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Energy Efficient Target Tracking in WSN: An Adaptive Approach

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A B S T R A C T

Target tracking in WSN is important task to communicate and provide the reliable service in the network. It locates the object area and helps us to track it continuously. Now a days finding the malicious node or target node is difficult in Wireless sensor networks under high node density domain. The goal of the study is to predict the different node failure types thereby finding the target node and tracking in a wireless sensor network (WSN). It is necessary to find fault-tolerant approach to increase the sensor network's resilience and capacity for self-healing. Different forms of WSN failures are typically attracted by the resource-constrained environment, remote deployment, and difficult monitoring settings. There are two approaches to tackle the issue, namely fault tolerance and fault avoidance techniques. In the proposed algorithm, distance-based Clustering for fault detection and creating tracking node based on node power for target tracking is employed. To make this state-of-the-art innovative the proposed work is simulated in NS2 and results are compared with outcome of current algorithms like Low Energy Adaptive, and it is found to be successful in terms of node energy depletion and latency.

Keywords: Wireless sensor Network, Power Based tracking (PBT), Time of Arrival (TOA), Packet Delivery Ratio (PDR), Cluster etc.

1. Introduction

Wireless sensor networks (WSNs) consist of large numbers of sensor nodes at diverse space with central controller acts as sink node. WSN works frequently independent of infrastructure. The network is built by a large number of inexpensive motes working together, and the base station receives the data that each mote collects through the sink node. Each mote's transmission power is frequently low to prevent interference. As a result, the range of connectivity between nodes quite smaller hence needed larger node density for proper function. The information from each mote may need to reach the target through multiple stages of nodes and base station which makes the sensor network complex. To ensure high dependability and low energy consumption in sensor networks, it is crucial to find and maintain a highly efficient multi-hop routing method. The typical sensor network with sink node and user is shown in figure (1).

There are various magnetic, thermal and proximity sensors which can detect and monitor the wide range of abnormal conditions in the area of deployment. Presently, wireless sensor networks have found fast expanding uses in fields including IoT, vehicular adhoc networks (VANETs), object surveillance, automated data gathering, and environmental monitoring. Target tracking typically consists of two phases from noisy sensor data readings, it must first estimate or anticipate target locations. It must then command the mobile sensor tracker to pursue or seize the moving object.

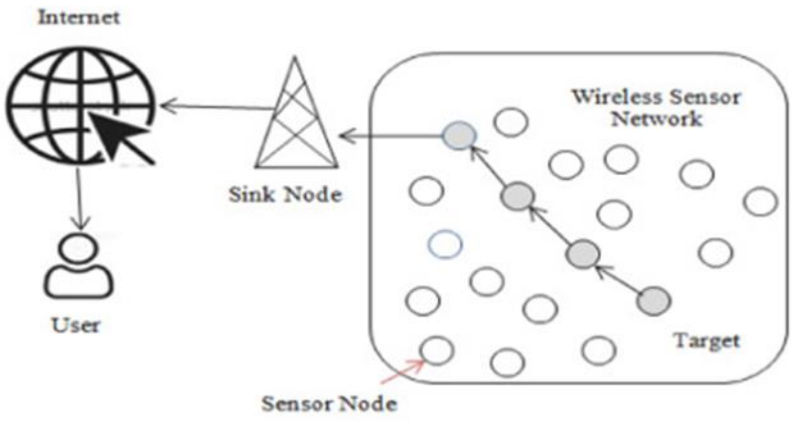

Figure 1: Typical

Wireless sensor network (WSN) technology has been successfully used for a number of distant applications, including environment sensing, tracking of moving objects, information collecting in difficult and hazardous situations, etc. The primary function in WSN involves sensing the environment, gathering crucial data, filtering the data according to the application and disseminate that data to the distant target. The many uses for WSN that include monitoring the weather, tracking habitats, keeping an eye on the climate, keeping an eye on aquatic life, etc. [1]. The WSN is made up of a base station (BS), a set of chosen cluster heads (CHs), and a large number of sensor nodes (SNs). Fig. 1 shows the WSN's architectural layout. The information gathered by nodes was then transmitted through the internet to the utility house. Because of the extreme deployment conditions, it is highly challenging to recharge a battery or replace SN. Because of this, SN's limited energy must be used extremely wisely to extend the network lifetime [2].

