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A Hybrid Approach for Cluster Head Selection in Wireless Sensor Networks Using a Modified Fuzzy-Particle Swarm Optimization Algorithm

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Abstract:

The wireless sensor network (WSN) is extensively utilized in the network for tracking purposes including identifying animals and monitoring, observing the environment, military monitoring, and surveillance of human activity. The clustering strategy based on transmission has a longer life cycle as an outcome of the elimination of data redundancies. The SN is typically split up into numerous categories, each of which has a CH. The detected data is sent to the corresponding Cluster Head (CH) by each base station (SN) in the clusters. Data from cluster SN was collected by the CHs as well as forwarded to the BS. While clusters are being generated, every node is not guaranteed to join a specific cluster. A few individual nodes, which are residual nodes from cluster creation, may still be present in the area being monitored region. To send data straight to the sink node, these nodes have to use more energy. For the path to be created with the best routing direction, these nodes must transmit several control announcements to determine the next ideal hop. The hybrid efficiency in terms of energy distributed clustering (HEED) lengthens the lifespan of a network's connections. Not many nodes in the sensor network are now not a part of any clusters after grouping using HEED. The process used in each cluster formation is the same. The proposed research uses the modified fuzzy particle swarm optimization (PSO) approach for cluster construction and CH election. To prevent the emergence of such residual nodes, grouping is careful. The throughput, latency, and energy consumption efficiency findings of simulation trials show that the technique is better than existing ones. The resulting findings are presented in the outcome sections.

Keywords: Wireless Sensor Network, Energy Management, Routing Protocol, Residual Energy.

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نهج هجين لاختيار رؤوس المجموعات في شبكات الاستشعار اللاسلكية باستخدام خوارزمية الأنماط الضبابية المعدلة والتحسين بمراعاة تأثير السرب الجسيمي

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الملخص
تُستخدم شبكة الاستشعار اللاسلكية (WSN) بشكل واسع في الشبكة لأغراض التتبع، بما في ذلك تحديد الحيوانات ومراقبتها، ومراقبة البيئة، والمراقبة العسكرية، ومراقبة نشاط الإنسان. تعمل استراتيجية التجميع القائمة على النقل على تحسين دورة حياة النظام نتيجة القضاء على التكرارات في البيانات. يتم تقسيم شبكة الاستشعار إلى عدة فئات، وكل فئة تحتوي على رئيس مجموعة .(CH) يتم إرسال البيانات المكتشفة إلى رؤوس المجموعات المقابلة (CH) من قبل كل محطة أساسية (SN) في المجموعات. يتم جمع بيانات المجموعة SN من قبل رؤوس المجموعات وإعادة إرسالها إلى النقطة الأساسية. أثناء إنشاء المجموعات، ليس كل عقدة مضمونة بالانضمام إلى مجموعة معينة. قد تكون هناك بعض العقد الفردية، وهي العقد المتبقية من إنشاء المجموعة، لا تزال موجودة في المنطقة المراقبة. يجب أن تستخدم هذه العقد لإرسال البيانات مباشرة إلى العقدة الباعثة، وبذلك يتعين عليها استخدام مزيد من الطاقة. يجب أن تقوم هذه العقد بنقل العديد من الإعلانات التحكمية لتحديد النقطة المثلى التالية للنقل. تعمل تقنية HEED على تمديد عمر اتصالات الشبكة. بعد التجميع باستخدامHEED ، تصبح العديد من العقد في شبكة الاستشعار جزءًا من أي مجموعات. العملية المستخدمة في كل تكوين للمجموعة هي نفسها. تستخدم البحث المقترح نهج تحسين خوارزمية السرب الجسيمي الضبابية المعدلة لبناء المجموعات واختيار رؤساء المجموعات. يتم اعتبار التجميع بعناية لمنع ظهور العقد المتبقية. تظهر نتائج التجارب المحاكاة للكفاءة في الإنتاج، والتأخير، واستهلاك الطاقة أن التقنية تفوق الطرق الموجودة حاليًا. تم عرض النتائج في الجزء الأخير من هذه الورقة.

الكلمات المفتاحية: شبكة الاستشعار اللاسلكية، إدارة الطاقة، بروتوكول التوجيه، الطاقة المتبقية.

1. Introduction

The environmental conditions of an environment are monitored and recorded by a collective of SN called a WSN, which is geographically dispersed and responsible for this task. WSNs are systems of nodes because they use wireless technology to observe and record information about the surroundings. The information that is collected is arranged at a central location using wireless communications. Gathering information duties in networks can include measuring pressure, temperature, soil moisture, and other physical parameters. Both randomized as well as predictable node configurations can be found in WSNs. Each of the nodes is dispersed randomly (e.g., thrown onto the site) at locations that are challenging for humans to obtain. Low starting power is utilized to charge an enormous number of nodes. Thus, the primary problems which these kinds of networks face are energy consumption as well as network longevity. A base station (BS) processes the data acquired by the nodes before sending it back. A single-hop or multi-hop approach to data transport is possible [1]. The WSN has come to be an amalgam of the most optimistic mechanisms in contemporary society. Through identifying changes made in observing locations, WSN analyses the external environment. Sound, pressure, humidity, vibration, temperature, intensity, as well as motion, are just a few of the variations brought on. In areas like military solicitations and biomedical applications, WSN applications are widely used in numerous systems for monitoring, and environmental surveillance systems [2]. Many of those nodes in the WSN continued to run on batteries, so they were able to be utilized for specialized functions designed to acquire, track, and subsequently distribute knowledge while drowned. Energy management happens to be a crucial topic within the context of the WSN. One of the basic forms of protocols for routing in sensing networking is flat routing, whereas the other is multilevel navigation [3].

