# An Empirical Study On Energy Efficient Data Gathering And Target Tracking In Wireless Sensor Network

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***Abstract***

*Wireless sensor network (WSN) is a group of distributed sensor nodes for monitoring the physical conditions of environment and arranging the collected data. Every sensor node has the ability for sensing, processing, transmission, etc. Sensor nodes are located in sensor field and organize among themselves to create the high-quality information regarding the physical environment. Every sensor nodes collects and transmits the data packets to the neighboring sensors and finally to the base station. Routing in WSN is the process of sending the data packets from sender node to the receiver node. Data gathering process gathers the data packets from all sensor nodes and transmits to the base station with lesser energy consumption. Target tracking is an important application in WSN where each sensor nodes monitor and report the location of moving objects to application user with lesser latency. Energy consumption is an essential concern in routing, data gathering and target tracking process. However, the existing target tracking techniques failed to improve the performance of the accuracy and reduce the energy consumption. In order to reduce the energy consumption during the routing, data gathering and target tracking, machine learning and ensemble classifier techniques can be used. Our main objective is to perform energy efficient data gathering and target tracking with lesser time consumption.*

**Keywords:** *Wireless sensor network (WSN), data gathering, routing, energy consumption, target tracking, high-quality information*

## I. INTRODUCTION

Wireless sensor network are described as the network of devices that transfers the gathered information from monitored area through wireless connection. Wireless Sensor Network is a type of wireless network with large number of circulating, self-directed, less powered devices termed motes. The networks comprise large number of spatially distributed, battery-operated to gather, process, and transmit data to the operators. Nodes are small computers that function jointly to form the networks. Recently, wireless sensor network has become leading research fields for the researchers. Sensor is a device that reacts and identifies the type of input from both physical and environmental conditions like pressure, heat, light, etc. The output of sensor is an electrical signal that is transmitted to controller for additional processing.

This paper is organized as follows:

Section II discusses the review on different data gathering and target tracking techniques in WSN, Section III portrays the study and analysis of the existing data gathering and target tracking techniques in WSN, Section IV describes the possible comparison of existing techniques. In Section V, the discussion and limitations of the existing data gathering and target tracking techniques in WSN are studied and Section VI concludes the paper.

## II. LITERATURE SURVEY

An efficient routing protocol termed Intelligent Energy Aware Secured Algorithm for Routing (IEASAR) was designed in [1] for enhancing the energy efficiency and security level. A modified minimum spanning tree approach was designed to identify the minimum distance path between the sender node and destination node for selecting the optimal and secured routing path. However, packet delivery ratio was not enhanced by IEASAR protocol. The rules and agents were not developed for route optimization. An analytic model was designed in [2] to improve the network lifetime from the network initialization until it disabled and established during data gathering in WSN. The temporal and spatial development of energy hole was studied and analytical results were employed in WSN routing to balance energy consumption and to enhance the network lifetime. But, the designed model failed to extend the network lifetime into energy harvesting WSNs.

An energy-efficient Localization and Tracking (eLOT) system was introduced in [3] with low-cost and portable hardware for exact target tracking. The fingerprint-based approaches were designed in eLOT for localization and tracking. But, the network size of eLOT was not extended to several buildings. An optics inspired optimization (OIO) based Cluster Head (CH) selection algorithm was introduced in [4] with many parameters like energy, distance and node degree. An OIO based routing algorithm identified the route from each CH to base station (BS). However, meta-heuristic technique for node employment was not employed for increasing coverage area and minimizing the number of nodes.

The data deliverability of greedy routing was classified through the successful data transmission from the sensors to the base station. $\eta$-guaranteed delivery was introduced in [5] where the successful data deliveries was not less than $\eta$. But, link scheduling in SINR model and individual setting of transmission power for every node failed to improve the energy-efficiency. Swarm intelligence (SI) based energy efficient hierarchical routing protocol called BeeSwarm was introduced in [6] for WSNs. The designed protocol comprised three phases and grouping of three phases used for enhancing the robustness level. Though the energy consumption was reduced, the routing overhead was not minimized through BeeSwarm approach.