We suggest our first approach, called UEC (Uniform Energy Clustering), which is based on the fault-tolerant technique, and our second strategy, named PBT (Power Based Tracking), which is a fault tracking mechanism, in order to avoid energy-related problems of SN in this situation. The PBT focuses on the mapping of tracking node (TN) according to the cluster population, whereas the UEC method is focused on the equal energy distribution among clusters. Clustering and routing are two of the most widely used and well-proven strategies for energy management, according to a thorough literature review [3].

Sensitivity: This phrase refers to the effect of repercussions brought on by the existence of a defect. In today's digitized world, where everything finally accommodates sensors, the employment of sensors is quite widespread. When these sensors malfunction for any reason, it has some effect on the system's general functionality and design. The costs of mistakes can be calculated based on a number of variables, including time, money, and effort. Due to this, Section 3 of our paper proposes a special sensitivity-based taxonomy.

Clustering: The development of clusters is a crucial component of the routing system. Homogeneous or heterogeneous SNs may form the cluster. The reason for clustering is that direct connection with BS is not appropriate when taking into account effective energy management since SNs have limited energy resources. Each cluster is typically run by a dominating CH node, which also manages the cluster members (CMs) and conducts data collecting and aggregation operations [4]. Figure (2) include information on several clustering technologies.

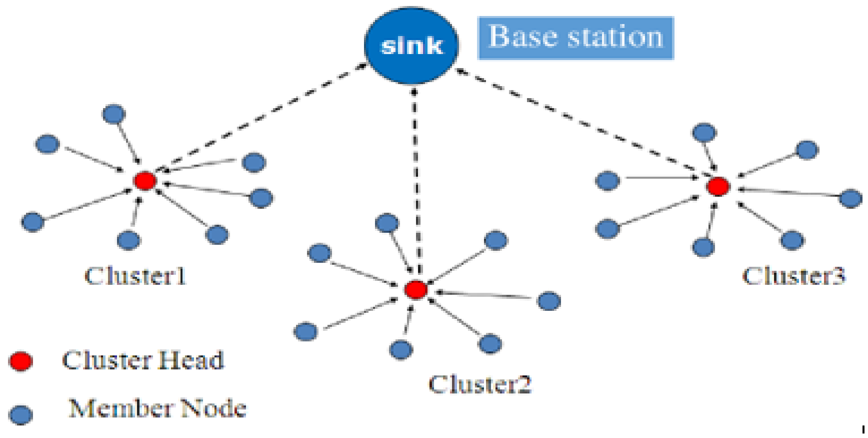

Figure 2: Multiple Clustered sensor Network

Routing is a recommended practice used by WSN clusters to pick the suitable TN and select the optimum path for communication, saving SNs' energy. The various clusters are connected to one another throughout the routing process either by a single hop or several hops. Without a doubt, direct communication is quicker and more effective than multi-hop communication, but if the deployment area is larger, the effectiveness of direct communication is decreased. Consequently, in order to improve the effectiveness of multi-hop communication, the network needs to be relay upon either inter-cluster or intra-cluster environment [5][6].

2. Related works

The different works carried under sensor network target tracking is presented in this section. To attain high accuracy, particle filtering has also been used with the radio Signal Strength (RSS) measurement model while dealing with correlated noise [7]. A geometrically aided predictive position tracking method was presented in [8] for target tracking and is capable of tracking targets even in the absence of enough signal sources. In addition to using stationary sensors, a number of additional studies concentrated on managing sensor mobility and controlling sensor behaviour to improve target tracking and position estimates. In their study of a distributed mobility management system for target tracking in [8] found that the trade-off between target tracking quality improvement, energy consumption, loss of connectivity, and coverage had to be taken into account.

