Energy Efficient Clustering and Routing Protocol for Internet of Things Using Optimization Algorithms

Ritika[1], Dr. Suneet Kumar[2]

[1]*Research Scholar, Department of Computer Science and Engineering, MM Engineering College, Maharishi Markandeshwar (Deemed to be University), Mullana-Ambala, Haryana, India*
[2]*Professor, Department of Computer Science and Engineering, MM Engineering College, Maharishi Markandeshwar (Deemed to be University), Mullana-Ambala, Haryana, India*
Email id: er.ritika2410@gmail.com1, suneetcit81@gmail.com

ABSTRACT
Internet of things (IOTs) are crucial in monitoring environmental conditions in remote areas, but they face significant challenges related to energy consumption, which affects network longevity and coverage. Clustering has proven effective in prolonging the life of sensor networks. FFA (Fruit Fly Algorithm) and ACO (Ant Colony Optimization) are emerging as encouraging solutions for creating clusters and establishing paths, respectively. This paper proposes a novel solution that integrates ACO for establishing paths with FFA for clustering. This method is tested in both homogeneous and heterogeneous settings using MATLAB, comparing its performance with two existing algorithms: Low Energy Adaptive Clustering Hierarchy (LEACH) and Biogeography-Based Optimization Algorithm (BOA). According to the findings, the suggested algorithm performs noticeably better than BOA and LEACH in the context of coverage area and network service period, especially in heterogeneous settings...
Keywords: Clustering, LEACH, Fruit Fly, BOA, Ant Colony, Path Optimization
How to cite this article: Ritika, Kumar S., Energy Efficient Clustering and Routing Protocol for Internet of Things Using Optimization Algorithms. Int J Drug Deliv Technol. 2026;16(3s): 446-454; DOI: 10.25258/ijddt.16.3s.56
Source of support: Nil.
Conflict of interest: None

INTRODUCTION

With an advancement industrial, electronics, communication, and contraction, the minute, low-energy, less-expensive, and multi-functional wireless sensor nodes (SNs) are developed rapidly in recent times. These nodes have potentials of environmental sensing, data collection, data processing [1], and wireless communication. Thus, Internet of things (IOTs) becomes capable of gathering information and reporting events in a self-organized way. Several applications, like tracking, video surveillance, remote monitoring, localization and event-reporting, make the deployment of IOT at an extensive level. At present, due to development of Internet of Things (IoT), the major research area on IOTs is of energy conservation that leads to alleviate the necessity of memory and the complexity of protocol design. A great increase is found in the number of embedded devices recently and thus, their association with Internet as the IoT is projected. A typical IOT has a number of sensor nodes and one sink node. SNs are employed for gathering the data and forwarding the data to base station (BS or sink) [2]. Figure 1 illustrates the diagrammatic representation of a WSN.

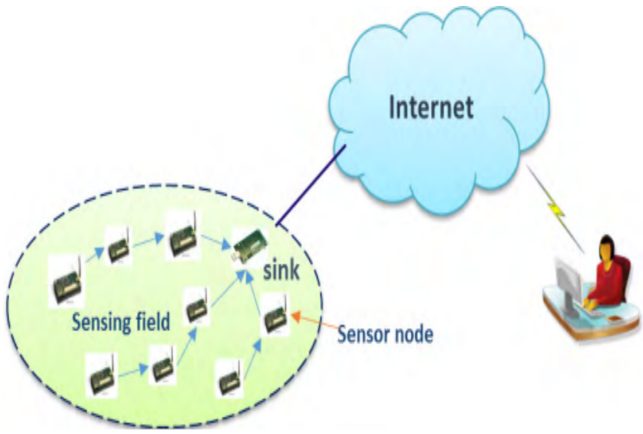

Figure 1: Diagrammatic representation of WSN

In IOT, the sensor nodes are responsible for sensing the environment and collecting raw data. Using the local processing, sensors are able to establish communication among one another. If essential, the data is aggregated and its transmission is done to a sink. The access is provided to users for the data taken from sensors via the sink node when the internet is used. Sensor networks are frequently considered as multi-hop and transferring messages is centred around data instead of node or destination. A many-to-one traffic pattern, is followed in these networks because of which a "hot-spot" problem is occurred. These networks are capable of maintaining a definite quality of service (QoS) [3]. Some issues are occurred in designing effectual protocols for IOTs due to restricted power, lower radio range, potentially higher density and an everchanging

**Author for Correspondence* : *Ritika*

environment. IOTs is extensively adopted in various applications, including industrial procedure monitoring and control, environmental surveillance and locale monitoring, clinical applications, home computerization, traffic controlling and prediction systems. In various applications, operating IOTs is essential for numerous years without any interference of humans. Though, sensor nodes are constricted with energy. A discontinuity is found in nodes in a IOT after drainage of energy in sensor nodes. Consequently, the performance of network is degraded. Thus, to enlarge the duration of network is essential task for network performance. The fundamental focus of routing protocols is on preserving the energy of SNs, for keeping them active for long time. It results in maximizing the life span of network and retaining its connectivity [4]. The neighbouring sensor nodes lead to generate same sensing data, thus, routing protocols in a IOT must emphasize on recognizing and removing the dismissed information. In addition, IOT allows to direct almost entire data flow amid several sources and one single sink whereas it is impossible to apply IP based organization in a direct way and sensor nodes are consisted of restricted data handling potential. On the contrary, the routing protocols suggested for physical networks are incapable of determining abovementioned issues. Further, their major concern is to acquire higher Quality of Service (QoS). Henceforth, such approaches are not appropriate for IOTs [5].