Mobile agent based compressive data gathering algorithm (MA-Greedy) was introduced in [7] where each sensor node was visited in M measurements. Coefficient of Variation (CV) was introduced to calculate the balance of the energy consumption. But, the data gathering accuracy was not enhanced by mobile agent based compressive data gathering algorithm. Data gathering from mobile sensors by mobile sinks is a demanding problem from static sensors. The problem was taken as NP-hard and two approximation algorithms were designed in [8]. The mobile sensors send the sensed data to the mobile sink within the communication regions and introduced recovery algorithm from mobile sink failure. However, the energy consumption was not reduced during the data gathering process through two approximation algorithms.

## III. ENERGY EFFICIENT DATA GATHERING AND TARGET TRACKING IN WSN

Wireless sensor networks (WSNs) are employed in many areas like medicine, education, agriculture and military applications. The essential features of sensor nodes are size, power, cost and maintenance. They have led to the wide spread use of sensor networks. WSNs are used for data collection and effective communication in vehicular sensor networks. WSNs consist of sensor nodes having limited energy and random distribution. An effective root discovery is important for providing optimal performance with respect to energy and security. The routing algorithm must consume minimum energy in which network run for large amount of time period with available energy. Energy efficiency is an essential feature for wireless communication. Energy is used by the sensor nodes obtained for threshold computation. The threshold value is an essential part in CH node election and cluster optimization. The energy consumed by node is due to computation and data transmission. The communication energy of sensor node is high when compared to the computational energy. The energy model of sensor network is designed with the communication energy.

### *A. An Intelligent Energy Aware Secured Algorithm for Routing in Wireless Sensor Networks*

WSNs are provided with the sensors to monitor and manage different activities. WSNs presents the cost optimization through energy saving. It is useful for guiding elder and disabled people to perform activities with the sensors. In wired networks, installation of nodes is frequently limited by high cost of wires. The development of WSNs enabled the access to unreachable areas such as risky, confidential areas, machineries and mobile assets by wireless sensors.

A new and effective routing protocol called Intelligent Energy Aware Secured Algorithm for Routing (IEASAR) was introduced which is secured by Trust and Energy efficient simultaneously. A new energy efficient protocol was introduced by Fuzzy C-means. A modified minimum spanning tree approach is introduced to identify the minimum distance path between sender node and destination node. In addition, an optimal and secured routing path is chosen. A routing protocol presents safe and secure transmission of data with lesser energy. The node trust value and path trust value are transmitted to Fuzzy clustering module to cluster the nodes. Cluster based routing algorithms are energy-efficient in wireless sensor networks because of cluster head utilization for routing process. Clustering based routing using Fuzzy C-means (FCM) mechanism and random node are chosen as the cluster head. All nodes contain similar amount of power and the node having the highest residual energy elects itself as cluster head. The routing of packets performed through the cluster heads. FCM cluster protocol is a centralized cluster algorithm. Base station is responsible for computing the energy consumption and choosing the trust in paths for data transmission. The diagrammatic representation of IEASAR is described in Figure 1.

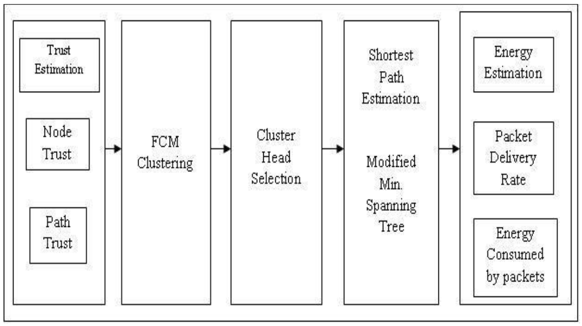


**Figure 1 Architecture of IEASAR Protocol**

In every node, intelligent agent is used to calculate the basic trust and to preserve the history about neighbours for improving performance of packet delivery rate. In IEASAR, two kinds of trust called basic and current trust are used. The basic trust is modernized dynamically depending on communication such as energy utilized, delay, packets dropped by node, node ability and node cooperation. The updated trust values are termed as current trust.