Multiple base stations (SN) make up the wireless sensor network (WSN). The study ineffective batteries power those SNs. As a result, node aggregation is essential for delivering the object of load distribution, fault tolerance, and network connectivity. When SNs are separated into groupings based on several factors and a group leader is selected from each group, this process is known as clustered. Single-hop, cluster-based, and chain-based transmission are just a few of the methods that can be used to convey sensed data sent to the BS. Cluster managers (CHs) of the clusters are the people in charge of each of the groups, which is referred to as a group. The cost of intra-cluster interpersonal interaction, the distance that exists between the CH and its participants, the location of the terminals concerning the starting platform (BS), the SNs' remaining energy, and other variables are components that affect how groupings are formed [4]. Monitoring nodes in the CHs, the BS, as well as final consumers are the main components of cluster-based WSNs. Each of the clusters is controlled through the CH, which is under constant contact through the BS. The best choice of the CH method, though, continues to be difficult to implement. The nodes in a network are occupied with node selection rather than interaction, which has an impact on transit performance when CH is frequently selected. There are still unresolved questions on what influences cluster formation and CH communications. In the implementing framework, it is therefore regarded as crucial [5]. When choosing the best CHs for WSNs, functional fitness specification is crucial. No matter the SN's orientation or accessible power, fitness parameters in the existing research have been established with identical or randomized value values. The suggested approach is new in that it computes an ideal fitness value for a particular SN using the remaining energy as well as its proximity to the starting point system. Channeling efficiency is calculated based on the least possible amount of hops, mean load, and distance from gateways and BS, and goal functions are taken into account for optimized grouping and routing [6]. This is crucial for the optimization of energy supplies to optimize the assets in complex systems. Zoning is thought to be the optimum option in this situation as well. The evolution of energy optimization utilizing intelligent models of clustering attracted a lot of study attention because of that. Generally speaking, clustered create CHs when connections are categorized as clustered. Then, the CH collects information from networks that are not CHs, or nodes that are included in the grouping but are not CHs. Following analysis, the information acquired is sent to the BS. In an Internet of Things (IoT) wireless sensor network, the CHs directly communicate data to the BS to shorten the background between them, so consuming less energy [7].

As a way to enhance the efficiency of the normal PSO even more, a modified Fuzzy PSO technique is described in the present research. The main contribution of this research is the creation of a method for specifically tuning the initialization of the coefficients of the conventional PSO. To do this, a fuzzy operator allocates acquiring the coefficients to each particulate throughout each iteration based on the fitness values for that particle along with the total amount of iterations. As a consequence of this, the method produced had a greater capacity for exploitation than the PSO as a whole. To conduct a comprehensive statistical evaluation, seven standard functions for testing were chosen. A total of 28000 computations of each of the competing procedures were performed for respectively of the test operations, which were each conducted in four-dimensional and 1000 instances respectively [8].

Initialize the population in the network model and then fitness it evaluated. Then the population is updated and the cluster head is selected by Modified Fuzzy Particle Swarm Optimization. The chance to take on the role of a CH in the protocol is given to every cluster member. The proposed method can be compared to obtain to enhance performance and robustness. The configuration of this essay is as accompanies: Section 2 contains the related work that is framed to understand the proposed paper with the existing methods while Section 3 elaborates the problem statement. Section 4 depicts the proposed hybrid approach for cluster head selection in WSN using a modified Fuzzy PSO algorithm. The simulation analysis setup is employed to evaluate the proposed hybrid routing algorithm in section 5. Finally, in section 6, the conclusion and future works are presented.