For all above-mentioned reasons, various protocols have been suggested to provide energy efficient routing especially in IOTs. These protocols have 4 categories on the basis of structure of network; the way to transmit data; the usage of location information; and the support of Quality of Service (QoS) or multiple routes.

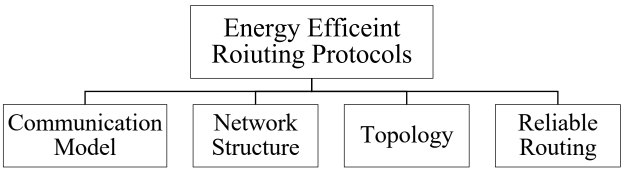

Figure 1: Division Criterion of Energy Efficient Routing Protocols

1) Communication Model

This class of protocols uses single-hop routing to provide neighbour-to-neighbour communication. With a given amount of energy, these data-centric protocols are able to transmit more data. Data delivery is not certain, though. These kinds of protocols are divided into three subcategories as mentioned below:

i. Query Based: This subcategory of protocols routes data via queries [6]. Every time a node requires fresh data, it sends out a message, or query, to other nodes that possess the data to request it. Subsequently, the node that possesses the requested data forwards them to the node that has executed the query. A protocol called Directed Diffusion (DD) practices a naming strategy for data packets. By dispersing data throughout the nodes and stopping pointless actions from occurring, it conserves energy. DD identifies interests as object name, transmission, or geographic location using a list of attribute-value pairs [7]. The BS broadcasts its interests to its neighbours and has the ability to cache them for later use. Gradients are used in interest caching. Gradient is a reply link that was sent by a neighbor that contains information on the data flow, duration, and expiration time of the interest that was received. The nodes are capable of aggregating data within the network using a minimal Steiner tree as a model. Multiple paths are produced between the BS and nodes by combining gradients and interests; one path is then selected using reinforcement. In order to accomplish this, the source node is reinforced to provide data more frequently by the BS sending the initial interest from the chosen path again at shorter intervals. When a route fails, DD looks for additional paths with lower casting ratios by reinitiating reinforcement in an attempt to construct a new or alternate path. The primary benefits of DD are that it eliminates the need for node addressing techniques and the requirement for comprehensive knowledge of network topology worldwide. High energy efficiency is also attained. Nevertheless, not all IOTs can use its query-driven approach [8]. Furthermore, DD is not appropriate for environmental monitoring. Furthermore, the naming scheme needs to be established in advance, contingent on the use case. A protocol called COUGAR [29] views the network as a distributed database system. Declarative queries are used to replace query processing's network layer operations, such as selecting pertinent nodes and using network data aggregation to reduce energy consumption. To replace the network layer functionalities, it imports a new layer called the query layer that stands between the application and network layers. Nodes choose a leader node in the COUGAR architecture to aggregate data and send it to the base station. The BS then creates a query plan and forwards it to the appropriate nodes, describing leader selection for the query along with details regarding in-network computation and data flow for incoming requests [9]. COUGAR's primary benefit is its ability to maintain energy efficiency despite having a large number of active nodes. However, using an additional layer result in additional overhead. Additionally, synchronization is required for data computation in the network.

ii. Coherent/Non-Coherent: Before routing the data, nodes in this subcategory process the collected data at the node level. A node using coherent protocols only performs minimal processing on the data it receives. In contrast, nodes that use non-coherent routing protocols preprocess the data they receive before forwarding it to other nodes known as aggregators for additional processing. The two most widely used routing protocols in this category are Single Winner Algorithm (SWE) and Multiple Winner Algorithm (MWE). Depending on computing capacity and energy reserves, SWE chooses an aggregator node known as the Central Node (CN) to carry out complicated calculations. A number of message broadcasts are required prior to the election of a CN. Each node announces its nomination in the initial message, which is then received by another node, which then compares the candidates with itself. Until a CN is elected, this analysis generates a next message transmission, by means of the comparison's finding being delivered again for a further evaluation. Better candidates build a minimum hop spanning tree during the message broadcasts, which is finally routed at the winner candidates and covers the whole network. High scalability is attained with SWE. A minimum hop spanning tree is also employed [10]. Nevertheless, choosing a CN result in significant energy usage. Furthermore, CN has a large overhead. To avoid unnecessary energy consumption and computational overhead when data is sent to CN from many sources, MWE is an extension of SWE. Every node in MWE maintains a list of the best candidate nodes as well as a set of the lowest energy paths to every source. Consequently, overhead and energy are both reduced. The best candidate is then chosen using SWE so that CN can aggregate data. As a result, less energy is used and a set of minimal energy paths to every source are identified. But there are significant delays and only a limited amount of scalability is possible.