### *B. Lifetime and Energy Hole Evolution Analysis in Data-Gathering Wireless Sensor Networks*

Wireless sensor networks (WSNs) are capable of sensing and computing process. Wireless communication is employed in many applications like military surveillance, environmental monitoring, infrastructure, diagnosis and industry applications. A data gathering in WSN has number of battery-powered sensor nodes for monitoring and transmitting data to the sink. When battery-powered sensor nodes are limited in energy resource and used in unattended hostile situation, it is essential to enhance the network lifetime of WSN. When the energy consumption is increased with the communication distance, multi-hop communication executes the data gathering for energy conservation. The nodes near the sink node transmit the data packets from additional nodes and drain energy resulting in energy hole around the sink node.

An analytic model was introduced to compute the network lifetime from network until it immobilized and determine the boundary of energy hole in data gathering. The energy consumption is considered to estimate the energy consumption of sensor nodes for data transmission, receiving and idle listening. An analytic model was introduced to compute the traffic load, energy consumption and lifetime of sensor nodes during entire network lifetime. The designed analytic model enhanced the network lifetime within minimal error rate. For validating the analytical results in WSN design, WSN routing process is carried out. The improved routing scheme depending on analytical results balances energy consumption and enhances the network lifetime like First Node Died Time (FNDT) and All Node Died Time (ANDT).

### *C. Energy-Efficient Localization and Tracking of Mobile Devices in Wireless Sensor Networks*

Wireless sensor networks (WSNs) are effectual for finding and tracking objects in different industrial atmospheres. An energy-efficient Localization and Tracking (eLOT) system was introduced with low-cost and portable hardware for accurate target tracking. The fingerprint localization and tracking approach with Adaptive Weighted K-Nearest Neighbour (AWKNN) was introduced in eLOT to present ubiquitous services both indoor and outdoor. The number of reference locations was varied in AWKNN consistent with environment for enhancing the localization accuracy. In eLOT system, battery recharging was accessible at anchor nodes to minimize the energy consumption at mobile nodes. Multi-radio modules were installed at the anchor nodes. One radio channel was preserved for wireless backhaul transmission. Another one is employed for transmission between anchor nodes and serving mobile nodes. An interference and collision were minimized through the channel allocation and access schemes for eLOT system. After that, removing the unnecessary transmission reduced the energy consumption of the mobile nodes. The designed schemes attained elegant tradeoff between the energy efficiency and localization accuracy. In eLOT, channel allocation schemes are employed to eliminate the interference between zones while coordinated backoff schemes are used for alleviating the intra-zone interference. Depending on location information, mobile nodes in eLOT associate with or switch to zone-specific channel while saving energy through minimizing the unnecessary transmissions.

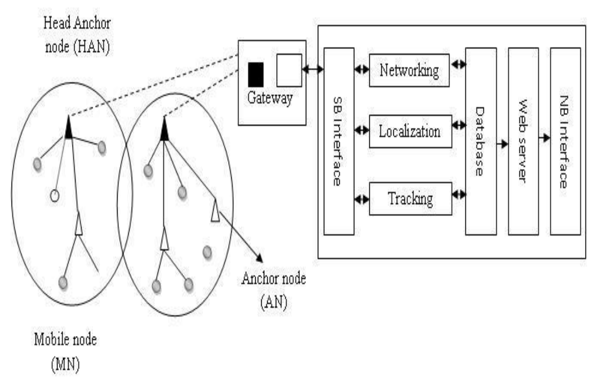


**Figure 2 Architecture Diagram of eLOT system**

In eLOT system, there are three types of links as described in figure 2, namely, the MN-to-AN, AN-to-HAN, and HAN-to-HAN links. HAN-to-HAN link transmits large quantity of data in fast and reliable manner for improving the system performance. It is possible for eLOT system to assign dedicated channel to link for guaranteeing the QoS performance of backhaul transmission. An additional two types of links called MN-to-AN and AN-to-HAN links share remaining available channels.

## IV. COMPARISON OF ENERGY EFFICIENT DATA GATHERING AND TARGET TRACKING & SUGGESTIONS

In order to compare the energy efficient data gathering and target tracking using different techniques, number of data is taken to perform the experiment. Various parameters are used for energy efficient data gathering and target tracking.