2. Related Works

Using residual power for Internet of Things applications, Behera et al. [9] advocated that cluster-head allotment in WSNs be based on. This article focuses on a useful head-of-the-cluster administration method that alternates choosing the cluster's leader amongst the nodes with the highest energy levels relative to the other nodes. Based on a simulation study, compared to the LEACH protocol, throughput, longevity, and residual energy have all risen by 60%, 66%, and 64%, respectively. The R-LEACH model improves the network's operational life by performing more operations and sending more packets to the BS. As a result of how the CH selection is done in LEACH, the system's span is constrained. Due to its higher energy consumption during chain creation and data transfer from the header to the other nodes, CBDAS places a further burden on battery life. Because the number of zones or clusters in the network influences the network longevity, the zone heading selection techniques used by GHND and IGHND have this drawback. Pitchaimanikam with Murugaboopathi developed a hybrid firefly approach paired with particle swarm optimization to find the environmentally friendly best cluster head for wireless sensor networks. The present study employs a hybrid Firefly Algorithm with Particle Swarm Optimization (HFAPSO) technique to find the optimal cluster heads to choose while utilizing the LEACH-C algorithm. The combined technique improves Firefly's general search behavior by utilizing PSO and gets the optimal cluster head placement. The performance of the suggested approach is analyzed using the number of living nodes, remaining energy, and throughput. Results show that the suggested approach has produced more effective capacity and remaining energy in comparison to the firefly algorithm. As the purpose of selecting the least energy-efficient perfect cluster head, this approach takes into consideration the leftover energy as well as distance among the nodes. The suggested technique is assessed, and the method's efficacy is evaluated [10]. Tyagi et al. [11] developed A Wireless Sensor Network with an Energy Efficient Routing Protocol Using a Two-Level Topology and Next Heading Selection Technique. This Following Cluster Heads (NCH) are chosen throughout the subsection of the Cluster Heads (CH) in this paper using the greatest Residual Energies (RE) of the sensing Node (SN), the smallest base stations (BS) geographical separation, and the ultimate neighbor nodes as the parameters of the network. As a result, the frequent CH decision-making process minimizes energy consumption to increase the network's effectiveness. The network serves as the conduit to facilitate interaction amongst cluster leaders. The other nodes in the system serve as Cluster Members (CM), with a single of the nodes in the cluster acting as a Cluster Head (CH). The method is utilized to maximize the network's CH supply to its fullest potential. The cluster's head or Cluster heads communicated the data to the BS after aggregating all of the information. The computer model shows how the protocols increased network longevity and system efficiency. Rambabu et al. [12] proposed Clustering heading determination for wireless sensor networks using the HABC-MBOA technique, which combines synthetic colonies of bees with monarch butterfly populations. The HABC-MBOA is an essential element in removing the ABC searching technique's shortcomings concerning the prospect of worldwide searching. As a consequence, there no longer exists a chance that the group of cluster heads will be overwhelmed with too many nodes that collect data, which would cause the nodes that collect data to quickly die during the setting up of an ineffective CH selection process. The simulation supported that the network's total amount of living nodes is 18.92% higher than that of the evaluated methodologies for cluster head picking. It could fail to develop a combination of an artificial colony of bees with a bacterium hunting strategy enabling resource stabilized head of cluster determination. Only 92.1% of the data is processed using this approach. Rathore et al. [13] proposed the process of choosing the heads of clusters in this work was approached originally. By using the shortest possible relay network idea, the cluster head selection seeks to reduce energy consumption and prolong the life of the connectivity. To achieve normal energy depletion, the chosen trajectories aggregate begins operation. When a small number of sub-cluster terminals are significantly loaded, this leads to quicker energy consumption. The use of electricity is influenced and determined by the distances between the clusters. As a consequence, the shortest route selection relay methodology causes the intended degradation of resources in each node in the array to produce an interaction with the closest nodes along the shortest way connecting the starting point of the cluster's leaders. Fuzz, as well as bio-inspired methodologies, are not used throughout the implementation of this kind of approach. It was found that the strategy's performance is forty-two percent superior to the MEDC.

3. Problem Statement

Using adaptive algorithms for performing energy-efficient node-based sensor clusters to decrease transmitting use of energy as well as raise the system's overall LT a fitness fiction methodology by taking into account several variables [14]. Because of the network's low sensing concentration and absence of installation knowledge, the approach struggles [15]. It takes a lot of different components to make a clustering method work. In practical terms, centralized management of any kind is challenging for a large sensor infrastructure. For an algorithm for clustering, it has to mainly spread. Following that, there must be a suitable CH deployment throughout the whole observing area so that effective sensor balancing may take place with all nodes, saving power. Furthermore, the procedure for clustering itself includes energy savings. Last but not least, the aforementioned algorithm needs to be able to handle heterogeneity energy-related situations of the said sort. The consistency of the battery's capacity at each node is challenging to guarantee. The amount of power lost while gathering information varies from CH to CH; the number of component groups and the area that is being monitored both contribute to this variation. Because of the different distances to the CH, the mentioned individuals see fluctuations in the amount of energy that is diffused among individuals. Because of the tighter observation and the subsequent updating of the network's execution, the reasoning for changing residual energy across every node that senses is to maximize the longevity of the network [16].

4. Proposed cluster formation: Wireless Sensor Networks using Modified Fuzzy PSO algorithm

To enable better accuracy and energy optimization in WSN, there are typically a lot of difficulties that need to be resolved. Usually, factors like energy, delay, and distance are used to obtain the WSN's CH. Temperatures and load factors are also taken into account with the integration of WSN into the devices. Reducing the distance, delay, load, and temperature while increasing the node's remaining power are the main goals of this effective selection of CH utilizing modified fuzzy-PSO. Figure 1 depicts the suggested CH Selecting Model in geometric form. CHs are typically selected from the essential number of nodes connected to a WSN, though the total amount of clusters may alter. As previously mentioned, the choice of CH in WSN is based on indicators of performance including node distance, delay, and residual energy. Therefore, all other nodes have not been permitted to connect with the BS, and only CHs can expressly do so. As the parameters gathered from both WSN networks are taken into account in WSN-Fuzzy PSO systems, the CH selection becomes more difficult. So, using variables like temperature, load, energy, distance, as well as node delay, a hybrid function is generated. Applying the Modified Fuzzy PSO technique we have suggested, this issue will be resolved. [17]. Figure 1 shows the Proposed CH selection in WSN using the Modified Fuzzy PSO system.

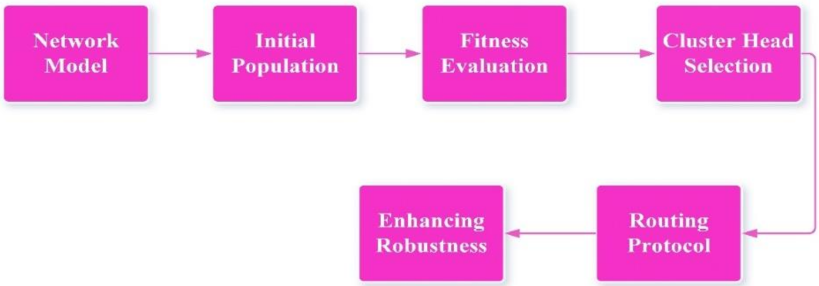

Figure 1. Proposed CH selection in WSN using Modified Fuzzy PSO system.