iii. Negotiation Based: Within the realm of routing protocols, a method known as Sensor Protocols for Information via Negotiation (SPIN) [11] involves a source node exchanging data with its destination after negotiation. SPIN employs a naming scheme based on high-level descriptors or metadata for data identification. Before actual data transmission, nodes exchange metadata via advertisement messages. The format of this metadata is application-dependent. Nodes broadcast packets containing advertisement messages (ADV) to their neighbors, and interested neighbors without the data respond with request messages (REQ). Subsequently, distribution nodes deliver the genuine data to concerned nodes. This intercession process effectively addresses issues like flooding and enhances energy efficiency by reducing redundant data and localizing topology changes. However, SPIN does not guarantee data delivery to the destination because intermediate sensor nodes may lack interest. Additionally, it is not suitable for applications requiring continuous data delivery, such as intruder detection [12].

2) Network Structure

Protocols within this category are divided into two subcategories based on how nodes are regarded: Flat and Hierarchical protocols.

i. Flat: In the Flat subcategory, nodes are treated equally and possess unique global addresses. A prominent protocol in this category is the TBRPF (Topology Dissemination Based on Reverse-Path Forwarding Protocol). This protocol operates by comparing past and present network states, broadcasting only the differences, resulting in smaller routing messages sent more frequently. Through the computation of minimum-hop pathways for propagating link-state modifications in the opposite direction, TBRPF creates spanning trees between two end points. Each source creates a broadcast tree after calculating the minimum-hop paths. Every node maintains a topology table containing link states, neighbouring nodes, parent and child lists, and sequence numbers of recent link state updates. New topology data modifies the spanning tree. When a node receives a link-state update from the source's parent with a higher sequence number compared to the relevant element in its architecture table, it accepts and forwards the update to its children. TBRPF offers multiple paths to the destination and requires less frequent updates. However, it may lead to bandwidth and packet wastage due to loop-freedom.

ii. Hierarchical: Within the Hierarchical subcategory [13], Internet of things (IOTs) are organized into clusters, each with an elected cluster head. Cluster heads facilitate communication with the Base Station (BS) at a higher level. Cluster nodes communicate with the cluster head and each other, as well as monitor the surrounding environment. The LEACH (Low Energy Adaptive Clustering Hierarchy) technique is one of the earliest hierarchical clustering protocols. In this protocol, nodes within a cluster collect and forward data to the CH, which integrates and transmits the data directly to the base station. Each node in the IOT randomly selects a value between 0 and 1. Selected node is turned out as the CH if the randomly chosen value by the node is less than the threshold value. The expression to compute the threshold value $T(n)$ is expressed as:

$$T(n) = \begin{cases} \dfrac{p}{1 - p \times mod(r, 1/p)} & n \in G \\ 0 & \end{cases}$$

where p defines the proportion of CH nodes in all the nodes of the IOT; $mod(r, 1/P)$ denotes the number of CH nodes whose selection is done in current round of circulation [16]. In the most recent 1/ p round, G represents the set of not chosen CH nodes; r is the network's session. It is possible to balance the energy usage of different cluster nodes by using the $T(n)$ topology. The LEACH algorithm incorporates clustering and periodic data gathering, aiming to reduce data transmission between nodes and the sink. By doing so, LEACH helps mitigate energy loss and extends the network's lifespan [14].

3) Topology

Most of the IOT protocols require location information related to nodes for computing the distance amid 2 nodes and estimating energy consumption. The implementation of these networks is spatially done on a region. Due to absence of addressing method, like the IP addresses, location information plays a significant role in routing data in an effectual manner. The Topology subcategory's protocols enable nodes to determine their own peer locations and message sources of information, which are regarded as reliable sources of information about the destination positioning. In Graph EMbedding for routing (GEM) protocol [15], a kind of this topology, virtual coordinates and two procedures: Virtual Polar Coordinate Space (VPCS) and Virtual Polar Coordinate Routing (VPCR), are deployed for routing the data. The primary procedure aims to create a spanning tree, where each node has a designated angle range and a root node. This angle range is divided into offspring nodes in their sub-trees by the parent node. The central point of mass and average location of each node inside a sub-tree are known to the parent nodes of that sub-tree. The following process uses GEM to route the data between any node and any point in the first process, as well as to characterize the points outside of the node's level and angle. The GEM is utilized for routing the messages successfully. Moreover, it offers void and tolerates the obstacles. This approach is effective for scaling based on size and density. While, an overloading is occurred in nodes of lower level.

