Prediction based Target Tracking in Wireless Sensor Network (WSN)

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Approval

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This thesis is dedicated to *my beloved parents*

Abstract

Wireless Sensor Networks (WSN) are used for monitoring purposes like physical monitoring, environmental monitoring, and area monitoring. WSNs cover many application areas such as security, health, environmental monitoring, industrial monitoring, and target tracking. Target tracking is a technique in which the target location is estimated through the Self-known positioned (SN). These applications require large data collection, data forwarding, and extensive monitoring. To cater all these requirements with scarce resources is a challenging job. To address these issues, we study WSN schemes that rely on the incorporation of sensing data and target tracking to achieve overall accuracy and energy efficiency. There are various solutions in the literature like Global Positioning System (GPS), Radio Frequency Identification (RFID), Received Signal Strength Indicator (RSSI), Trilateration, and Multilateration but every solution has some drawbacks associated with it. Therefore, a new dynamic clustering based tracking technique is proposed in this thesis to address these issues. The proposed scheme reduces the energy consumption by activating few SN, results in prolonging the WSN lifetime. The results of the adaptive scheme are simulated that depicts an accurate, precision-based target tracking can be achieved using only a few sensors.

Keywords: *Wireless Sensors Network (WSN), Sensor node(SN),Global Positioning System (GPS), Radio Frequency Identification(RFID), Received Signal Strength Indication(RSSI)*

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Abbreviations

WSN	Wireless Sensor Network
SN	Sensor Node
CH	Cluster Head
RSS	Radio Signal Strength
BS	Base Station
SPIN	Sensor Protocol for Information via Negotiation
REBMR	Rumor as an Energy-Balancing Multipath Routing
NHs	Neighborhood Heuristics
KF	Extended Kalman filter
EKF	Extended Kalman filter
UKF	Unscented Kalman filter
PF	Particle Filters
RCAM	Random way and Constant Acceleration Model
LSA	Least Square Algorithm
RW	Random Walk Model

Chapter 1

Introduction

1.1 Motivation

Wireless Sensor Network (WSN) usually expresses a wireless network comprised of small devices, called sensors node (SN). This SN based network ranges from a few to hundreds of thousands dispersed over a specific area to acquire measurements [1]. A SN differs in sizes from a grain of dust to a size of shoe. The cost of SN similarly varies from a few dollars to hundreds of dollar depending upon the complexity of the SN and environment in which these SNs is used.

These SN have been contiguously dispersed over the area. These SN interconnect with each other in such a way that they all act as a single monitoring unit. In WSN, SN performs many tasks like sensing, gathering information, processing, and communication. These SNs senses or gathers the specific type of information depending upon the user's application. After gathering the information, SN forwards that information to the sink node or Cluster Head (CH) with the subject to the adopted network topology. Due to SN independence in relation to human interference and cost-effectiveness, they are used in many areas like event-driven based area monitoring from fire, floods and hailstorms[2], health monitoring [3, 4], sub-aquatic underground and space area investigation[5], industrial, agricultural and environmental monitoring and surveillance[6, 7].

In many application of WSN, information is beneficial if the referred SN location is known. Moreover, a precise location of the target in any area ushers new applications for industrial services and in case of emergency[8], cargo tracking and warehouse management. This precised, detailed information can improve safety, make search and rescue more efficient, target localization and detection. Hence, this accurate information about SN location is a very useful resource, which improves our daily life.

The idea of wireless localization was first to formulate for the mobile network, with which many applications and services are designed for its users. Due to the rapid increase of varied smart devices; e.g. mobile-phones, tablets, which provide autonomous and seamless interfaced applications for multiple wireless networks has made the location information more crucial for location-dependent applications.

On the contrary, SN is very minute, low cost and has a very small battery power (non-rechargeable and removable) commonly dispersed in vast numbers over a targeted area with a very small control over its location (space, underwater etc.). Since the SNs have very nominal processing capabilities, the key requirement is to develop fast, precision-based localization schemes which are self-disciplined, self-sustained in term of communication and computation.

In this thesis, an improved prediction based localization scheme is presented for target tracking in a WSN which overcome various limitations precise and accurate prediction of target location, activating few SN to track. Proposed method and results are discussed in Chapter 3.

1.2 Wireless Sensor Network (WSN)

1.2.1 Overview

WSN is very essential in the development of a smart environment; e.g. smart cities, smart building, smart grid, transportation and shipping system, factories etc. , since they act as a mediator between the real world and smart systems. WSN bids vasts number of benefits in many areas such as healthcare, military, industrial and environmental. SNs are varied from application to application, e.g. a type of SN can only compute physical properties like pressure, humidity, temperature while the other SN can acquire information like position, velocity, and speed or sense identification information like a fingerprint, voice, and retina [9].

Nowadays, WSN is commonly used in environmental and habitat monitoring application such as animal and birds tracking [10], agricultural land monitoring, irrigation on land

[11], flood control[12], forest fire detection [13], pollution study[14] and so on.

Wildfires are one of the fatal threats in the world. It is reported in [15] that a total of 55,911 wildfires burned more than 8.5 million acres in the USA during 2018. One way to monitor and observe the wildfire is through satellite [16], but in [17] disagree with this approach because of long scanning time and low image resolution quality limit the effectiveness. Author than propose WSN based wildfire monitoring system in which SN collect multiple measurements like temperature and humidity and send gathered information to the base station (BS).

Another environmental application is flood control. One example of flood control management system using WSN is proposed in [18]. In [18], multiple SN are deployed in the field like rainfall sensor, water level sensor, climate sensor. These SN regularly get information and forward it to the BS. Authorities at BS analyze the gathered information and take necessary measurements.

Moreover, WSN also have a great impact on the health sector with many applications like tele-medicine, tele-monitoring of physiological data, tracking and observing patient location, health status [19, 20]. Furthermore, authors in [21] proposed a WSN enabled remote monitoring system for elderly people. With the help of WSN major incidents like fall, unfamiliar behavioral activities can be observed.

These SNs are also used to track and report the position of the target. Target tracking is one the most important application of WSN. Target tracking can be done in many fields like campus monitoring, habitat monitoring, border monitoring to minimize the illegal border crossing and battlefield monitoring Target tracking is explained in section 1.3.

1.2.2 Architecture

WSN follows the Open Systems Interconnection (OSI) model. The architecture of WSN consists of five layers; Application layer, Transport layer, Network layer, Data link layer and Physical layer.In addition to these five layers, there are three cross layers called Task Management plane, Mobility Management plane and Power Management plane [22]. These three layers are used to manage the network and work together in such a way that SN acts as one unit and to improve the efficiency of the WSN.

The architecture of WSN is shown in figure 1.1 .

1. Application Layer:

   The application layer is responsible for traffic management and offers application through which useful information can be extracted from the data.

2. Transport Layer:

   The main function of the transport layer is to avoid congestion and improve data reliability. Transport layer protocols are further divided into two types

   - Data Driven: All data must be delivered to the destination(BS) from SN.
   - Event Driven: Upon detecting the event, data must be sent to the BS.