In [9], a continuous nonlinear periodically time-varying method for adaptive target estimation and mobile sensor navigation in a target-encircling trajectory was suggested. Furthermore, Author in work [5] have demonstrated that direct TOA localization outperforms TDOA localization in terms of performance. improved localization algorithms from TOA measurements result in improved navigation control since the mobile sensor navigation control depends on the estimated location findings. The primary flaw in the current method is the measurement of time of arrival (TOA) being delayed. Here, each anchor sensor node logs and transmits its TOA measurement of the target signal and mobile sensor signal to the data fusion sensor. The different target tracking methods are tabulated in Table 1.

Table 1: Target Tracking Methodologies

Sl. No.	**Problem Area**	**Problem Statement**
1.	Designing of MAC	How the connectivity can be sustainable when the whole network works with fixed transmission power? How the node tunes its transmission power as per intra-cluster or inter-cluster communication?
2.	Scheduling	Designing of efficient scheduling algorithm for switching between intra-cluster and inter-cluster communication. How to enable parallel intracluster and inter-cluster communication?
3.	CH Selection	How to avoid frequent CH rotation? How to avoid overburden from CH? How to assign CH according to cluster population? Which factor should consider either time or R as threshold for CH rotation?
4.	Cluster Size	How to decide the best cluster size for efficient management of energy? What size of a cluster will avoid traffic and overhead problem? What will be the best topology for data transmission? During dynamic deployment environment which localisation technique needs to adopt for CMs?
5.	Synchronisation	How to manage synchronisation within clusters? How to avoid energy loss during unsynchronised transmission process?
6.	Duty Cycle	How to manage the sleep and awake phase among clusters in distributed sensor networks? How to stop sensing redundant data by the CM and enable them for sleep state?

2.1 Open Research Issues

Some essential characteristics that influence the motivation for WSN research are provided by the enabling applications. Existing implementations have requirements and features that are unique to that application, such as environmental monitoring, health monitoring, industrial monitoring, and military tracking. With the advances in technology and these tailored to the application qualities and needs, several hardware platforms and software development are possible. There have been many different hardware platforms and technologies created over time, but more experimental effort is required to make these applications more dependable and resilient in the real world. The way individuals interact with technology and the world might be improved and altered by WSNs. Real business and industry demands must be identified in order to determine the path of future WSNs. To bridge the gap between the creation of business solutions and currently available technology, research and development must interact. using a sensor technology to industrial applications will improve business processes as well as open up more problems for researchers.

2.2 Background and Motivation

Over the years, several systems for determining sensor node position have been developed, including: the GPS, infrared, ultrasonic, and radio frequency (RF). The necessity that a monitored object contains a tracking device is a feature shared by all of these systems. Additionally, a lot of these methods call for the monitored device to actively take part in the localization procedure by executing a portion of the localization algorithm. As a result, the system can give the user location information and other services linked to the position estimation [10][11]. The global positioning system (GPS), although dominating the field of navigation and tracking technology, has certain drawbacks. For example, interior surroundings have no or very little functionality, and users must carry an end device. These days, device-free localization (DFL) and the tracking of individuals in enclosed spaces have the potential to be used for a wide range of purposes, such as the monitoring of shoppers in malls to Analyse how they respond to the placement of adverts and products, the detection of intrusions into important structures or infrastructure, and localisation. WSNs, or wireless sensor networks, are an appropriate technology for carrying out these functions [12].

3. Proposed Work Description

3.1 Fault Tolerance

In the multiple sensor nodes, the unusual characteristics of nodes or when actual service deviates from anticipated service, there is a systemic defect that may be verified. Hardware malfunction and software flaws are the two main reasons why faults happen. Communication faults, link faults, node faults, energy depletion-based faults, physical damage-based faults, intruder attack-based faults, and other fault types are all potential in WSN. There are two approaches to address the WSN flaw. The first is a fault tolerance mechanism in which the required healing procedure must be adopted following the onset of the defect. The second is fault prevention methods, which stop environments where faults arise.