4) Reliable Routing
There is a necessity of location information of nodes in various IOT protocols for computing the distance amid 2 nodes and estimating the energy consumption. The sensor networks are executed in an area. However, location information is effective for routing data because no addressing method, like the IP addresses, is available. SPEED (Stateless Protocol for rEal-timE communication) is a QoS routing protocol, utilizes in IOTs for offering lower end to end delays (EED), assists every node in maintaining neighboring node information, and considers a geographic forwarding for exploring routes. This protocol offers a certain speed for each packet in the network for providing efficiency to every application in estimating EED of packet when the distance to the base station (BS) is divided with the speed of the packet and avoiding congestion for overfilled networks. The routing module of this protocol is known as Stateless Geographic Non deterministic Forwarding (SNFG) which is executed with another 4 modules in the network layer [16]. Moreover, this module assists in maintaining a desired delivery speed over network and a two-tier adaption is utilized to divert traffic at network layer and regulate the packets sent to the MAC layer at local level. Multi path and Multi SPEED (MMSPEED) is effective to attain higher QoS in Timeliness and Reliability fields. In initial field, this protocol ensures to provide multiple speed options to deliver packets whereas, in second one, the probabilistic multipath forwarding (PMF) is executed to accomplish diverse requirements. Moreover, no network geographic information is required. However, the localized geographic packet forwarding (LGPF) and dynamic compensation are assisted in balancing any local decision imprecisions in the routing path. This protocol is energy efficient as well as scalable. Though, in case of higher load, this protocol is not applicable for fulfilling the demands related to EED.

2. LITERATURE REVIEW

N. D. Tan, et.al (2023) suggested an energy-efficient routing protocol relied on two-level tree-based clustering (EE-TLT) method for stabilizing and deploying the energy of sensor node (SN) efficiently [17]. This method aimed to split the regional network into clusters according to the number of nodes balanced in every cluster. The TLT method was employed to separate nodes into polygons and transmit data through short links. The cluster head (CH) was verified in every polygon, or relay CH node in every sector using the remaining energy and remoteness from participating nodes and base station. Additionally, this protocol was assisted in choosing the precise stage length of transmitting data in each session to maximize the number of data packets towards base station. The simulation results depicted that the suggested protocol was effective to balance energy consumption (EC) among sensing devices along with enhancing the proportion of data packets received in base station and energy efficacy under homogeneous and heterogeneous networks.

S. Tabbassum, et.al (2024) introduced an energy-efficient clustering and intrusion detection system (EEC-IDS) routing method to transmit data in a IOT [18]. The LEACH was designed for effectively transmitting data. The fuzzy logic (FL) and artificial neural networks (ANNs) were put forward to detect intrusions. At first, the information was collected after placing the nodes at random in network and initializing them. For ensuring energy dissipation among nodes, LEACH model was deployed for randomly selecting cluster heads and allocating this part to several nodes depending upon a round-robin management (RRM) method. The interruption was detected for verifying the occurrence of intruders in network. In IOT, a Fuzzy interference rule (FIR) was exploited for distinguishing malevolent nodes from authentic ones. At last, an ANN was distinguished the harmful nodes from suspected ones. The results demonstrated that the introduced system offered an accuracy of 97%, specificity of 97%, and sensitivity of 95%. The utilized methods were suitable to transmit data energy-efficiently.

R. Jia, et.al (2024) presented an energy-saving sensor network node coverage (ESNC) framework for ensuring the coverage of every monitoring point via at least one sensor node [19]. An energy-efficient coverage (EEC) technique was developed relied on improved gray wolf algorithm (IGWA) for optimizing the way to execute sensor nodes (SNs) and making the node coverage effective. The results exhibited that the developed algorithm was robust to optimize the network coverage and offered the coverage of monitoring target points up to 100%. Under the 30-D circumstance, this algorithm was performed well and offered little standard deviation (SD). The given methods were useful for enhancing resource usage, alleviating maintenance costs, and promoting viable growth of Internet of things (IOTs).

Y. Gong, et.al (2022) projected an energy-efficient Query-Driven Clustering (EE-QDC) protocol for making the IOT more energy-efficient [20]. First of all, a size-balanced network partitioning (SNP) algorithm was exploited for dividing huge-scale IOT into diverse minor sub-networks using 5G infrastructure. After that, an estimation-based mechanism was focused on keeping the energy consumption (EC) in centralized sub-network information preservation at lower level. In addition, the centralized QDC algorithms were put forward to cluster query targets, for saving higher EC so that nodes were clustered on a global scale. In the end, an energy-efficient and load-balanced routing (EE-LBR) protocol was employed for inter-cluster routing in every sub-network. The experimental results revealed that the projected protocol was highly energy efficient and assisted in prolonging the duration of network, query success rate (QSR) and energy usage in contrast to other methods in IOTs.

S. Kumar De, et.al (2023) devised an energy-efficient coverage area optimization (EECAO) method in which Minimum Overlapped Full Area Coverage using hybridized Genetic Algorithm-Particle Swarm Optimization (MOFAC-GA-PSO) algorithm was implemented [21]. The fundamental objective was to enhance the coverage area, alleviate coverage holes and energy need. This method overcame these issues at 100% area coverage. They made comparison between the new and the suggested approaches. The devised method offered a coverage rate up to 100% and developed a network whose duration was lasted 11.06 days in comparison with the traditional methods. Furthermore, this method enhanced the coverage area, and lessened the coverage hole and energy need.