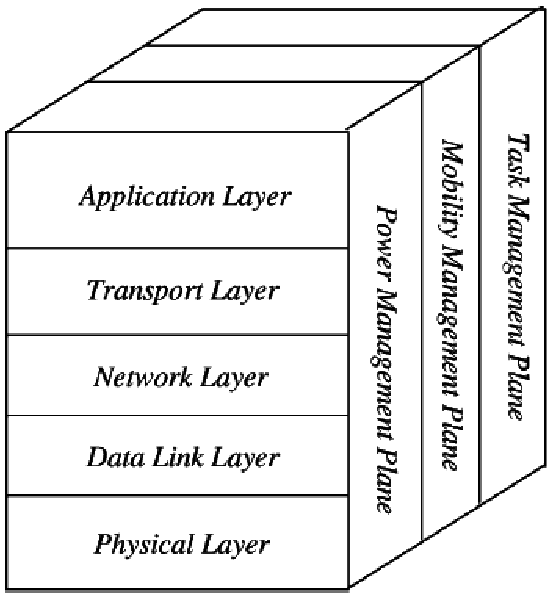

Figure 1.1: Architecture of WSN

3. Network Layer:

   The main purpose of this layer is routing. There are a lot of routing protocols for this layer like flat routing, hierarchical routing or time driven, task driven, and event-driven.

4. Data link Layer:

   This layer is responsible for multiplexing, error control, point to point reliable data delivery.

5. Physical Layer:

   The physical layer provides a medium to transmit the bits over a physical medium. It is also responsible for data encryption modulation.

1.2.3 Application of WSN

There are numerous applications of WSN in many areas like traffic monitoring and control, military, industrial automation. Some of the applications are:

- Military Applications:

  WSN can be used in military applications such as accessing health and fatigue level can enhance the physical and mental level of soldiers during battlefield. It will be really helpful to track wounded soldiers and retreat them from the dangerous battlefield environment [23].

- Security and Surveillance:

  These SNs are also used for localization for moving objects. This target tracking can be used in many fields like warehouse management, shipment tracking, surveillance, and security.

- Healthcare Applications:

  WSN can assists in the medical field for patient monitoring and healthcare. The new concept of m-health [24] and 4G-Health [25] is combined with the Internet of m-Health things (m-IoT) [26] enables new ways for telemedicine, drug delivery to a specific person and patient monitoring. It also makes monitoring easy for doctor and patient where a patient can perform exercise remotely under the supervision of a doctor using a computer.

- Fault Detection:

  WSN is also very useful in the fault detection and monitoring of machinery, building. These SNs are valuable in the implementation of industrial automation, data center monitoring. These SNs can be placed in such locations very hard to access with the wired system like rotatory machinery, unstrapped vehicles and machinery [27].

- Distributed Computing:

  WSN can be effective in preventing from vast consequences of natural disasters like flood, wildfires, avalanches. SNs have been dispersed in rivers, where a change in water level can be monitor remotely with the help of SNs.

- Detecting Ambient Conditions:

  Area monitoring is a common application of WSN. Monitoring of soil, environment, pressure [28], temperature, precision agriculture can be implemented with the assistance SN.

  These SN can also be used for the detection of chemical agents/ biological agents outbreak [29]. With information like that loss of human life can be avoided.

Application chart of WSN is shown in figure 1.2.

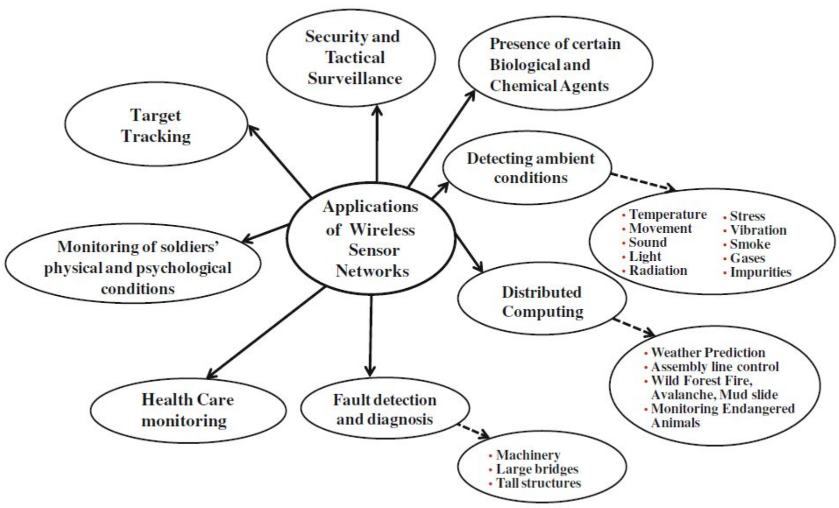

Figure 1.2: Applications of WSN

1.3 Target Tracking in WSN

Among all applications of WSN, one of the most prominent application is target tracking. Target tracking can be used in many fields such as campus monitoring, small animal and birds habitat monitoring, illegal border crossing, and battlefield surveillance.

Target tracking can be either implemented with the of a single SN or by the cooperation of multiple SNs. The formerly mentioned method results in rapid energy wastage, excessive computation cost, and low accuracy. However, the latter method gives us better accuracy, more energy efficient, and less computation.

Due to the absence of standardization, many classifications of target tracking has been proposed. Figure 1.3 shows the possible classification of target tracking WSNs.

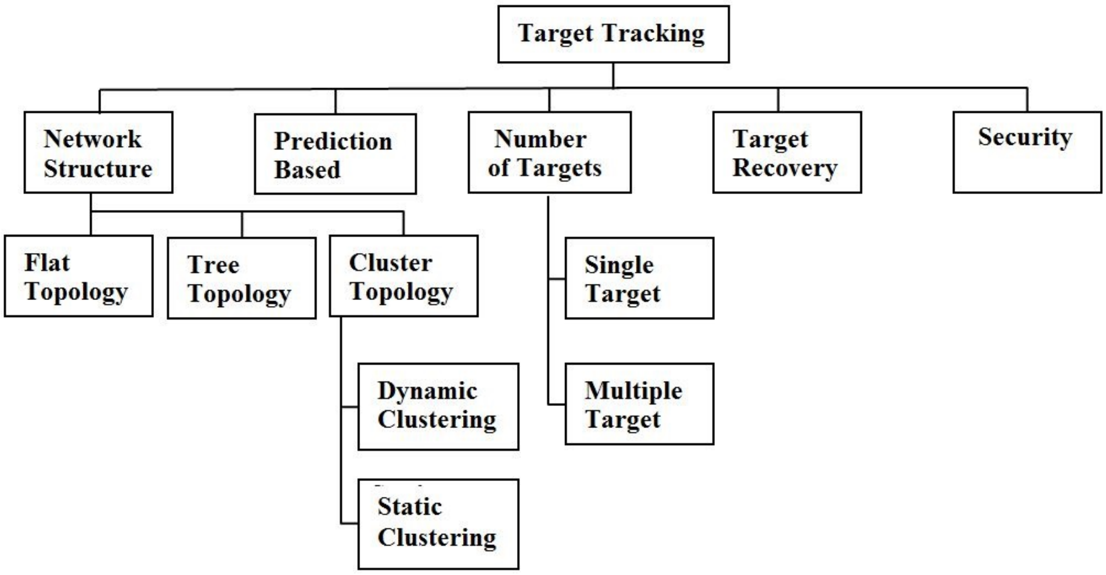

Figure 1.3: Classification of Target Tracking in WSN

1.3.1 Classification of Target Tracking Technique

Target tracking has been studied and explored from different angles by researchers. Target tracking has been divided into multiples aspects like efficient energy consumption of the SN, network topology, precision, number of targets and so on.