3.2Target Tracking

By tracing a target's roaming path, the target tracking WSN program seeks to find the target and ascertain its whereabouts. By continuously monitoring the environment, WSN offers us the opportunity to increase energy efficiency. Figure 3 illustrates the target tracking trajectory.

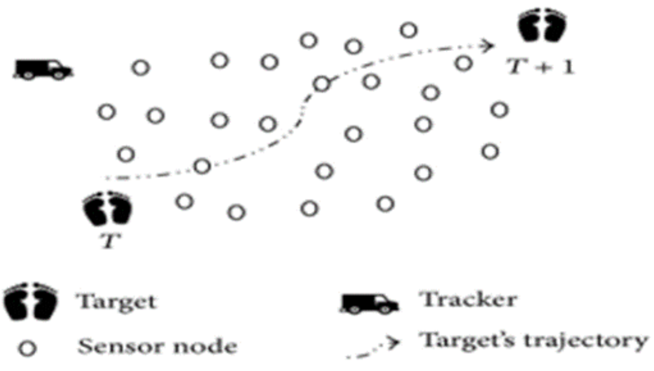

Figure 3: Target Tracking Trajectory

The network consists of numerous moving nodes whose path will be followed by the moving node (vehicle in figure). The network consists of three subsystems namely sensing, moving node prediction and communication facility. The sensing subsystem, which is made up of the initial node that recognizes the target and later joining nodes, senses the target. A prediction-based algorithm in the second subsystem follows the targeted target's path. The third subsystem, communication, is responsible for sending information from one node to another. These three subsystems work together and maintain their connections.

3.3 Target Tracking Approaches

In this part, we have concentrated on demonstrating various techniques that may be used to monitor the specified target. The multiple clusters are formed based on the associated distance between them. The time between two succeeding tracking events, or the uniform sampling interval, is used in the bulk of recent studies on WSN target tracking. The target is tracked using the three nearby nodes in [13]. Entropy-based sensor selection is another way [14] for selecting the next sensor. Each time step, it selects one tasking sensor, and it selects the sensor whose measurement causes the target local distribution to shrink the most. In this part, the researchers' current approaches to the target tracking problem in WSN are explained

3.4 Centralized Approach

In a centralized system, the base station serves as the central node and receives data from all of the nodes. The monitoring algorithm is always executed by the base station, and the results are delivered to the sensor nodes. In the event that several sensor nodes are concurrently sending data to the base station, it can become overloaded. The fact that all the data is processed by a single station means that a single point of failure might damage the entire network and reduce tracking performance. A centralized methodology underlies all four levels of Optimized Communication and Organization (OCO). The first stage, position collection, collects and stores the locations of the network's nodes in the base station. Sensing, border node identification, node removal, and routing are all done in the second processing stage.

When the target is lost, a signal is sent to the neighbouring nodes so they can find the lost target after being initially detected by border nodes. The final step, known as maintenance, is started when one of the nodes fails. The base only removes dead nodes. This strategy outperforms the first two approaches in terms of maximum accuracy, effective energy dissipation, and minimal communication overhead.