K. H. V. Prasad, et.al (2023) intended a secure and energy-efficient clustering and routing (SEECR) method for an edge-assisted IOT setting [22]. This method initially aimed to develop a network depending upon a quad-tree structure (QTS) for maximizing the network efficiency and mitigating the complexity. Thereafter, the LEA (Lightweight Encryption Algorithm) was adopted to validate the sensors leveraging ID and position. This algorithm removed the unauthentic sensor nodes (SNs) to offer higher security. The Tasmanian Devil Optimization (TDO) method was utilized to realize clustering and select the precise cluster head (CH). For alleviating energy consumption, an Improved Twin Delayed Deep Deterministic Policy Gradient (ITD3) algorithm was used to execute duty cycling so that the duration of network was prolonged. Eventually, a game theory-based Generative Adversarial Network (GTGAN) was exploited to establish a multipath routing securely. An emergency message was sent after selecting highest-ranked routes, and the non-emergency message was transmitted after selecting the medium-ranked routes that led to mitigate data loss. The results demonstrated the supremacy of intended method over traditional methods concerning life span of network.

R. Alsaqour, et.al (2022) presented a distributed energy-efficient aggregation protocol (DEECP) for mitigating the energy consumption and prolonging the duration of IOT [23]. The clustering notion was employed for selecting cluster heads (CHs) in accordance with election probability (EP) depending upon the ratio amid lingering energy and average energy of every node. However, this technique was incapable of providing precise solution. Therefore, an optimization threshold (OT) technique was established to select CH on the basis of 3 energy levels of a sensor: lower, higher and super, and compute the distances from base stations (BSs) and possible nodes. The selection of these nodes was done as CHs later on for optimizing the existing method. Diverse metrics, such as dead nodes, alive motes, and throughput were considered to compute the established method. The experiments confirmed that the suggested protocol was effectual to make the network stable and prolong the network's life period.

J. Reyes, et.al (2022) recommended a simple energy-aware routing (EAR) technique based on Game of Life cellular automaton (GoLCA) to offer a homogeneous energy depletion [24]. The duration of network was extended on the basis of distinct factors, like remaining power, overall alive peers, and a sleeping timetable. Finally, a discrete dynamic framework was put forward in which diverse behaviours of IOT were considered via a set of rules along with a varying A-star algorithmic solution. The simulation outcomes proved that the new solution was robust for equalizing energy usage when the life span of network was extended. Additionally, this technique was integrated with path-planning (PP) algorithms for enhancing EC in sparse IOTs.

M. V. N. R. Pavan Kumar, et.al (2022) formulated an energy-efficient Modified-Greedy Perimeter Stateless Routing (GPSR) method for determining the optimal path according to energy consumption and avoiding malicious activity [25]. This method directed the data via incident surveillance nodes, to transmit packets in a reliable way. Hence, this method was assisted in generating an energy-efficient routing (EER) method. Due to restricted memory nodes and battery power, various issues were occurred while implementing this method in IOT. In sensor nodes (SNs), least hop amid source and target node led to maximize energy efficacy and lower latency. The simulation outcomes exhibited that the formulated method was useful to alleviate energy usage and latency which resulted in prolonging the lifetime of SN system.

M. J. Rhesa, et.al (2024) suggested a new Davies-Bouldin K Nearest Neighbor (DBKNN) method and Radial-Adaptive Neuro Fuzzy Interference System (Radial-ANFIS) algorithms for energy-efficient IOTs [26]. Primarily, the utilized nodes were split. Subsequently, this method was focused on extracting node features. The Laplacian Cubic Cheetah Optimizer (LCCO) algorithm was utilized to select CHs leveraging features, and primary approach for nodes' clustering. The next task was to assign weights to every clustered node. The AI-GTBO (Adaptive Intensed Golden Tortoise Beetle Optimizer) algorithm was helped in choosing relay nodes considering weight value. The useless node was detected by inserting analytic output into second algorithm. The NRI-PCA (Newton Raphson Iterative Principal Component Analysis) was executed for transmitting the data to BS. The findings depicted that the presented method was useful for mitigating energy consumption and maximizing throughput and duration of network. This method lessened the energy usage up to 1364J.

3. RESEARCH METHODOLOGY

Deploying network, creating clusters, and routing of data from cluster heads to a central base station are the main objectives of this work. The clustering is managed with the Fruit Fly Algorithm, while Ant Colony Optimization is used for establishing data paths. The following details describe these processes:

1. Network Deployment: - A key requirement for using a clustered wireless sensor network is randomly distributed nodes. This randomness leads to the emergence of cluster heads, which can create various issues. It is crucial to prevent cluster heads from becoming disposable due to their high energy usage. Additionally, cluster heads limit long-distance communication, requiring additional nodes to relay messages. The process for selecting cluster heads is often unplanned and imperfect. The location and condition of nodes can make them difficult to deploy in remote areas of the network, further compounding the problem of unsuitable node selection. Due to the condition of the nodes, there is a mismatch in their availability, making it difficult for them to stay active within the network and almost impossible for them to operate in remote locations. These nodes act as cluster heads when the energy levels within the cluster increase. The original node consumes less energy compared to the sender and receiver nodes. When the system is structured to utilize a wide frequency range efficiently, battery consumption is significantly reduced compared to other nodes. A parent node is selected for each cluster head to isolate functions and increase efficiency. Each sensor node is assigned two value functions to determine its capability, which helps in selecting it as a cluster head. The nearby nodes' average power is determined wr.t. their remoteness from the sink, and the degree of connectivity among nodes creates specific functions. To form a cluster head, nodes with higher degrees need to be generated. These higher degree cluster heads can cover many nodes without requiring costly connections.