1. Network Structure:

   In [30], the author has distributed the network structure into three categories: Tree based structure, cluster, and leader based network structure. They have coupled each category with prediction based strategies to make protocol more energy efficient and minimize chances of target lost. In [31], the author divides the network structure into two types: hierarchical and peer to peer. The hierarchical network further divided into four structures: activation based, cluster based, tree based and hybrid. The peer to peer based network composed of embedded filters: distributed Kalman filtering (DKF) and Distributed scalable Sigma-Point Kalman filter (DSPKF).

We differentiate network structures into three types: Flat structure, Tree based, and Cluster based network structure.

- *Flat Structure*

  It is a type of no topology or the lack of topology. In a flat network, each SN contributes an equal role in network development and establishment. In this topology, SNs broadcast data until it reached the destination SN. This architecture doesn't consider efficient energy consumption of SNs.

- *Tree Structure*

  In tree based network structure, deployed SNs construct a logical tree based architecture. Data travel from leaf SN to root SN. This way energy is preserved because it reserves SNs from packet flooding and broadcasting.

- *Cluster Structure*

  Clusters are shaped when the network is deployed and their responsibilities are defined such as the number of SNs, coverage area etc. Cluster based topology provides us with scalability and efficient use of bandwidth than other topologies. If CH is selected through local network processing fewer packets are transmitted to a BS which results in efficient energy consumption, efficient bandwidth usage, and security. Clustering can be static or dynamic.

  – *Static Cluster*

    Static clusters are created at network establishment time and it remains fixed during the whole lifetime of the network. Apart from its simplicity, it has several drawbacks such as the life of the whole cluster is dependent upon CH, no possibility of data sharing or collaboration among clusters.

  – *Dynamic Cluster*

    The clusters are established dynamically as target travels. It is better than static clustering because of flexibility. New clusters are formed as the necessity arose. As target entered, the cluster is created while the other SNs remain asleep. Only one cluster is activated at a time which results in energy perseverance but the flaw of dynamic clustering is data redundancy and interfering issues.

2. Prediction Based Tracking:

In prediction based tracking methods, prediction techniques are used to predict the future target position. SNs near to the next location are turned on while others remain asleep which result in saving the energy of SNs and prolonging the network overall lifetime. Different techniques and models are suggested to predict the next expected position of the mobile target.

3. Number of Targets:

   Target tracking on the basis of the target can be divided into two types: single target tracking and multiple target tracking.

   - *Single Target*

     Tracking a single target consumes less power and energy efficient. It generates a low traffic load during the target tracking.

   - *Multiple Targets*

     Tracking multiple targets is a very challenging task. It becomes more challenging because of difference in speed, directions of targets. Due to the presence of multiple targets, SNs receive multiple target information. The main hurdle is to differentiate which information belongs to which target. This improbability in information results in the data association problem.

4. Target Recovery:

   Prediction based algorithm in WSN sometime suffers the loss of target due to the sudden change of speed, node failure, computational loss, location estimation error, prediction error and presence of coverage holes in the network. This raises the need for a robust recovery mechanism to recapture the lost target. Recovery mechanism should be fast, resilient and energy efficient. A lot of research has been done in this area to cater to this issue.

5. Security:

   Security is one of the important issues to be considered in target tracking due to some mission-critical applications. In mission-critical applications, these SNs are deployed in unfriendly, hostile areas and these SNs can be easily compromised or captured by intruder/enemies. These compromised SNs can cause falsified, bogus data forwarding; such as exact target location, and make reliability of target tracking doubtful.

1.4 Challenges & Research Problems

Many challenges are faced during the target tracking. Challenges mentioned in the figure 1.4 must be tackled carefully to enhance the efficiency of target tracking in WSN.

Figure 1.4: Challenges in Target Tracking

1.4.1 Data Management

In cluster based tracking, SNs forward their data packets to their associated CH. After receiving these packets from SNs, CH accumulates the data and removes the repetition in an accurate manner. During this process of accumulation, data latency and energy consumption are tried to keep minimum as much as can.

1.4.2 Recovery of Target

Errors in prediction, hurdles in the network, change of path or speed causes the loss of target. A robust tracking algorithm is much needed to tackle this problem.

1.4.3 Node Failure

In WSN, SNs are liable to failure due to battery depletion, the occurrence of catastrophe, hardware failure and due to external attack. This arises the need of protocols which can cope up with these challenges. This issue can be solved by periodic information sharing among SNs.

1.4.4 Network Coverage

Target tracking and coverage of network area are directly related and work for hand in hand. The overall performance of the tracking algorithm depends on the coverage of the network. If the network contains holes or SNs are scantly distributes, the performance of the network is degraded. For better accuracy from target tracking, the network must not have any holes or sparse.

1.4.5 Life Time

SNs run on batteries which are non-rechargeable and sometime in the non-changeable environment. Due to which energy efficiency is a very serious issue in WSN specifically in sensitive target tracking applications. There are states of SN which cause more energy consumption like idle, listening, overhearing, and packet collision. Energy efficient algorithms are essential and to cope this issue energy harvesting can be incorporated.

1.4.6 Throughput

In target tracking, the throughput decrease due to packet collision, loss of connectivity. Some application requires high throughput; e.g. border or battlefield monitoring. This can be achieved by traffic priorities and efficient scheduling algorithms.

1.4.7 Precision and Prediction

This term in the context of target tracking usually talk about that information received at sink or BS is accurate and trustworthy. Implementation of error resilient and vigorous mechanism like adaptive scheduling algorithms, prediction and optimization based schemes can improve target localization error.

1.4.8 Security

It is one of the most important features in target tracking. information should be authentic and main its integrity during its whole life cycle. In mission-critical scenarios, SN can be compromised or fake data can be forwarded through them. To improve this issue, public and private keys are used for encryption. The public key is shared with everyone while a unique private key for encryption/decryption is kept secret.

1.4.9 Data Flow

The data flow need vary from scenario to scenarios like emergency and normal day data traffic. Such mechanisms should be implemented in which there is no interruption in the emergency scenarios.

1.5 Contribution

Accuracy and lifetime are some critical of the research problems in the target tracking that must be addressed to improve the efficiency of target tracking as mentioned in section 1.4. Moreover, multiple problems like delay, overhead can be overcome by sufficient resource utilization.

In this thesis, following contributions have been made:

- An adaptive dynamic clustering scheme is proposed to tackles the target tracking more precisely. By incorporating hybrid RSS proportions and simple geometry, a novel scheme is presented to minimize the tracking error.

- The basic idea behind this research is to reduce target tracking error and improve the target tracking under any scenario (Normal or Emergency). Further explanation of this topic will be presented in Chapter 3.