### *A. Energy Consumption*

Energy consumption is defined as the amount of energy consumed for performing the routing process. It is the product of number of sensor nodes and energy consumed by one sensor node. It is measured in terms of joules (J). It is mathematically formulated as,

$$EC = * \textit{Energy consumed by one sensor node} \quad (1)$$

From (1), '$N$' represents the number of sensor nodes. When the energy consumption is lesser, the method is said to be more efficient.

**Table 1 Tabulation of Energy Consumption**

| Number of Sensor Nodes (Number) | Energy Consumption (J) | | |
|---|---|---|---|
| | IEASAR Protocol | Analytic model | eLOT System |
| 10 | 56 | 62 | 65 |
| 20 | 59 | 64 | 69 |
| 30 | 62 | 69 | 75 |
| 40 | 66 | 71 | 77 |
| 50 | 62 | 66 | 72 |
| 60 | 58 | 64 | 68 |
| 70 | 63 | 67 | 74 |
| 80 | 66 | 70 | 77 |
| 90 | 70 | 74 | 81 |
| 100 | 75 | 79 | 84 |

Table 1 explains the energy consumption of three different techniques for different number of sensor node ranging from 10 to 100. Energy consumption comparison takes place on existing Intelligent Energy Aware Secured Algorithm for Routing (IEASAR) protocol, Analytic model and energy-efficient Localization and Tracking (eLOT) system. From the table value, it is clear that the energy consumption does not get linearly increased with respect to number of sensor nodes. The graphical representation of energy consumption is described in figure 3.

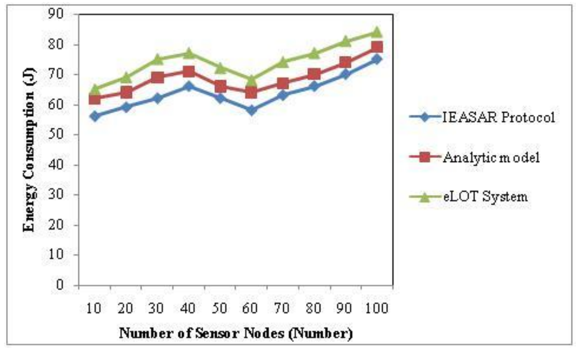


**Figure 3 Measure of Energy Consumption**

From figure 3, energy consumption based on different number of sensor nodes is described. It is clear that energy consumption of Intelligent Energy Aware Secured Algorithm for Routing (IEASAR) is lesser than that of Analytic model and energy-efficient Localization and tracking (eLOT) system. This is because of new energy efficient protocol by Fuzzy C-means. The node trust value and path trust value are sent to the Fuzzy clustering module to group the sensor nodes. Cluster based routing algorithms are energy-efficient in wireless sensor networks due to the cluster head utilization for routing process. The energy consumption of IEASAR protocol is 7% lesser than Analytic model and 14% lesser than energy-efficient Localization and tracking (eLOT) system.

### *B. Data Gathering Accuracy*

Data gathering accuracy is defined as the ratio of the number of data packets gathered accurately to the total number of data packets. It is measured in terms of percentage (%). It is mathematically formulated as,

$$\textit{Data Gathering Accuracy} = \frac{\textit{Number of data packets gathered accurately}}{\textit{Total number of data packets}} \quad (2)$$

From (2), data gathering accuracy is calculated. When the data gathering accuracy is higher, the method is said to be more efficient.

**Table 2 Tabulation of Data Gathering Accuracy**

| Number of Data Packets (Number) | Data Gathering Accuracy (%) | | |
|---|---|---|---|
| | IEASAR Protocol | Analytic model | eLOT System |
| 10 | 72 | 79 | 65 |
| 20 | 75 | 81 | 67 |
| 30 | 78 | 84 | 70 |
| 40 | 81 | 87 | 72 |
| 50 | 79 | 85 | 69 |
| 60 | 75 | 83 | 66 |
| 70 | 71 | 78 | 63 |
| 80 | 69 | 75 | 61 |
| 90 | 73 | 77 | 65 |
| 100 | 75 | 80 | 69 |

Table 2 describes the data gathering accuracy for different number of data packets ranging from 10 to 100. Data gathering accuracy comparison takes place on existing Intelligent Energy Aware Secured Algorithm for Routing (IEASAR) protocol, Analytic model and energy-efficient Localization and Tracking (eLOT) system. From the table value, it is observed that data gathering accuracy does not get linearly increased with respect to number of data packets. The graphical representation of data gathering accuracy is described in figure 4.