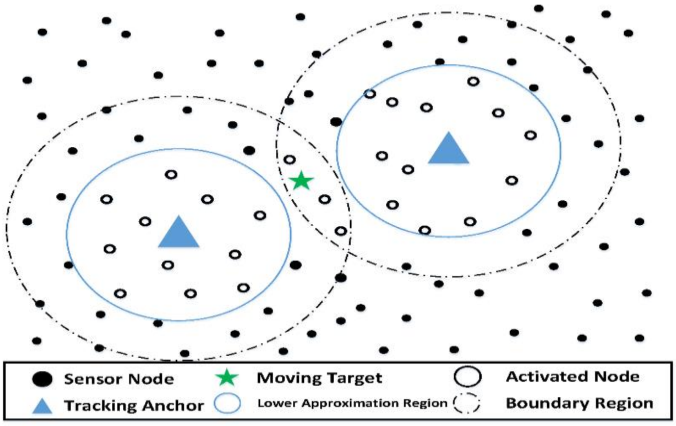

Figure 4: Multiple Clustered Sensor Network with Moving Target

3.5 Distributed Approach

With a distributed approach, each node is given an equal amount of work and responsibility and there is no central point of control in the network. The Kalman filter is a recursive method that uses a number of mathematical equations to estimate the state of a process while concentrating on decreasing mean squared error. The Kalman filter is the most effective and efficient filtering technique. The use of particle filters is another distributed technique. Target tracking is a dynamic state estimation issue that is based on the Monte Carlo approach and is present in the particle filter process. PF constructs an observation model that is connected to the current target observation in order to calculate the target position at each time step. The continuous posterior density function sample used by PF is given the necessary weights, which are adjusted over time. A particle and the proper weight are allocated to the node that locates the target first.

3.6 Energy Efficiency and Power Management in Tracking

Energy and power issues are essential in wireless sensor networks because they affect the network's durability. Routing algorithms and the relative mobility of the nodes must be energy and power efficient in order to enhance network performance overall. The solutions utilized in the following sections of the proposed work result in energy and power savings, extending the life of the network. Self-Organizing Networks for Energy Efficiency The network architecture that has to be changed for the entire process is also chosen by this technique, along with which nodes should be online when. The following are the subclasses of the network self-organization approach:

Dynamic Clustering: There are pure dynamic clustering and hybrid clustering techniques. The simplest is Adaptive Dynamic Cluster Based Tracking. It entails building a cluster head based on the distance and lowest ID. This message is sent to nodes that are within range of detection, and those that reply join the cluster. The reconfiguration is quickly finished. A alternative clustering technique called Particle Filter gives a particle to the node that finds the object first. The aim is treated as a problem of dynamic state estimation using this approach, which is based on the Monte Carlo method. Two widely utilized techniques are hybrid Cluster-based target tracking and herd-based target tracking.

3.7 Power Management in Target Tracking:

The fundamental idea behind power management is to dynamically encourage nodes to prolong sensor nodes' periods of sleep-in order to reduce WSN energy consumption. In order to reduce energy consumption, power management considers a number of factors, such as waking up the sensor node on time, learning about adjacent nodes, and the distance between the current node and other nodes. This allows for the identification of the precise sleep state and length of a node. Two of the policies in this category are dynamic power management and adaptive cooperative power management. The periodic dormancy and activation of the sensor nodes form the basis of the dynamic power management strategy. The node has a timer that is used to record the length of time since an event has been picked up. The node enters a preset sleep phase once the timeout expires before resuming the active state. The relative placements of the target and sensor nodes serve as the foundation for the adaptive cooperative power management technique. These points control the on/off state of the sensor nodes. The sleep state and interval are selected by each sensor node independently in line with the self-decision strategy.

4. Fault Tolerance Network Design

Due to physical damage, interference from the environment, or a lack of electricity, some sensor nodes may malfunction or get blocked. The main goal of the sensor network shouldn't be impacted by sensor node failure. This is a problem with fault tolerance or dependability. The capacity to maintain sensor network functionality in the presence of sensor node failures is known as fault tolerance. The likelihood of not experiencing a failure within the time span (0; t) is captured by the Poisson distribution when modelling the reliability or fault tolerance of a sensor node provided by

$$R_k(t) = \exp(-\lambda_k t) \quad (1)$$

where and, respectively, represent the time period and the sensor node k failure rate. You should be aware that protocols and algorithms may be created to handle the degree of fault tolerance needed by sensor networks. The procedures can be more liberal if there is less interference in the environment where the sensor nodes are installed. For instance, the fault tolerance requirement may be minimal if sensor nodes are being installed in a home to monitor humidity and temperature levels since these types of sensor networks are resistant to damage and interference from the outside environment.