- Future trends and research challenges are also identified that can help to improve the target tracking in future. Explanation of these challenges along with conclusion is presented in Chapter 4.

Chapter 2

Literature Review

The aim of this Chapter is to provide a comprehensive report of previous work and a lot of research is conducted on making target tracking efficient. A detailed survey of all the existing protocols is presented in this Chapter. In Section 2.1, target tracking schemes are resuscitated with the potential to resolve problem. Finally, a brief summary of this Chapter is presented in Section 2.2.

2.1 Target Tracking Schemes

In [32], author proposed a static clustering based trilateration technique to track the target in WSN. Tracking is done by distance using RSSI. Distance of target is compute by the difference of time in send and receiving the radio signal and how much time it consumes. All SN calculate distance independently and forward it to the CH. CH aggregate all the received information and forward it to the BS.

In [33], probability-based technique; Sensor Protocol for Information via Negotiation (SPIN), is proposed to avoid duplicate packet flooding and instituting routing path to some extent. It consists of three types of messages (i) Advertisement (ADV), (ii) Request (REQ), (iii)Data (DA). As soon as, SNs receive some new data, SN sends ADV message to a neighbor. Interested SN sends REQ message to the sender. As a result, DATA message is sent only to the interested SN. SPIN is a resource-aware and adaptive protocol. SN assess their energy, cost of data transmission, receiving, and computation. By calculating such parameters SNs can make the decision more effectively. SPIN also improve network lifetime by reducing the flooding and redundant data. The flaw of

SPIN is that it does not guarantee data delivery.

Author of [34], propose a rumor based routing protocol called Rumor as an Energy-Balancing Multipath Routing (REBMR). REBMR is a static SN based network protocol, which follows client-server architecture. In REBMR, BS acts as a server while SN acts a client. BS execute major tasks like path selection, network maintenance, sending control packets. While SN is responsible for sensing data, forwarding data to other SN or to the BS. REBMR performed well for small WSN. However, in case of large area WSN the maintenance of agents (SNs) and table in each SN is become very complex. Overhead of REBMR is related to multiple factors like time to live, a number of agents and queries. Leader SN becomes aware of target or event from event agents. Leaders SN after applying the heuristics technique decide the route for next hop selection. The main advantage of REBMR is no topology maintenance, energy efficient, and good quality of routes, on the other hand, disadvantages of REBMR is unreliability, high delay, unawareness of new neighbor arrival and died neighbor.

In [35], authors proposed an object tracking algorithm based on Fuzzy Sensing Model in correspondence with RSSI (Radio Signal Strength Indicator) to track the target. The author proposed a tree structure based tracking called "dynamic convoy tree-base collaboration". Tree configuration, expansion, and shrinking are implemented using fuzzy sensing model. The use of this model reduces the overall number of network reconfiguration, data packets exchanged between BS and SNs. When a target enters in the under observed area, SN senses the target. After sense and tracking the target, SN finds its own location via GPS and sends the calculated target location to the BS. Convoy tree is established and this tree follows the target as it travels in the monitoring area. All nodes near the target connect themselves to the tree. Thus giving us 100% coverage while far nodes will remain in sleep mode, results in saving energy. Proposed algorithm works better in term of energy efficiency and mobile target tracking.

The authors of [36], a novel routing scheme based on Neighborhood Heuristics (NHs) model for tree-structured is proposed, for stable routes to maintain the high values. The NHs is implemented underneath the Routing Protocol for Low power and Lossy network. This scheme coupled SNs routing metric with its neighbors (like energy, distance) to spotlight available routes. This additional information regarding neighbors assists in the selection of the route and maintains the overall routing quality. NH unify the route failover capability and route quality into a single metric. By combining these two parameters, the authors shift the paradigm from route choice on the best path to better failover option. The proposed routing scheme is energy efficient and performs better even in a lossy network environment.

Dynamic Look ahead Spanning Tree Algorithm (DLSTA) is suggested in [37] to minimize the chances of target lost by pre-constructing look ahead cluster along with the target predicted trajectory before it arrives. In DLSTA when the SN detects the target, it dispersed the information with its neighbor SNs. The closest SN to the target is selected as a root SN. Root SN constructs the cluster tree with its neighbor distant from one or more hop distance from itself. Root calculates the location, next predicted position, and speed of the target. After the calculation is completed the process look ahead spanning tree is initiated. The look ahead spanning tree depends upon the velocity of the target. Multiples trees are constructed to minimize the target loss. The number of trees changes dynamically relatively to the target speed as shown in figure 2.1.

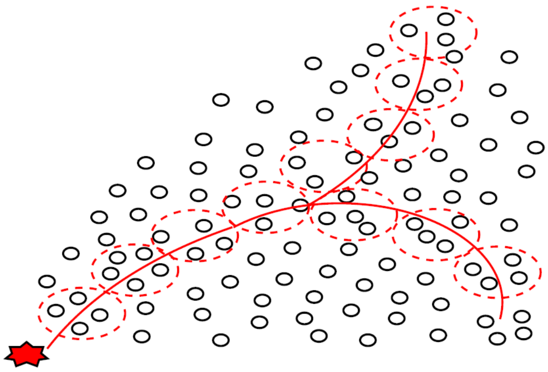

Figure 2.1: Working of DLSTA

To ensure the accurate prediction multiple filters such as Extended Kalman filter (EKF) and Particle Filters (PF) are used in DLSTA. This accurate prior knowledge assists in preserving the energy of SN and improves the overall network lifetime.

A novel Dual Head Static Clustering Algorithm (DHSCA) is proposed in [38] to improve the overall network lifetime and energy consumption. The proposed algorithms work in three phases called, initialization phase, set up phase, and data transfer phase as shown in the figure 2.2.

The initialization phase is initiated only once; at the beginning of the network, dividing the whole network into static clusters on the basis of the geophysical location of SNs.

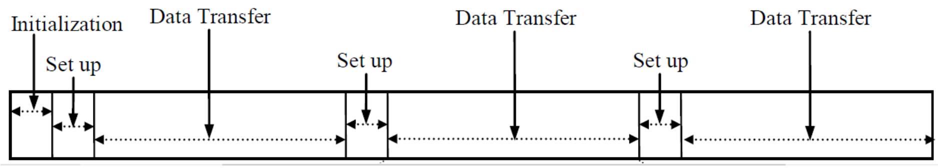

Figure 2.2: Three phases of DHSCA

Thus, eliminate the cluster formation overhead like in dynamic clustering. In set up phase two nodes are selected as CH; one for data aggregation called Aggregating Cluster Head (ACH) and other for data transmission called Transmitting Cluster Head (TCH), on the basis of residual energy and distance from other SNs.

The third phase is divided into two parts -intracluster and intercluster communication. The collected information first sends to the ACH by all SNs. ACH remove the redundancy and discard the useless information and forward it to the TCH. In the second part, TCH sends the data the BS.

In [39], a new target tracking algorithm; Boundary Static Clustering Target Tracking (BCTT), is proposed. BCTT uses static clusters to address the scalability of WSN, the boundary tracking issues by allowing boundary sensor to become the member of cluster. BCTT also allows the boundary area SNs to collaborate and share information, by allowing this the overall tracking efficiency is increased. The proposed scheme is efficient than dynamic and hybrid in terms of overhead of cluster formation and destruction. The drawback of the BCTT is that it is less fault tolerant and if border CH died no recovery mechanism is in place.