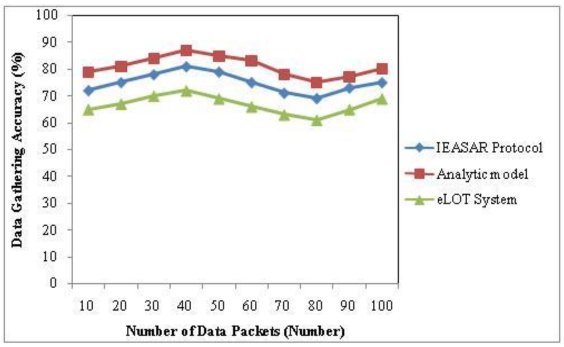


**Figure 4 Measure of Data Gathering Accuracy**

From figure 4, data gathering accuracy based on different number of data packets is described. It is clear that data gathering accuracy of Analytic model is higher than that of Intelligent Energy Aware Secured Algorithm for Routing (IEASAR) and energy-efficient Localization and tracking (eLOT) system. This is because it determines the traffic load, energy consumption and lifetime of sensor nodes during entire network lifetime for efficient data gathering. The network lifetime under specified percentage of dead nodes was taken and remaining energy of network is depending on analytical performances. The data gathering accuracy of analytic model is 8% higher than Intelligent Energy Aware Secured Algorithm for Routing (IEASAR) and 21% higher than energy-efficient Localization and tracking (eLOT) system.

### *C. Target Tracking Time*

Target tracking time is defined as the amount of time consumed for tracking the target objects. It is the difference of starting time and ending time of target tracking. It is measured in terms of milliseconds (ms). It is mathematically formulated as,

$$Target\ Tracking\ Time = Ending\ time - Starting\ time\ of\ target\ tracking \quad (3)$$

From (3), the target tracking time is computed. When the target tracking time is lesser, the method is said to be more efficient.

**Table 3 Tabulation of Target Tracking Time**

| Number of Data Packets (Number) | Target Tracking Time (ms) | | |
|---|---|---|---|
| | IEASAR Protocol | Analytic model | eLOT System |
| 10 | 45 | 31 | 25 |
| 20 | 47 | 35 | 27 |
| 30 | 51 | 38 | 29 |
| 40 | 54 | 41 | 31 |
| 50 | 52 | 39 | 28 |
| 60 | 55 | 43 | 32 |
| 70 | 57 | 46 | 35 |
| 80 | 54 | 42 | 33 |
| 90 | 58 | 47 | 36 |
| 100 | 61 | 52 | 39 |

Table 3 explains target tracking time for different number of data packets ranging from 10 to 100. Target tracking time comparison takes place on existing Intelligent Energy Aware Secured Algorithm for Routing (IEASAR) protocol, Analytic model and energy-efficient Localization and Tracking (eLOT) system. From the table value, it is clear that target tracking time does not get linearly increased with respect to number of data packets. The graphical representation of target tracking time is explained in figure 5.

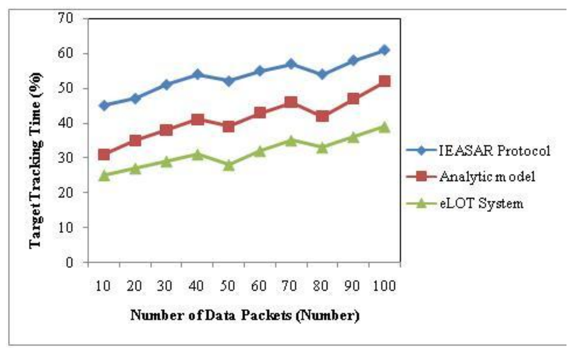


**Figure 5 Measure of Target Tracking Time**

From figure 5, target tracking time based on different number of data packets is explained. It is clear that target tracking time of energy-efficient Localization and tracking (eLOT) system is lesser than that of Intelligent Energy Aware Secured Algorithm for Routing (IEASAR) and Analytic model. This is because fingerprint localization and tracking approach with Adaptive Weighted K-Nearest Neighbour (AWKNN) was introduced in eLOT to present ubiquitous services both indoor and outdoor with low cost. The target tracking time of energy-efficient Localization and tracking (eLOT) system is 41% lesser than Intelligent Energy Aware Secured Algorithm for Routing (IEASAR) and 24% lesser than analytic model.