4.1 Network Model

The WSN model, which consists of a node, is used. The sensor nodes in question are effective in sending the data they have collected to the node that sinks C_s. The consistent distribution of resources, whereby the information is spread using the highest frequency level and with the dimensions of K_n and K_m in meters, determines the data transfer pattern for every sensor node. The nodes with sensors form a cluster that is represented by the letter P_n. The word B_c^ndesignates the matching CH in each of the clusters. CH-oriented networking is a new method for sending data from all of the terminals to the C_s. In this section standard node to CH distance is indicated as di j with the distance between C_s and CH given through d_{HA}. This algorithm's primary benefits are improved endurance and structural information transfer. Regarding the purpose of selecting the best cluster heads, it took fewer limitations into account. Additional constraints are added to the suggested approach to address that problem [18]. Figure 2 demonstrates the Design of the WSN with the proposed CHS shown [19].

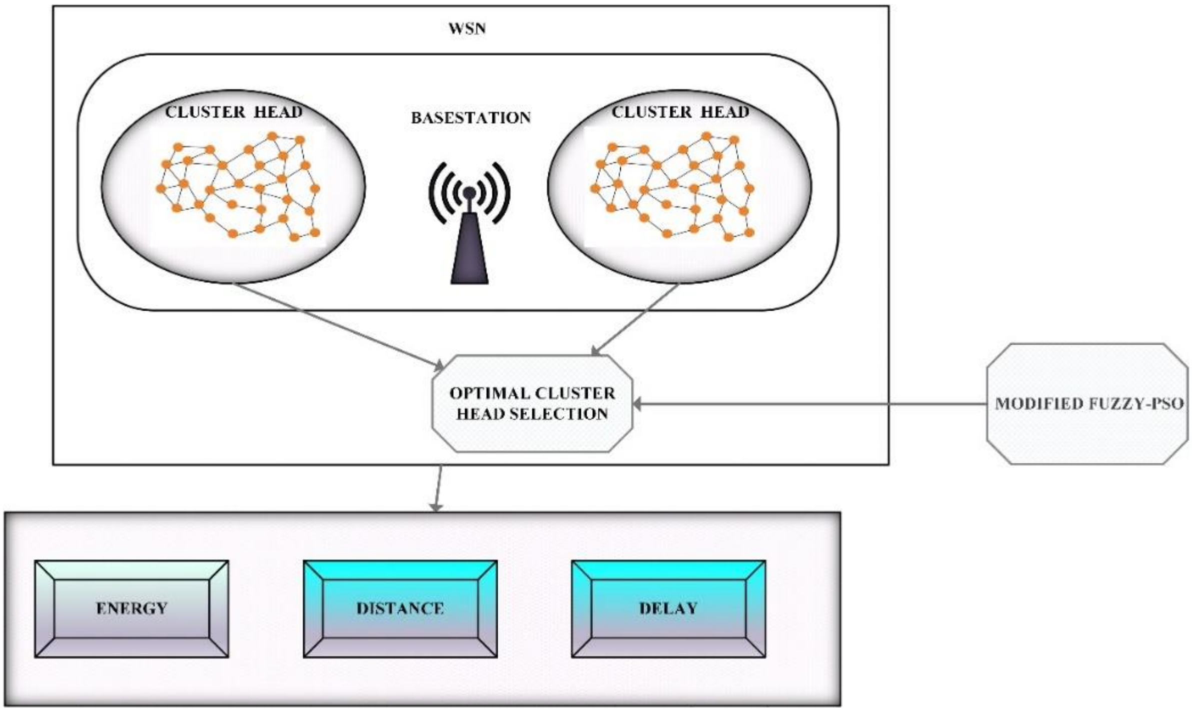

Figure 2. Design of the WSN with the proposed CHS

4.2 Criteria for Choosing CH for WSN

To be able to derive a multi-objective operation, the choice of CH for WSN uses, loading the distance, delay, as well as energy [7] is shown in Eqns. (1), (2), and (3). This approach aims to maximize the normalized energies left in the node by optimizing the load, temperatures, latency, and distance among all possible networks. In this section ω and ρ constant denotes 0.3 and 0.9 [20].

$$O_A = \frac{energy}{load} \tag{1}$$

Eqn. (1) both energy as well as load and energy with temperature ensure that energy is greater and load is smaller. Energy along with temperature also ensures that energy is greater and temperature is smaller.

$$O_B = \frac{\rho}{distance} + (1 - \rho)O_A \tag{2}$$

$$O_C = \omega O_B + \frac{(1-\omega)}{delay} \tag{3}$$

The numerical representation of each of the five indicators of effectiveness is explained in the portion of the article that follows.