A Static Cluster and Dynamic Cluster Head (SCDCH) algorithm is proposed in [40]. Author coupled SCDCH with Newton-Gaussian algorithm to predict the target trajectory and error estimation. When SNs find the target in its locality, one of them became a CH on the basis of highest energy level. Dynamic Source Routing (DSR) is used to collect the data from active SN and forward it to the CH. This protocol gives the high accuracy and reduces energy consumption, thus prolong the network lifetime overall.

In [41], the author proposed two algorithms; (i) Distributed Cluster-based Algorithm for Target Tracking (DCTT) and Prediction-based Clustering algorithm for Target Tracking (PCTT), for vehicular tracking in a Vehicular Ad-hoc Network (VANET). DCTT is a dynamic clustering algorithm in which CH is responsible for target location information, aggregation of data received and forwarding it to sink node called Command and Control

Center (CC). A Target Failure Probability (TFP) is maintained and shared by SNs among each other. TFP is a metric designed for selection of CH. If CH is lost, the best node with the minimum TFP is selected as a CH.
PCTT is centralized VANET based clustering algorithm. In PCTT, CH is responsible for management of cluster and target tracking. Permission to join cluster, calculation and selection criteria for CH, maintenance decisions all are executed by CH.

In [42], a Dynamic Clustering based Distributed filtering(ACDF) scheme is proposed for target tracking in a WSN. ACDF is a two stage hierarchal technique which is energy efficient and robust in target tracking. At the first stage, SN calculates their estimated distance from the mobile target and shares it with all cluster members and CH. Apart from receiving the SN estimated distance calculation, CH also calculates its distance from the target and aggregate it with the receive data from SNs. CH will be selected on the basis of residual energy. The proposed scheme gives us better and accurate target tracking in an energy efficient way.

In [43], a scheme is proposed to track and predict the next location of the target. The proposed scheme is consists of three steps; (i) clustering, (ii) tracking, and(iii) prediction. In the first step, the network is divided into static clusters and CH will be selected. CH will be selected whether on the basis of residual energy or distance from the BS. Author opted trilateration mechanism is used to track the target and unify this tracking mechanism with Linear Prediction (LP) model to predict the next location of the target. Only SN, closest to the next location will be active while the rest will remain asleep. This mechanism maintains high accuracy, improve network lifetime.

In [44], an energy efficient tracking scheme is proposed by unifying two algorithms; Auto Regressive Integrated Moving Average (ARIMA) and Unscented Kalman Filter (UKF). The proposed scheme gives better position estimation because of dual predictive algorithms. ARIMA is a time series based statistical method in which after observing the target in equal intervals, predicts its future location based on its past with the least possible error. UKF gives the estimated target position. The proposed scheme preserve overall energy of SNs results in improve the network lifetime.

In [45], an accurate and energy efficient target tracking scheme based on prediction is proposed. Least Square Algorithm (LSA) is used to track the mobile target location in collaboration with neighbor SNs and Random way and Constant Acceleration Model

(RCAM) is used to calculate target mobility parameters like speed, direction, and acceleration. Proposed scheme preserves the overall energy by only activating the target close SN, thus result in prolonging the overall network lifetime.

In [46], the author proposed Dual Prediction based Routing (DPR) algorithm. DPR is an energy efficient prediction based clustering algorithm. Target next location is predicted two times, (i) at nodes level (ii) at BS. If the difference between them in under the threshold, the BS is not updated which results in lessen the packet transmission, reduce overall overhead. Target is tracked by SNs through trilateration algorithm then forward the information to their respective CH called “leader“, which aggregate the data and forward the information to BS. DPR perform better in energy consumption, network lifetime.

2.2 Summary

In this Chapter, an effective summary of previous researches carried out for efficient target tracking has been presented. Moreover, the advantages and disadvantages of the protocols in the literature have also been discussed. Following problems have been observed during literature analysis:

- Throughput of WSN
- Effective utilization of resources
- Delays during transmissions
- Efficient Target Tracking
- Energy efficiency

Chapter 3

Proposed Methodology

In WSN, SN has a very limited capacity to process the data due to its restricted battery power. Therefore, target tracking is a challenging job in WSN. From the chapter 2, it is observed that most of the techniques either they deplete the SN energy rapidly or have very low accuracy, there is a need for robust tracking scheme which tracks the target location more efficiently and accurately.

Therefore, a new algorithm has been designed in this chapter for efficient target tracking. This algorithm minimize the energy consumption and improve the accuracy of target tracking.

For evaluation, the proposed algorithm is presented in two different scenarios:

1. Normal Scenario
2. Emergency Scenario

Results show that the proposed algorithm has outperformed in terms of throughput and superframe efficiency in a steady condition.

Rest of Chapter is organized as follows: In Section 3.1, system frame work is explained. Section 3.2 presents the working of the proposed algorithm in a normal scenario(target tracked in regular intervals). In Section 3.3,proposed algorithm simulation is carried out in an emergency scenario. The Section 3.4 gives the conclusion of work.

3.1 System Framework

We here outline some assumption for WSN, for the purpose of simplicity. The assumption are:

1. Every SN knows its own location.
2. Every SN also knows the location of its neighbor.
3. All SN are equipped with the Omni directional antenna.

In assumption (1), we assume that SNs are static and there is no link failure during the computation period. All SN sends their measurements to the CH. CH receive the data from different SN, process it and then forward the information to the BS.

We assume a 100 m ×100 m area under-observation and SN are uniformly distributed throughout in the field. The sink or BS is located at five different points. The area under observation is shown in figure 3.1.

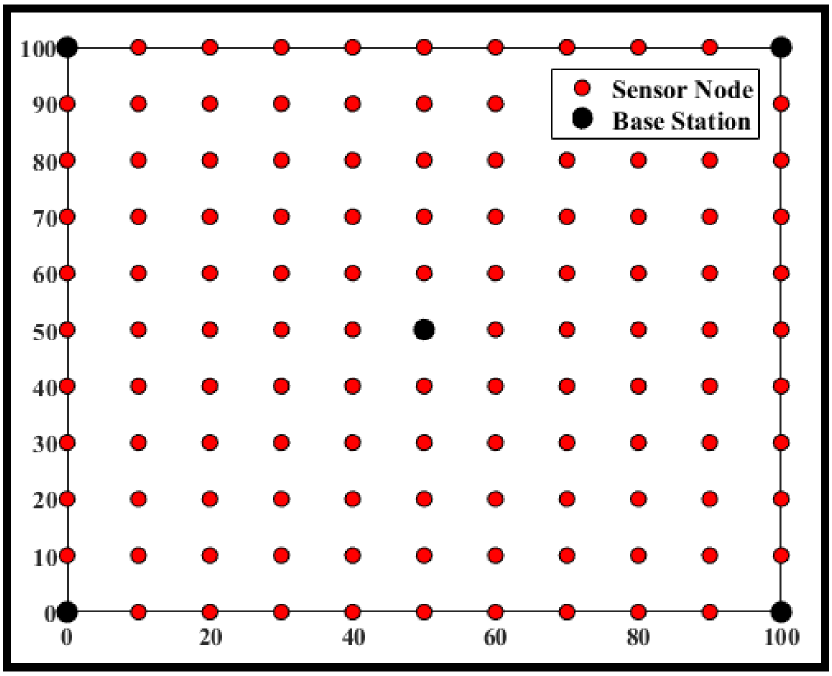

Figure 3.1: Network Topology

To evaluate of the proposed algorithm, we run the simulations in Matlab R2016a with the following parameters as shown in table 3.1.