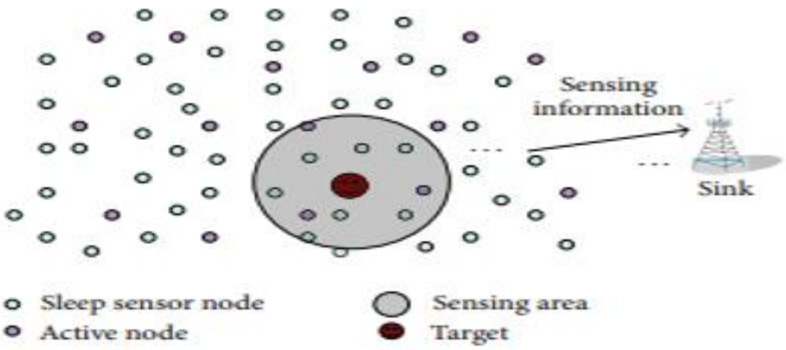

Figure 5: Tracker Node Selection Scenario to Track Target

On the other hand, because the information gathered are crucial and sensor nodes might be damaged by hostile acts, high fault tolerance is required when sensor nodes are placed in a battlefield for surveillance and detection. As a result, the application of the sensor networks determines the fault tolerance level, thus this must be taken into consideration while developing the schemes. To determine these faults well in advance and initiate the actions are badly required. This necessitates the fault detection and tracking algorithms to set up in the area of action. The wireless sensor network (WSN) application of target tracking is crucial. Target tracking methods now in use essentially schedule nodes based on predicted trajectories. The target recovery mechanism searches for the target after it has been lost owing to prediction mistakes, which might necessitate the system activating a lot more nodes and consuming more energy. Furthermore, because target recovery takes so long, the target data may be lost. We provide a fault-tolerant sensor scheduling (FTSS) technique to address this issue in order to assail the target loss probability. In order to save energy, we also create a low-power scheduling system for FTSS.

4.1 Efficient and Adaptive Node Selection.

Dynamically choosing the best set of sensor nodes for tracking task can reduce the energy consumption of the network and improve tracking accuracy. As Figure 2 shows, there are many sensor nodes in the sensing area. However, tracking a target does not need so many sensor nodes. Generally, we should select sensor nodes which can bring more information among the candidate nodes in this area. The sink is required to decide which nodes should be active for the next task and which nodes should be kept sleeping to save energy.

4.2 System Model

The following assumptions are assumed since we concentrate on the application scenario of monitoring a single moving object in a large-scale WSN.

1. In a region of interest, sensor nodes are dispersed at random, with the sink in the middle. Similar energy is first applied to all of the sensors.

2. Clustering is created based on the distance associated between nodes and Each node has the same hardware, software, and energy storage characteristics. Nodes are conscious of their coordinates since they are outfitted with GPS or other positioning tools. There are no energy limitations on the sink node.

3. To guarantee target detect target tracking node is identified based on the higher power associated in that cluster.

Our radio model for energy dissipation follows the following assumptions. The energy dissipation for transmitting k-bit packets over d is

$$\mathrm{Etx}(\mathrm{k},\mathrm{d}) = k(E_{elec} + efs\ \times d^2) \quad d < do \qquad (2)$$

$$\mathrm{Etx}(\mathrm{k},\mathrm{d}) = k(E_{elec} + emp\ \times d^4) \quad d < do \qquad (3)$$

And the energy dissipation of receiving k bit packets over d is given by

$$E_{rx}(k) = k \times E_{elec} \qquad (4)$$

Here d_o is the threshold distance. E_{elec} denotes transmitting circuit loss, while efs and emp denotes energy coefficients of power amplification respectively. Target tracking sensor scheduling involves selecting an appropriate node set from candidate nodes near the target's expected location. This section suggests a fault-tolerant sensor scheduling strategy (FTSS) to address the target loss issue brought on by prediction mistakes. To initially group the sensor nodes activated throughout the tracking phase, we use a dynamic clustering technique. The fault-tolerant domain is then built close to the target's anticipated position to reduce target loss in advance. Finally, using a better binary grey wolf optimizer, we schedule the state of the nodes in the fault-tolerant domain and discover the best plan.