4.2.1. Energy

Eqns. (4) to (7) shows how much energy is used. Where $E(S_{ie})$ denotes the energy of ie^{th} node and $E(ch_{je})$ presents the energy of je^{th} CH.

$$energy = \frac{energy(a)}{energy(a)} \tag{4}$$

$energy(a)$ Symbolizes the node with the highest energy and also $energy(b)$ signifies the energy of each node in the cluster.

$$energy(a) = \sum_{je=1}^{A} nE(je) \tag{5}$$

In eqn. (5), n is a constant between [0, 1], and A is the number of nodes in the cluster.

$$nE(je) = \sum_{je=1; ie \in je}^{A} (1 - E(S_{ie}) * E(ch_{je})); 1 \leq je \leq A. \tag{6}$$

Except for the cluster head, i.e. iterates throughout all the regular networks in Eqn. (6), ranging from 1 to A.

$$energy(b) = A * max_{ie=1}^{A} \left(E(S_{ie}) * max_{je=1}^{A} E\left(ch_{je}\right) \right). \tag{7}$$

The energy produced in Eqn. (7) is the greatest while i.e. changes from one to A, and it is used as a source of power for the ie^{th} cluster.

4.2.2. Distance

The mathematical illustration of the distance between each approach, given by Eqn. (8), has a distance (a) quantity that falls inside the range [0, 1]. Distance (a) in Eq. (9), reflects the system's distances between the CH as well as the BS. This is the length between a normal node and that of the CH. Eqn. (10) also relates to the separation between two standard nodes.

$$distance(a) = \frac{distance(a)}{distance(b)} \tag{8}$$

$$distance(a) = \sum_{ie=1}^{B} \sum_{je=1}^{A} ||S_{ie} - ch_{je}|| + ||ch_{je} - BS|| \tag{9}$$

$$distance(a) = \sum_{ie=1}^{B} \sum_{je=1}^{A} ||S_{ie} - S_{je}||. \tag{10}$$

4.2.3. Delay

The mathematical representation of network delay, characterized by the ratio of CH in the WSN and the number of nodes is described by Eqn. (11); the range of network delay is [0, 1]. Fewer nodes in the group as a whole decrease delay in most cases.

$$delay = \frac{max_{je=1}^{A}(ch_{je})}{B} \tag{11}$$

The Lively system receives information regarding the terminals' temperatures as well as load. For the best CH selection, nodes with low temperatures and low loads are taken into account.

4.3 Optimized cluster head selection using the modified particle swarm optimization algorithm

4.3.1 Initial Population

The population's size has been established in CHS-MPSO. Consistent numbers that are random are created as characters for each of the values of Q_k,D_k, E_k, F_k along with their corresponding intervals to build a potentially feasible option (particle). The initial population's representative solutions are operable. Every response from the population passes through the assessment procedure while optimizing fitness [21]**.**

4.3.2 Fitness Evaluation

The fitness value of a solution is determined by evaluating it against the function for fitness. The standard of the particle is indicated by its fitness level. In this article, a brand-new fitness function is created to pinpoint the precise efficacy of the particles generated. Energy intake and performance are influenced by the following factors[22]:

a) Intracluster distance:

The distance that lies between each cluster's CH and its member sensor nodes, collectively known as the intra-cluster distance, is calculated. It has an immediate impact on the non-CH nodes' consumption of energy, which in turn has an impact on the network's lifespan. In other words, the intra-cluster distance is inversely correlated with the network lifespan, hence the smallest intracluster distance increases network longevity.

b) **Residual energy**:

The system's lifespan directly relates to its energy usage. The longer the network lifespan, the larger the sensor node's residual power. Accordingly, the factor of remaining energy and the network's lifetime are directly correlated.

c) Node density and Distance of CH from BS:

Because CH gathers information from the participating networks of every cluster before sending it instantly to the BS, the distance between CH and BS is correlated with the node density for CH in this case. As a result, we employed Pearson's correlation coefficients specified in the Eqn. (20) to determine the connection between both of these variables.

$$r = \frac{m(\sum(ab) - (\sum a)(\sum b))}{\sqrt{[m\sum a^2 - (\sum a)^2][m\sum b^2 - (\sum b)^2]}} \quad (20)$$

The correlation coefficient (r), the number of CHs (m), the nearby node density (a) of each CH and the central CH's separation from the BS (b) are all given in this case.

Utilizing each of these elements, we created a function for fitness that is stated in Eqn. (21).

$$Fitness = r \times \frac{\sum_{i=1}^{N} Residual\ energy(i)}{ICD} \quad (21)$$

The public as a whole prefers the option with the highest fitness.

4.3.3 Population Updating

The Eqn. (24) illustrates the particle's updated velocity in the traditional PSO. These two variables, $C_a$andC_b, are under your control. When the velocity changes following the localized best particle and the global best particle, accordingly, the parameters $C_a$and $C_b$are applicable. The suggested method involves progressively increasing C_b while gradually decreasing $C_a$to move every particle over the whole search space, as opposed to convergent towards a local minimum. Particles later converge upon the global optimum throughout the optimization process.