Table 3.1: Simulation Parameters

Parameteres	**Values**
Sensor Nodes	116
Base Stations	5
Channel	Wireless
MAC Protocol	IEEE 802.11.4
Routing Protocol	AODV
Antenna	Omni

3.2 Normal Scenario: Target Tracking after Regular Interval

In this section, we assume that target is entered in the surveillance area under the normal scenario. We track the target location after regular interval and inform the BS .

Target track is randomly generated using Normal Distribution. The normal distribution is represented as:

$$\boldsymbol{X \sim N(\mu, \sigma^2)} \tag{3.2.1}$$

In equation 3.2.1, X is a random variable distributed normally with mean μ and variance σ^2, used to get random points on $x - axis$ and $y - axis$.

Probability Density function (PDF) of normal distribution can be written in the form of equation as:

$$\boldsymbol{\varphi(x)} = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}x^2} \tag{3.2.2}$$

$$f(x|\mu, \sigma^2) = \frac{1}{\sigma} \varphi(\frac{x-\mu}{\sigma}) \tag{3.2.3}$$

In this scenario, when SN detects the target in its range, it informs its neighbor SNs. Only those SNs which are close to the target awake while others remain asleep thus results in preserving overall network energy and prolonging WSN life.

Target can be located at any given time by using equation 3.2.4

$$d_i = \sqrt{(x_i - x_t)^2 + (y_i - y_t)^2} \qquad where (i = 1, 2, 3...) \tag{3.2.4}$$

Algorithm 1 Target Tracking under Normal Scenario Algorithm

Input: Number of SNs and BS

Output: Target localization after Regular Interval

Initialize : Position of SNs $SN_P i = (x_s i,\ y_s i)$

Position of BS $BS_{Pi} = (x_b i,\ y_b i)$

$SN\_status = [0,1] \quad \because \begin{Bmatrix} 0 \text{ for Sleep} \\ 1 \text{ for Awake} \end{Bmatrix}$

while (Target in under surveillance) **do**
  if (Time_{int}== End) **then**
    $\text{Target}_{pos} = (\text{tx}_{pos},\text{ty}_{pos})$
    for each $\text{SN}_i = 0$ to N **do**
      if (Target_{pos} close to SN) **then**
        SN_i_status=1;
      else
        SN_i_status=0;
      end if
      for each SN_i_status== 1 **do**
        SNs form a cluster and CH is selected
        Each $\text{SN}_{cluster}$ calculate d_{x_i,y_i}
        $\text{SN}_{cluster} \rightarrow \text{CH}$
        CH process information and calculate Target_{pos}
        $\text{Target}_{pos} \rightarrow \text{BS}_i$ $\quad\because$ nearest $\text{BS}_{position}$ to the CH
        SN_i_status=0;
      end for
    end for
  end if
  Time_{int} = Start
end while
return $\text{Target}_{pos} = (\text{tx}_{pos},\text{ty}_{pos}) = 0$

Awake SNs form a cluster and among the SN which is closest to the BS is selected as a CH as shown in figure 3.2. All active SNs calculate target location and send their calculated target location information to the CH. After receiving all the calculated results from the SN, CH process and aggregate all the receive information. After processing the information, CH predicts the target location and sends that information to the BS.

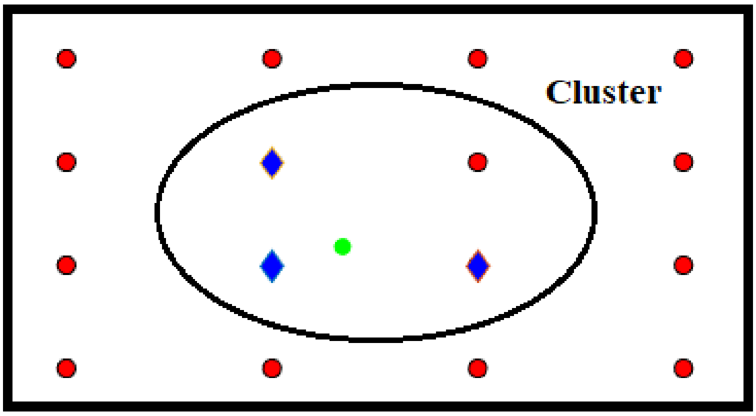

Figure 3.2: Creation of cluster

The figure 3.3 shows the target location after regular intervals of time.

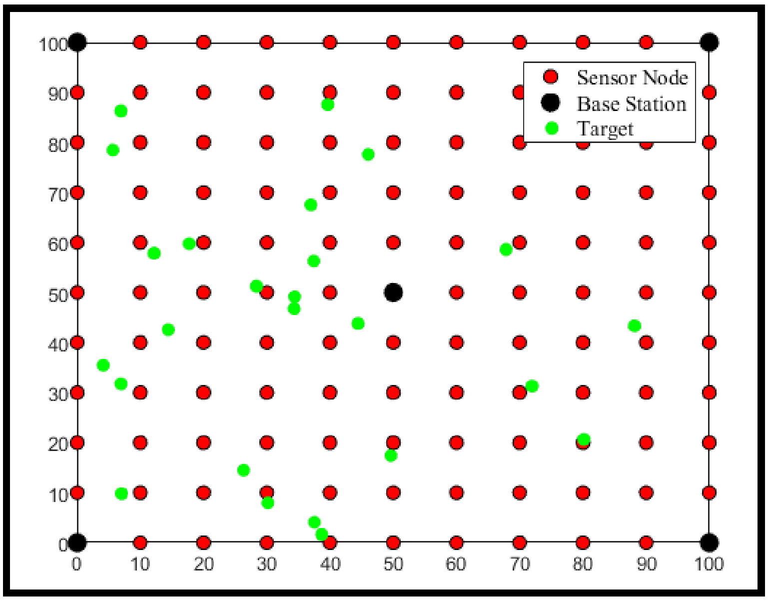

Figure 3.3: Target Tracking under Normal Scenario

We simulate the Normal scenario 25 times after regular intervals of time for both base[32] as well as for the proposed target tracking technique and display their tracking results individually.

In figure 3.4, displays the target tracking with the base[32] technique (trilateration technique).