## V. DISCUSSION AND LIMITATIONS ON ENERGY EFFICIENT DATA GATHERING AND TARGET TRACKING IN WSN

FCM based clustering approach in IEASAR approach identified the optimal routes for communication. With cluster head rotation and modified minimum spanning tree approach, better results were obtained. The key achievement was minimizing the energy utilization and enhanced the packets delivery count. The designed protocol provided secure communication. But, packet delivery ratio was not enhanced using IEASAR protocol. The rules and agents were not employed for route optimization. A network-level scheme coordinating collision and interference was introduced to achieve high energy efficiency. Depending on the location information, mobile devices in eLOT associates with particular channel in specified area. The network size of eLOT was not extended to the many buildings.

An analytic model estimated the network lifetime from the network initialization until it gets disabled and determined boundary of energy hole in data-gathering. The temporal and spatial development of energy hole balanced the energy consumption and improved the network lifetime for routing in WSN. With analytic model, network lifetime was calculated under given percentage of dead nodes. The designed model failed to improve the lifetime in WSNs. When the sensor nodes were supplied through stochastic renewable energy, it was demanding to examine and optimize the network lifetime under continuous and unbalanced energy supply.

### *A. Related Works*

A non-uniform distribution of sensing data field were used in [9] to reduce the number of data ferries and to assure the recovered data quality. The designed learning plan minimized the number of data ferries while enhancing the data quality through learning statistical allocation of collected data. However, packet loss rate was not minimized through the compressive data gathering process. A weighted spatial-temporal compressive sensing method was designed in [10] to improve the reconstructed data accuracy. But, the clustering accuracy was not enhanced for nodes located outside transmission area during the data gathering process. In addition, cluster size on lifetime and accuracy was not taken into consideration during the data clustering process.

A generalized unscented information filter (GUIF) was designed in [11] for target tracking in WSN. Nodes were embedded sensors with their measurement noise to target distance. The consensus method was designed for execution of GUIF. State estimation error of local estimators was bounded in meansquare under network connectivity and collective observability considerations. However, the target tracking accuracy was not enhanced using GUIF. A data suppression approach was introduced in [13] for target chasing in WSNs. A sensor node transmitted the actual target position to mobile sink when information was valuable for reducing the time where target gets caught by sink node. However, wireless sensor networks with multiple actors failed to take decisions and perform actions depending on the delivered senor readings.

A sinusoidal waveform with duration was employed in [14] to transmit the sensor decision to fusion center (FC). All sensor decisions were sent to the FC over an invalid wireless channels depending on time division multiple access techniques. But, the delay time was not minimized by PTA algorithm. TDMA need clock synchronization between sensors and fusion center for monitoring the delays. Mixed maximum likelihood (ML)-Bayesian framework was introduced in [12] for accurate target tracking algorithm in radio environment. The radio environment was computed by ML approach and the target tracking was carried out through Bayesian filtering technique. But, the energy consumption was not reduced during indoor target tracking process in WSN.

### *B. Future Direction*

The future direction of the energy efficient data gathering and target tracking can be carried out using machine learning and ensemble classification techniques for improving the performance of the wireless sensor network.

## VI. CONCLUSION

A comparison of different existing energy efficient data gathering and target tracking is studied. From the study, it is observed that the existing techniques failed to take the decisions and perform the actions depending on the delivered senor reading with multiple actors in wireless sensor networks. The survival review shows that the existing IEASAR protocol failed to improve the packet delivery ratio. In addition, the designed model failed to extend the network lifetime into energy harvesting WSNs. The wide range of experiments on existing methods determines the performance of many energy efficient data gathering and target tracking techniques with its limitations. Finally, from the result, the research work can be carried out using machine learning and ensemble learning techniques for improving the performance of data gathering and target tracking.

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