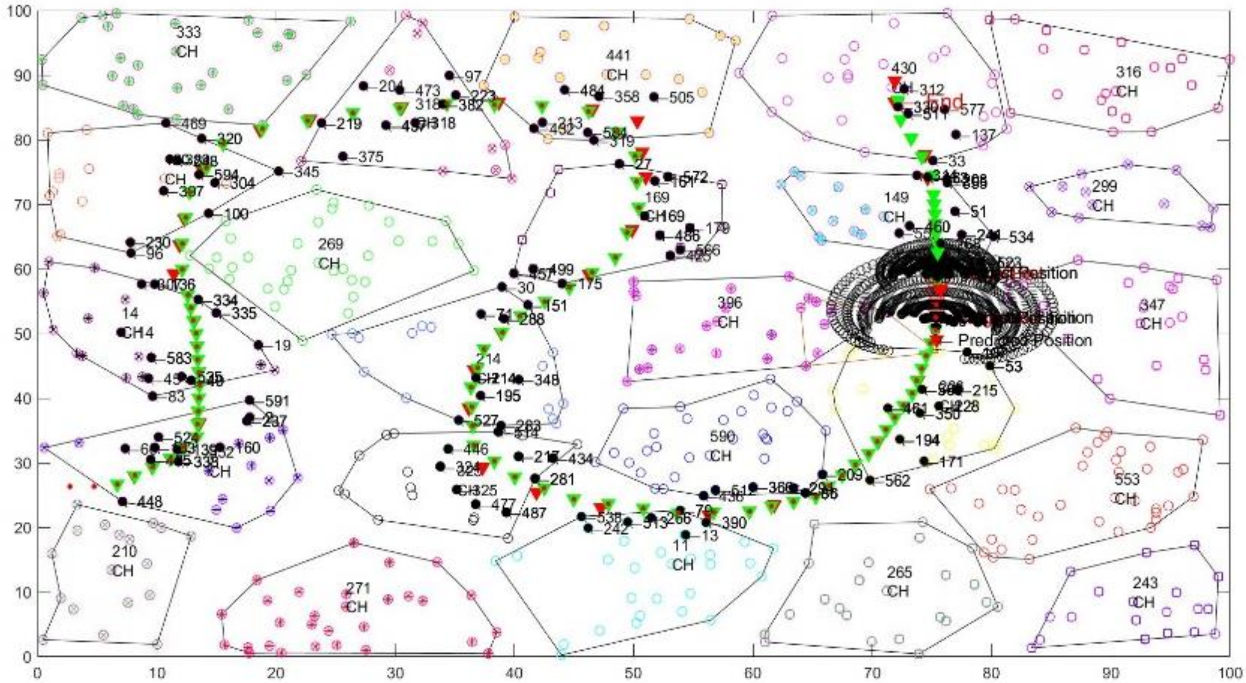

Figure 8: Velocity based contour recovery method for Typical case scenario

Table 3 summarizes performance of various recovery methods used in the current work. Recovery Energy Consumed is the total amount of energy consumed by each sensor node in the network to recover the target. It consists of energy for sensing, processing, data transmission and receiving, and sleep. On a particular trajectory, the number of target lost instances mainly attributed to an erroneous prediction or hole is shown by the number of times the target was missed. It is found that the performance of velocity-based contour algorithm (Contour $_{velocity}$) is better in comparison to other methods like Circle$_{Fixed}$, Circle $_{velocity}$ and Contour $_{Fixed}$ approaches.

TRACKING METHOD	**RECOVERY ALGORITHM (Joules)**	**RECOVERY ENERGY (Joules)**	**No. of Times Target lost**
KALMAN	$Circle_{fixed}$	18.9056	4
	$Circle_{velocity}$	19.1977	2
	$Contour_{fixed}$	35.5718	4
	$Contour_{velocity}$	8.2916	2

Table 3: Simulation results with different recovery methods

VII. CONCLUSION

The energy required during loss target recovery in a WSN is evaluated in this research. If the prediction based tracking method fails, the target becomes lost, necessitating the use of an energy-effective recovery mechanism to re-locate the target while using the fewest network resources possible. The correlation between the energy required by different recovery strategies is defined in this research. The velocity-based contour algorithm utilized minimum energy compared to other algorithms. Based on analysis done on implemented work we can conclude that velocity-based contour approach in target recovery provides energy efficient approach as compared to other recovery algorithm.

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