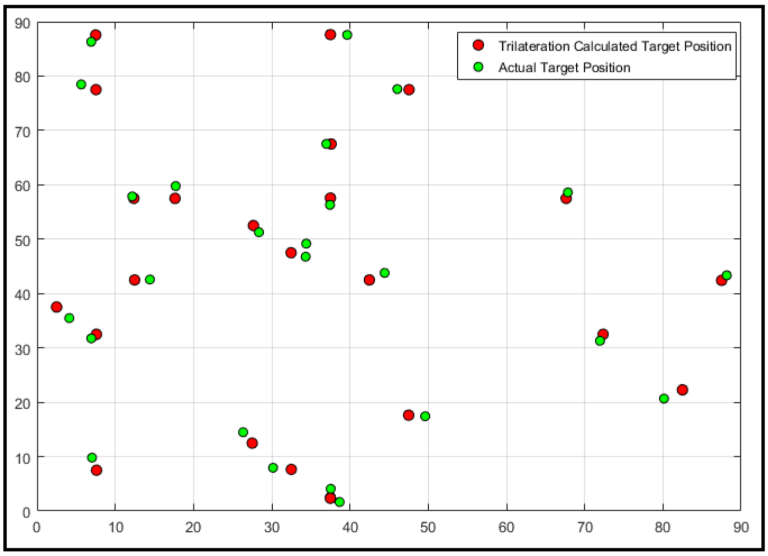

Figure 3.4: Target Tracking under Normal Scenario with Base Scheme

The figure 3.5, displayed the target tracking with the proposed scheme.

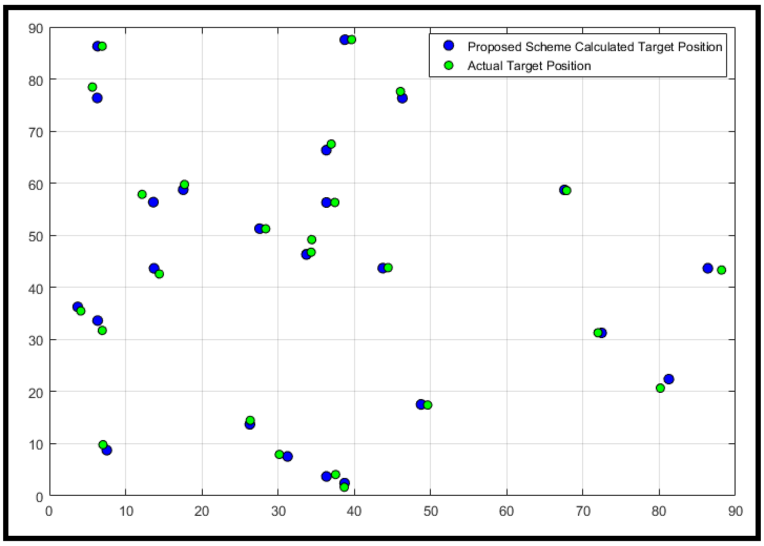

Figure 3.5: Target Tracking under Normal Scenario with Proposed Scheme

We compare the both (base and proposed) schemes using equation 3.2.5 to calculate the error.

$$error^t = \sqrt{({X^t}_{pre} - {X^t}_{real})^2 - ({Y^t}_{pre} - {Y^t}_{real})^2} \tag{3.2.5}$$

Figure 3.6 clearly show that the proposed scheme works better than the base [32] scheme in terms of predicting the target location.

Proposed scheme is 17% better than the base [32] scheme in term of predicting the

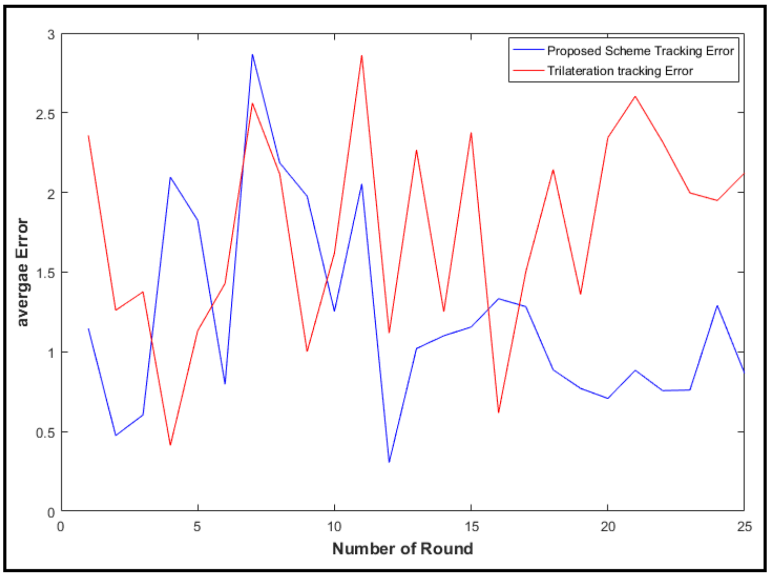

Figure 3.6: Comparison of Base and Proposed Schemes Tracking Error

target location. A complete analysis is given in the table 3.2.

Table 3.2: Simulation Results

Topology	Lifetime	Interval sec	Average Error	RMSE
Base	100	4	1.7641	1.328
Proposed	100	4	1.2162	1.102

3.3 Emergency Scenario: Complete Path Tracking

In this section, we assumed that the target have been entered in the surveillance area and get involve in some illegal or rogue activity. So an emergency scenario is activated among SN and target full path is observed.

We have simulated this scenario under the same parameters as mentioned in 3.1.

In emergency case, random target track is generated by Random Walk (RW) model. RW model is a stochastic process based model, which describe the random path; consisting of sequence numbers, in a given mathematical space from point A to point B.

Algorithm 2 Target Tracking under Emergency Scenario Algorithm

Input: Number of SNs and BS

Output: Target localization for complete path

Initialize : Position of SNs $SN_{P}i$=($x_{s}i$, $y_{s}i$)

Position of BS BS_{Pi}=($x_{b}i$, $y_{b}i$)

$SN\_status = [0,1] \quad \because \left\{ \begin{matrix} \text{0 for Sleep} \\ \text{1 for Awake} \end{matrix} \right\}$

while (Target in under surveillance) **do**
  Target$_{pos}$ = (tx$_{pos}$,ty$_{pos}$)
  for each SN$_{i}$ = 0 to N **do**
    SN$_{i}$_status=1;
    if (Target$_{pos}$ close to SN) **then**
      SNs form a cluster and CH is selected
      Each SN$_{cluster}$ calculate d$_{(x_i,y_i)}$
      Each SN$_{cluster}$ calculate d$_{traj}$
      SN$_{cluster}$ $\rightarrow$ CH
      CH process information and calculate Target$_{pos}$
      Target$_{pos}$ $\rightarrow$ BS$_{i}$ $\because$ nearest BS$_{position}$ to the CH
    end if
  end for
end while
SN$_{i}$_status=0;
return Target$_{pos}$ = (tx$_{pos}$,ty$_{pos}$) =0

In emergency case scenario, all asleep SNs have been awaken, their status (SN$_{i}$_status) changes from 0 to 1. This scenario will remain initiated till the target is in the area.

SNs which are close to the Target$_{pos}$ will create a cluster, while all non-cluster SNs remain active. Among all SNs$_{cluster}$ a CH will be selected on basis of closeness to the BS$_{i}$.

Each SN$_{cluster}$ calculates the target location (d$_{(x_i,y_i)}$), target trajectory (d$_{traj}$). SNs forward the calculated results to the CH.

CH process and aggregate all the received information and forward it to the closest BS$_{i}$.