4.3 Contributions

Our primary contributions to this study work are as follows:

(i) After studying the many faults that may occur in a WSN, we developed a novel taxonomy of defects.

(ii) Next, we looked at the performances of a few popular algorithms that are already in use.

(iii) we suggest two novel fault-handling and target detection algorithms called UEC and PBT.

(iv) Finally, using simulation, the performance of the suggested method was thoroughly compared to well-known techniques.

The remainder of the essay is structured as follows: The literature overview and current research concerns are covered in Section 2. The problem with the suggested taxonomy in WSN is examined in Section 3. Sections 4 and Section 5 separately discuss the simulation-based setup and outcomes. The paper is concluded in Section 6.

4.4 Applications

Node Tracking, object surveillance, and damage control by regulating the node behaviour are uses for WSNs. WSNs are primarily used for traffic status monitoring, object tracking, nuclear reactor management, automatic handling of production units, habitat monitoring, and fire detection. Défense applications for threats, oversight in countries border, communications, computers, intelligence, surveillance, investigation, and targeting (C4ISRT) systems may fully include wireless sensor networks. A particularly promising sensing method for military C4ISRT, sensor networks have the qualities of quick deployment, self-management, and fault tolerance.

5. Performance and Evaluation

To evaluate the performance of the proposed approach of PBT, we simulated a network with 100 sensors nodes randomly laid out in a 2 km × 2 km area. We also compare our simulation results with the closest node selection (in which the nodes closest to the target are selected to track), the weighted distance node selection method (in which a node is selected once time according to its own information utility) and entropy-based method in terms of Mean square errors, execution time and energy cost. The sink is fixed and located at (100, 150). The performance of various tracking schemes are depicted in table 2.

Table 2: Comparison of Different Approaches for Tracking

Approaches	Terms	
	Average energy cost of the system (J)	Fail Tracking percentage (%)
Weighted distance	0.226	0.73
Closest	0.251	1.26
Entropy Based	0.243	0.63
PBT	0.213	0.66

The sensing range of each sensor node is *R* sensing = 10 m. Moreover, each sensor has a sight angle of 40 degrees and the measurement error follows a Gaussian distribution whose standard deviation is 3 degrees. We also assume that each node has an initial energy of 1 J (Joule). A very widely used energy consumption model is adopted, as described in

$$E_{Tx}(k, d) = (E_{Tx\text{-}elec} + \varepsilon_{amp} * d^{\alpha}) * k \quad (5)$$

$$E_{Rx}(k) = E_{Rx\text{-}elec} * k \quad (6)$$

Graphs are illustrated according to the energy dissipation factor described in equation 5 & 6.

5.1 Simulation Parameters

- Packet delivery Ratio: It is the ratio of packets transmitted to the total numbr of packets received in the defined duration of execution time. It will be measured in percentage.
- Distance ratio: It is defined as the distance associated of each sensor node with respect to the other nodes in the cluster.It is used to form the clusters.it is measured in feet.
- End to end delay: It is defined as the total time required to send a packet from the tracking node to the sink node. It will be measured in in milli seconds.

5.2 Result Analysis

- The Results are obtained from the NS2 simulation considering different node mobility. The graph shown in figure 6 represents the progress of PDR considering various node densities. From the graph it is evident that the PDR is improved to nearly 70 % at higher node density. Lesser collision in the packets due to the presence of only single tracking node which can reduces the packet flooding in the network. This can rise the value of PDR as shown in figure 6.
- The figure shown in 7 illustrates the associated distance between the nodes. This will help us to perform the efficient distance based clustering. Nodes N1, N4 and N6 form the cluster 1 due to their position in the near vicinity, whereas N2, N3 and N5 forms the cluster 2 due to their closer distance.
- End to end delay is presented in figure 8 considering various node density. From the graph it is clear that the average delay at node densities of 30-40 is less than 6ms which is significant when we compare the proposed work with existing works which lies between 12-13ms [5]. The improvement in the end-to-end delay is due to the lesser hand off between the tracker node. This is because of the lesser congestion and hence improves the life time of the tracking node.