2. Cluster Formation: - Once the network is set up, it will be partitioned into clusters in regard to distance. The clustering process is optimized leveraging the Fruit Fly Algorithm. Fruit flies are known for their sharp intellect of smell and keen eyesight, which they use to find food. FOA's advantages are its rapid optimization speed and parameter adaptability, leveraging swarm intelligence to quickly and efficiently adjust parameters. The primary goal of this algorithm is to repeatedly refine the populace of fruit flies in the solution space, driven by a fitness function that serves as an odour concentration decision function. There are normally four steps in this process.

Initialization: This step involves setting the initial parts of the populace of fruit flies, including starting places, dimension of populace, maximal repetitions, starting positions, and size of the step. These parameters allow fruit flies to move toward their aim with arbitrary flying instructions and coverage areas.

$$X(i) = X_0 + Step$$

$$Y(i) = Y_0 + Step$$

In this context, X_0 and Y_0 define the starting location of fruit fly.

Judgment: Use fitness function to measure the concentration of the scent of the fruit fly location

$$Smell\ (i) = Function(S(i))$$

$$S(i) = \frac{1}{Sqrt(X(i)2 + Y(i) \wedge 2)}$$

Movement: This step consists of identifying the fruit fly with the maximal attentiveness within the populace and setting its position as the optimal location. The rest of the fruit flies are then directed to move toward this ideal position, following their starting size of the step.

Iteration: Proceed with steps (2) and (3) until the maximum allowed iterations is reached or the fragrance attentiveness meets the predetermined threshold. The following formula defines the RMSE (root mean square error) selected by fitness function

$$min\delta_R = \sqrt{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2 / n}$$

This formula uses $\hat{y}_i$ to represent the estimated location value, y_i for the distinct location data used in processing, or n for the number of data points and δ_R for RMSE.

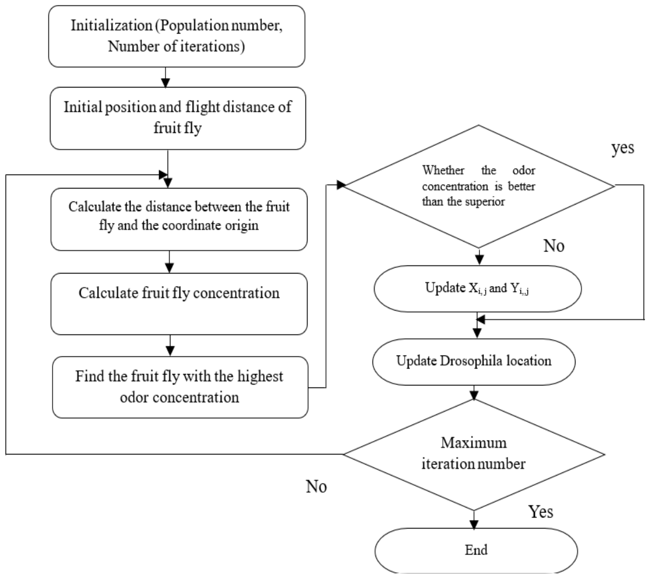

Figure 2: Cluster Forming process using Fruit fly

3. Path Establishment: - The route for relaying data is set from the CH to the sink, and the Ant Colony Optimization (ACO) algorithm is employed to optimize this pathway. ACO is a nature leveraged that emulates the behaviour of factual ants when they look for the most direct route to sources of food. Ants typically follow paths marked by the highest pheromone intensities. The ACO algorithm is a crucial agent-reliant approach that mimics ant behaviour naturally by using cooperative and optimization methods. By imitating the behaviour of ants, ACO rapidly identifies the most direct pathway from a source of food to their end point, even without visual indicators. The ACO algorithm generates solutions over multiple iterations. In each round, several ants develop a complete approach using both heuristic knowledge and the collective experiences from previous groups of ants. The pheromone trail on the solution components represents these cumulative experiences. Following the transition rule, each ant visits different cluster heads, starting from a randomly chosen one. The process of learning is driven by frequently updating the pheromone data.