The values of C_a and C_b thus get taken into account throughout this article concerning the Eqns. (22) and (23)

$$C_a(t) = (C_{am} - C_{bn}) \times \frac{t}{t_m} + C_{an} \quad (22)$$

$$C_b(t) = (C_{bn} - C_{bm}) \times \frac{t}{t_m} + C_{am} \quad (23)$$

The primary source of motivation for the development of the particle swarm optimization technique was animal behavior, particularly that of birds and fish. To choose the optimal outcome, the group members travel across a potentially troublesome area. Every particle's velocity and position can be represented, accordingly, by position as well as velocity vectors having an index value of I. The optimal positions for every single particle as well as among all iterations of components correspond to C_{best} and D_{best}. Based on the chosen fitness function, the velocity and position can be adjusted for every iteration. The following is how the preceding description is represented mathematically[23].

$$New\ Velocity(V): V_A(T+1) = WV_A(T) + \rho_a(C_{best} - X_a(T)) + \rho_b(D_{best} - X_a(T)),\ T=1, 2\ldots d \quad (24)$$

$$New\ Position(X):\ X_a(T+1) = X_a(T) + V_a(T+1) \quad (25)$$

T corresponds to the discrete-time index expression with a range that defines the (d) space of the search dimension. The accelerating factors are ρ_a. The inertia of the value (W), which is used for modifying the orientation, organizes the particle's velocity. Using ρ_a & $\rho_b$throughout each iteration manipulation, the influence of the particle's optimum velocity as well as position can be managed. The velocity restraining approach is used in the context of Eqn. (24) for the objective of controlling. Out-of-range may be achieved by changing eqn. (26) in the manner described below to limit this type of velocity enhancement. The updated location is shown in eqn. (25).

$$V_a(T+1) = \omega[V_a(T) + \rho_a(C_{best} - X_a(T)) + \rho_b(D_{best} - X_a(T))] \quad (26)$$

$$\omega = 2\left(\left|2 - \gamma - \sqrt{\gamma^2 - 4\gamma}\right|\right)^{-1},\ \text{when } \gamma^2 = \rho_a + \rho_b > 2 \quad (27)$$

The constriction factor methodology (CFM) that is indicated by the value of the variable ω is used to modify eqn. (27) in this case. The locations are updated by applying Eqn. (24) after updating each particle's velocity. Each time a solution is iterated, a new population is created by updating all 108 strings from each of the solutions.

4.4 Routing Protocol

The suggested technique takes advantage of hybrid efficiency in terms of energy-distributed clustering (HEED). The initially developed hierarchical routing protocol built on clusters is called Low Energy Adaptive Clustering Hierarchy (LEACH). The chance to take on the role of a CH in the protocol is given to every cluster member. There are presently many different clustering and routing protocols available for the task of effective data collection and transfer. With this approach, power distribution is accomplished by expanding the protocol known as LEACH by employing node degree as well as balance energy as metrics in cluster selection[24]. When communicating between clusters, it operates in multi-hop systems and uses an adaptive transmission power. The primary objectives of HEED are to (i) extend the lifespan of the network by distributing energy consumption, (ii) Complete the clustering process in a predictable number of iterations, (iii) have minimal control above its potential, and (iv) Produce well-distributed CHs with compact clustered. Using a combination of two clustering arguments, the current method in this protocol's implementation randomly selects CHs. To mathematically select an initial set of both CHs, each sensor network's balance power is utilized as the initial argument. The following argument, which is used to dissolve ties, is the cost of intra-cluster communication as a function of cluster density and node degrees. Compared to LEACH grouping, this protocol increases the network's lifespan since LEACH specifically selects CHs, causing some nodes to fail more quickly. The final CHs chosen in HEED are evenly dispersed throughout the network, which lowers the cost of communication**.** Figure 3 represents the architecture of the routing protocol in HEED [25].