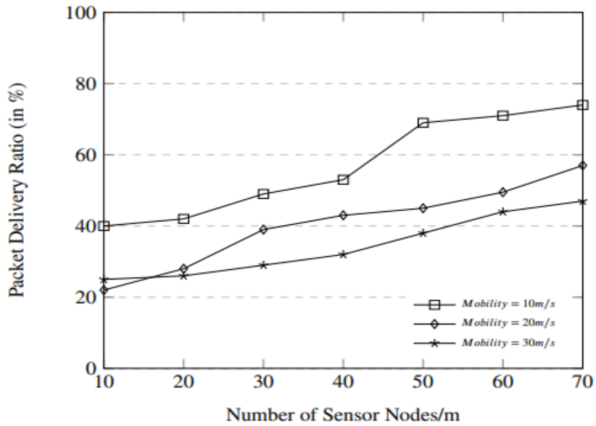

Figure 6: PDR Vs Number of Sensor Nodes

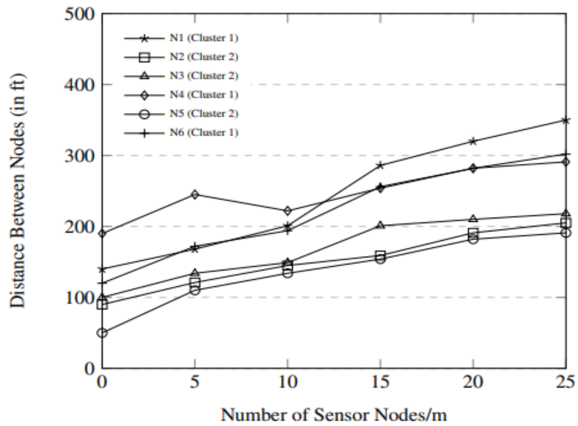

Figure 7: Distance Vs Number of Sensor Nodes

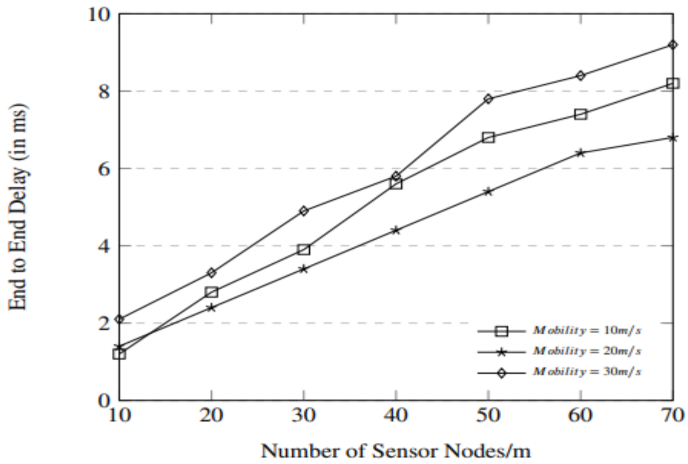

Figure 8: End to End Delay Vs Number of Sensor Nodes

6. Conclusion

In order to save network energy and ensure data accuracy during data transmission we have explored mechanism of target node identification in this research, as well as some cutting-edge tracking approaches. The uniform energy distribution scheme and power-based tracking in the proposed scheme saves the node energy and increase the life time of the sensor network. Since only single node which is having higher power will be selected as tracking node all other nodes will be in sleeping mode and hence saves the energy of the network which is crucial in most application. The proposed work has less handoffs as only tracking node will be acting as a gateway node to the sink node. Thus, the parameters like PDR, Energy and latency will be improved nearly by 12% when compared to the existing approaches.

Future scope of this work would be detecting multiple malicious nodes and tracking with minimum tracker nodes.

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