1. The rule of transition

While navigating route, city r is the primary starting point of the k^{th} ant. The choice of the following city, s, is made from the set of distant cities recorded in J_r^k.

$$s = \underset{u \in J_r^k}{argmax} [\tau_i(r,u)^{\alpha}.\eta(r,u)^{\beta}] if q \le q_0 (Exploitation)$$

The $p_k(r,s)$ is the probability for visiting the new city s.

$$p_k(r,s) = \begin{cases} \frac{\tau(r,s)^{\alpha}.\eta(r,s)^{\beta}}{\sum_{u \in J_r^k} \tau(r,u)^{\alpha}.\eta(r,u)^{\beta}} & if\ s \in J_r^k \\ o & otherwise\ if q > q_0 \end{cases}$$

2. The rule of updating pheromone

The strategy is improved through pheromone trail updates, which involve both local and global updating. The formula for the local trail update is as follows:

$$\tau(r,u) = (1-\rho)\tau(r,s) + \sum_{k=1}^{m} \Delta\tau_k\,(r,s)$$

Here, the pheromone evaporation rate is denoted by $\rho(0 < \rho < 1)$. The quantity of pheromone added to the edge (r,s) by the k-th ant during its tour is represented by $\Delta\tau_k(r,s)$.

$$\Delta\tau_k(r,s) = \begin{cases} \frac{Q}{L_k} & (r,s) \in \pi_k \\ 0 & otherwise \end{cases}$$

In this context, the constant metric is Q while L_k denotes the total distance of the sequence π_k that the ant has travelled.

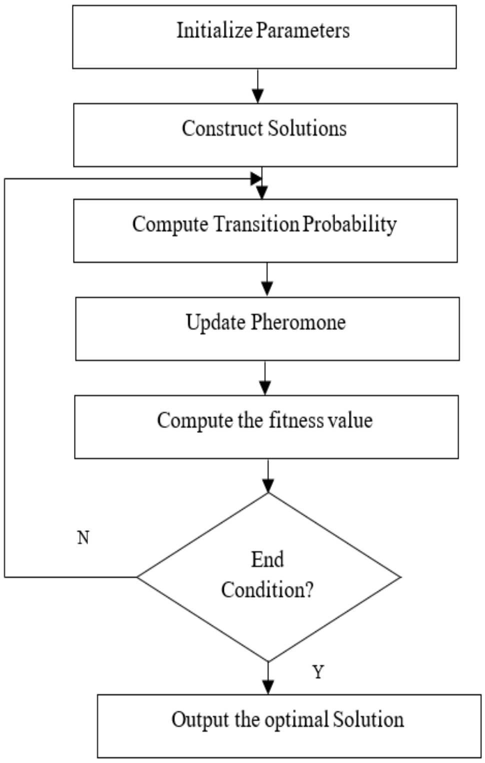

Figure 2: Optimizing Path using ACO

4. RESULT AND DISCUSSION

This project aims to reduce energy requirement in Internet of things and extend their lifespan. Two optimization algorithms, the Fruit Fly Optimization algorithm (FOA) and ACO, are employed for this purpose. The network is segmented into clusters, with a cluster head elected by means of energy level and distance. The cluster head is a node with the shortest distance to the base station and the highest energy within its cluster. FOA is used to form and optimize the clusters. The CH is responsible for transferring data acquired from the cluster nodes to the sink. The ideal path for data delivery is established between two end points (i.e. cluster head to the base station). The ACO algorithm is used to optimize the route between these two points. This work uses both homogeneous and heterogeneous networks to evaluate the devised model. The table 1 presents a list of simulation metrics.

Table 1: Simulation Metrics

Parameter	Description	Value
A	area of network	(0, 0)–(200, 250)
L-BS	BS location	(150, 250)
N	number of nodes in network	100
$E_{initial}$	initial energy of all nodes	0.5 J
E_{fs}	free space channel model	50 pJ/bit
E_{mp}	multi-path fading channel model	0.0013 pJ/bit/m^4
d_0	distance threshold	87 m
E_{DA}	data aggregation energy	5 nJ/bit/signal
DP size	data packet size in bit	4000
CP size	control packet size in bit	200

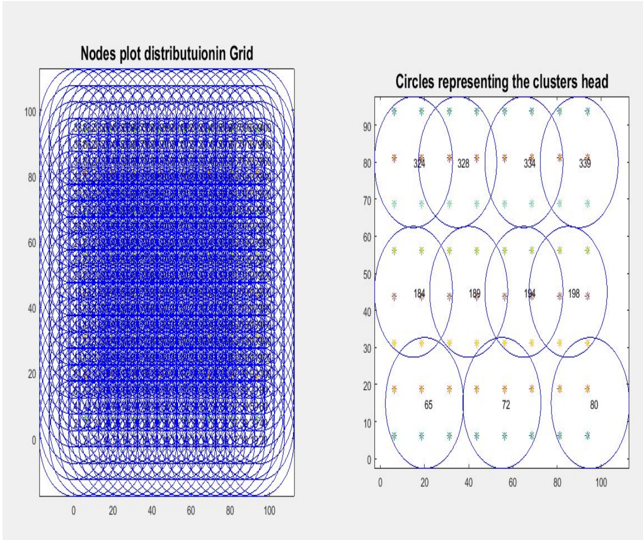

Figure 3: Distribution of Nodes and Construction of clusters

Figure 3 demonstrates the setup of the entire network with a fixed number of nodes. The network is partitioned into clusters, with nodes randomly distributed across it. The figure also shows the cluster heads in each cluster, which are responsible for aggregating data.