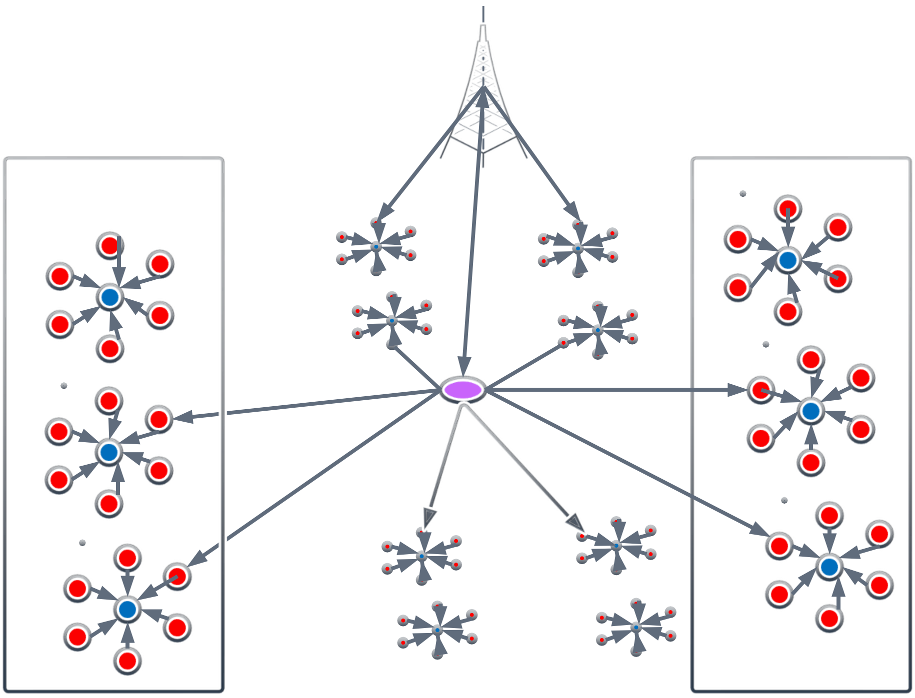

Figure 3. Architecture of routing protocol in HEED

4.5 Energy Management

There's a demand for appropriate solutions for networks that are capable of handling power-related difficulties as energy management has always been a crucial problem for networking. The efficiency of the network's components as a whole is enhanced by its capacity to operate for a longer time and to carry out its tasks effectively. The right control of energy is viewed as the most important aspect of operating the network effectively and dependably. Utilizing sensor resources wisely and extending network longevity are the primary goals of clustering methods. This extends the lifespan and efficiency of the network, and the optimization-based energy-efficient clustering protocol (PSO-EEC) is presented [26]. To select the best CH for the clusters as the relay nodes for sending information to the BS, the suggested method employs the PSO methodology. To select the best CH for overseeing cluster operations, the CH nomination process uses the function of fitness, which takes the energy consumption ratio of nodes in the separation between networks and the cluster head, as well as node degree into account. To conserve energy on the part of the CH, the technique suggested uses relay nodes to transport data gathered by the CH to the BS. A PSO-based fitness function that uses the remaining energy of the CH with the distance that separates the CH from the BS to identify the most suitable CH to execute the relay job selects the nodes for the relay from among the chosen CHs. In the advocated designs, the procedures for CH selection thus relay appointment are energy efficient and conserve system energy [27]. These modifications enable the algorithm to adapt to changing network conditions, improving its robustness.

5. Result and Discussion

The following part evaluates the performance of the proposed approach. The suggested technique is put into practice with the software Matlab. The idea involves building sensor node groupings constantly, accounting for how much energy they have, and optimizing routing schemes to cut down on energy consumption and lengthen network lifetime. The technique's throughput and energy efficiency were compared to those of other recent algorithms in the study to see how well it performs. The graphs for population updating, fitness assessment, and sensor node setup are offered. And the results underline how the recommended approach may help wireless sensor networks function more efficiently and endure longer. The y-axis displays the chance predictions assigned to each sensor node, whereas the x-axis displays the positions of the sensor nodes. Standard sensor node calibration is made up of these two dimensions.

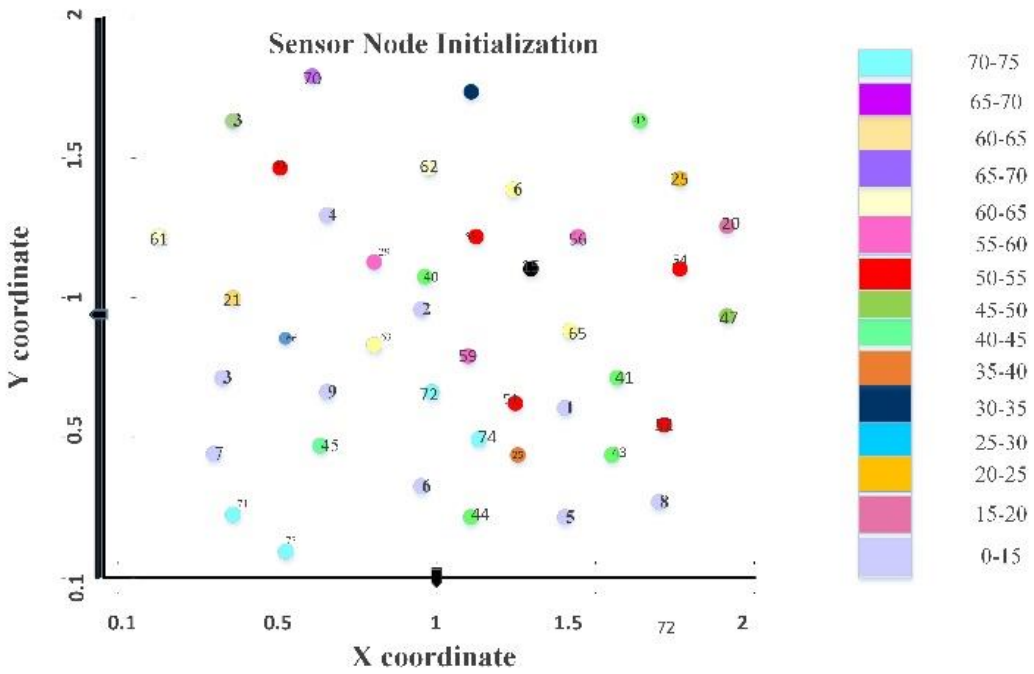

Figure 4. Initial Population

The sensor node's initial graph is shown in Figure 4. Each of the sensor nodes in a network is represented by a location on the x-axis, whereas the graph's y-axis displays predicted probabilities for each value. Every point's size as well as location corresponds to an estimated probability assigned to the related sensor node. Visualizing the total distribution of values for probability among sensor nodes facilitates an understanding of how cluster heads are selected by considering these numbers. In contrast, typical nodes would be designated as extra sensor nodes, and cluster heads should be assigned to nodes with sensors that had probability values below a specific threshold. The starting point of every sense node includes a unique description. The nodes will start grouping according to their proximity to the selected cluster heads as the clustering procedure progresses. Cluster heads are represented in terms of distinct nodes in the network. Cluster generation is finished once each sensor node has been properly assigned to a cluster as well as has its particular cluster head. Figure 5 displays the structure of the WSN that is based on the technique of clustering and cluster creation. It provides an accurate representation of how the structure of the network is clustered.