We simulated the to the given scenario for base [32] as well as proposed scheme for target track shown in figure 3.7.

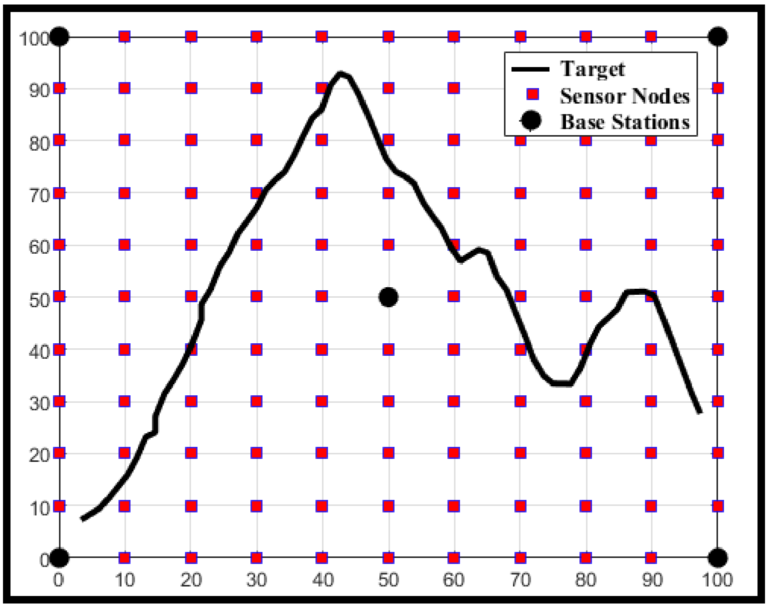

Figure 3.7: Target track under Emergency Scenario

SN tracks the target and forward it to the CH. CH predicts the target location and forward the information to the BS. Routing packets have to travel within the clusters thus reducing the routing overhead and prolonging the overall network lifetime.

Tracking error notable reduced by using dynamic clustering-based technique as shown in the figure 3.8.

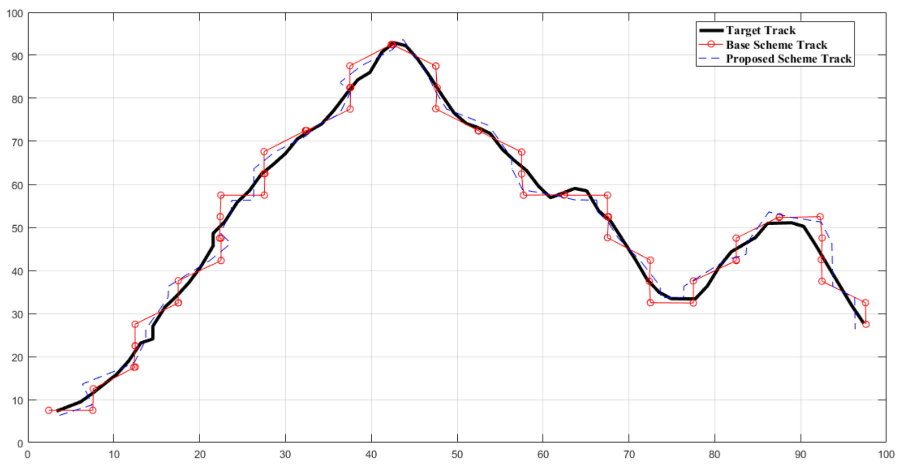

Figure 3.8: Target tracking under Emergency Scenario with base and proposed scheme

Simulation study shows that proposed methodology gives better results compared to the base [32]. The tracking error between base and proposed scheme is shown in the figure 3.9. Furthermore, it shows that proposed scheme outperform the base [32] scheme 8.60% in term of target tracking.

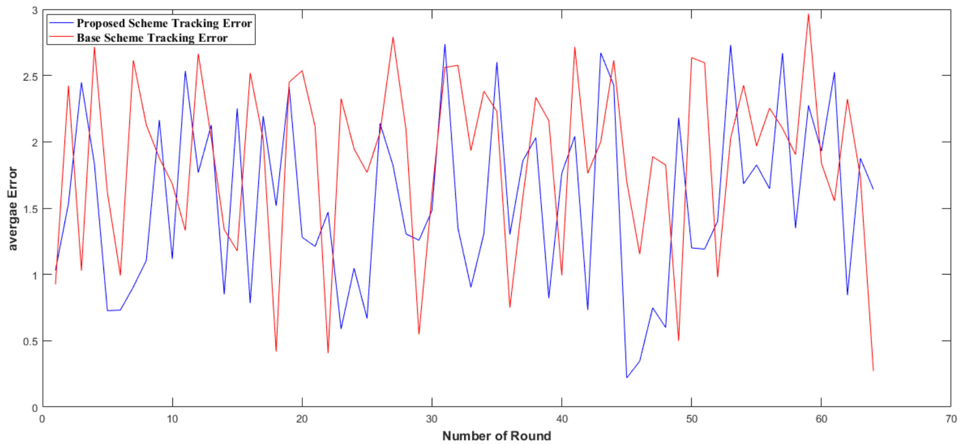

Figure 3.9: Comparison of Base and Proposed Schemes Tracking Error

3.4 Conclusion

A dynamic clustering-based scheme has been presented in this chapter for target tracking in WSN with aim to improve accuracy or prediction. The proposed scheme has been simulated along with the base in two different scenarios (Normal & Emergency). The proposed scheme outperform the base technique in both scenario. In Normal scenario, the proposed scheme perform 17% efficiently while in Emergency scenario the proposed scheme perform 8.60 % better than the Base technique.

CHAPTER 4

Conclusion & Open Research Issues

Potential future problems for target tracking in WSN are identified in this Chapter. In Section 4.1, open research issues are presented that can help the research community to make target tracking more efficient.

4.1 Open Research Issues

From analysis, following open research issue in target tracking are identified.

- Energy Harvesting:

  SN are most of the time deployed in difficult area, where recovery or change of SN is difficult. However, in case of emergency these SN are required to report more frequently, thus requiring more energy. From the analysis, it has been observed that sleeping mode is mostly used to extend the lifetime of the SN. This helps in preserving their battery as these SN cannot be recharged easily. The provision of other resources in WSN SN is an alternate way to improve their lifetime and reduce their dependency on the standard battery. There are multiple ambient energy sources available such as solar, vibration, sound, RF, thermoelectric, etc. Therefore, development of a good energy harvester is one of the potential challenge and its realization can do wonders for future Target tracking in WSN. In addition, RF energy harvesting based energy cooperation can also be availed.

Furthermore, energy aggregation combined with data aggregation can reduce transmission time, contention among nodes thus increasing throughput and decreasing delay.

- Optimization Techniques:

  To improve the target tracking, we can unify the different target techniques with optimization methods. We can embed the target tracking schemes with Ant-Farm, Particle Swarm Optimization (PSO), Firefly Optimization techniques.

- Security:

  Sometime these SN are deployed in critical areas like border, battlefield area. In mission critical or emergency scenarios, SN can easily be jeopardize. Target can use the jeopardized SN for transmission of fake SN or bogus data. This could affect the overall tracking performance.

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