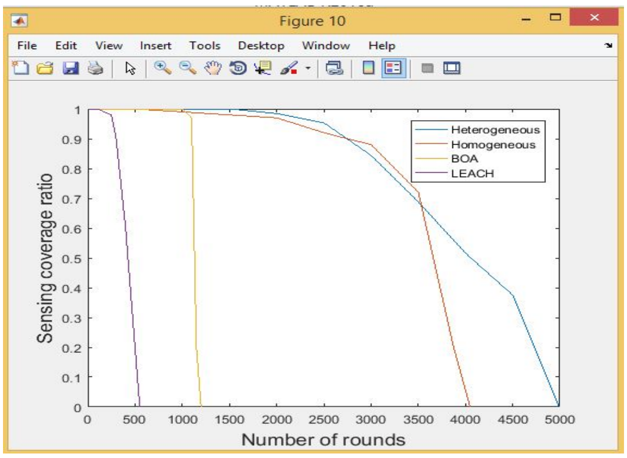

Figure 4: Sensing coverage ratio

Figure 4 shows how sensor coverage ratios from dissimilar algorithms are assessed for evaluating efficiency level. The proposed method and BOA are compared with the LEACH technique in both homogeneous and heterogeneous settings. The analysis indicates that the proposed model achieves better results than the BOA and LEACH protocols in a heterogeneous setting when compared to a homogeneous one.

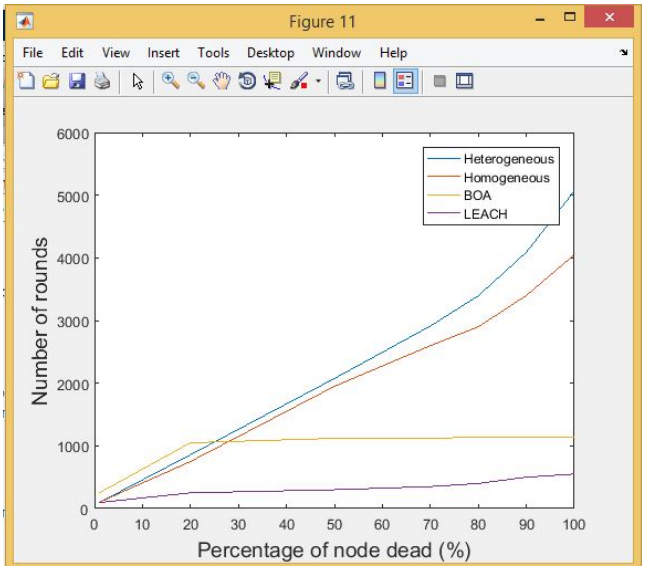

Figure 5: Percentage of dead nodes

Figure 5 compares the percentage of dead nodes in the presented approach with the BOA and LEACH algorithms in both homogeneous and heterogeneous environments. The analysis indicates that the suggested algorithm performs best in heterogeneous settings in comparison to other approaches.

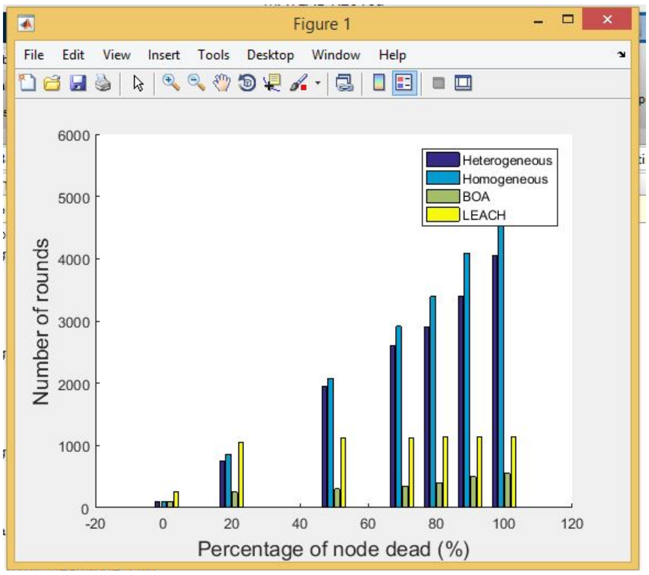

Figure 6: Analysis of Network's Service Period

Figure 6 presents a comparison of the network service period for the presented approach, BOA, and LEACH protocols in both homogeneous and heterogeneous contexts. The results suggest that the presented approach in the heterogeneous scenario outperforms the other approaches in terms of longevity.

CONCLUSION

This work presents a novel approach for IOTs that combines the FFA (Fruit Fly Algorithm) with ACO (Ant Colony Optimization) for cluster creation and pathfinding. The performance of the proposed algorithm is tested in both homogeneous and heterogeneous scenarios using MATLAB tool. The proposed method is compared to two common algorithms: the BOA (Biogeography-Based Optimization Algorithm) and the LEACH. In the context of network longevity and coverage area, the proposed algorithm surpasses both BOA and LEACH expressly in heterogeneous setting. This demonstrates the efficiency of this method in dealing with energy usage and boosting the efficiency and consistency of Internet of things (IOTs), especially in cases where rigorous environmental monitoring is needed..

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