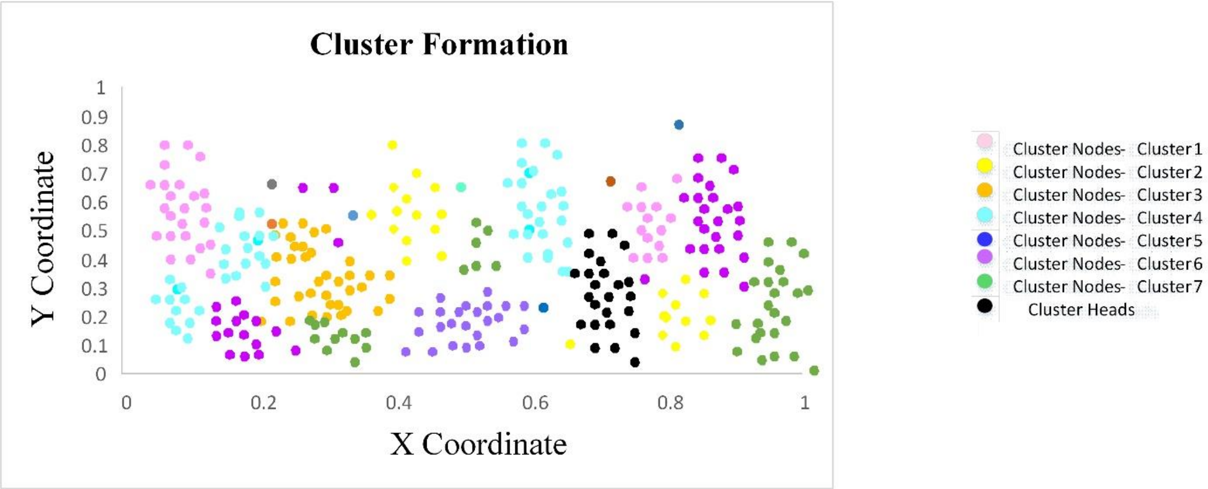

Figure 5. Cluster Formation

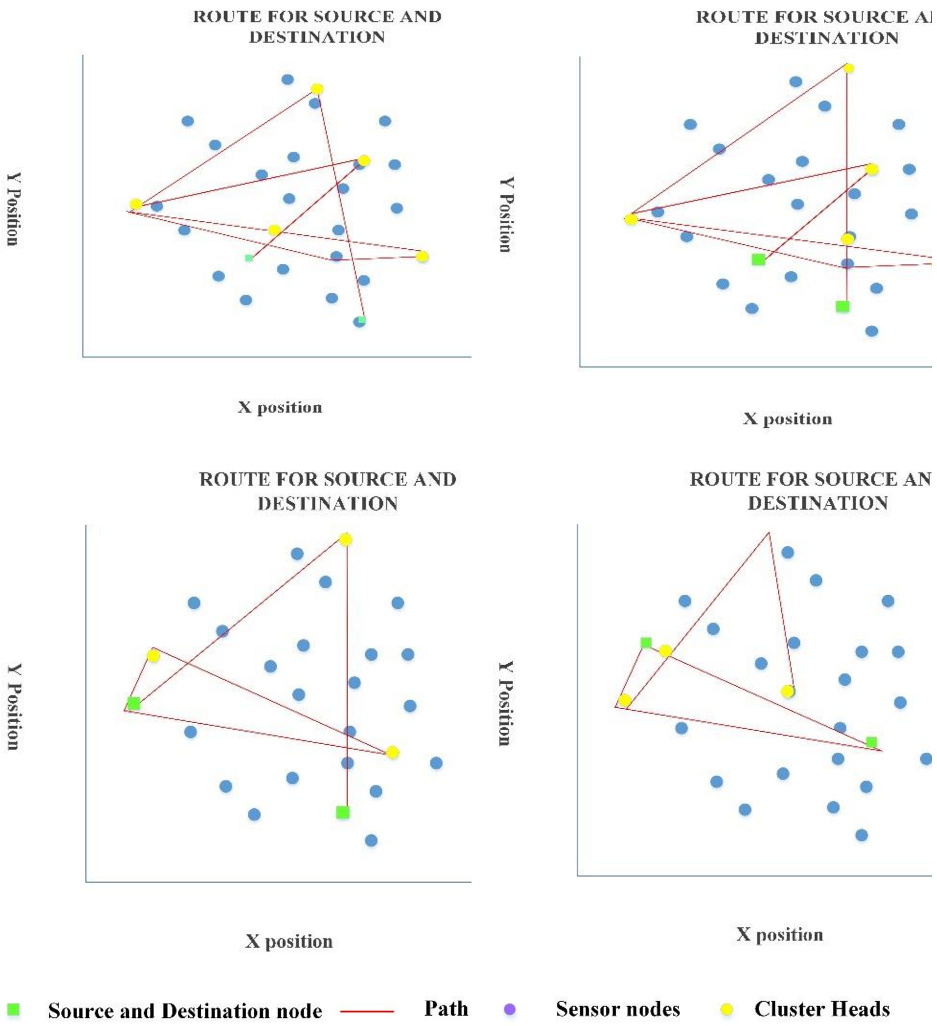

Figure 6. Route for the source (1) to various destination

The path connecting origin (1) to different endpoints is shown in Figure 6 The sensor nodes in a structure are represented by nodes that appear in the graphs that show the path, whereas the cluster heads show the connections amongst the sensor nodes in terms of interactions. The destination nodes (3, 5, 6, 7, 8, and 9) are linked to the initial node (1) via the cluster heads in the image above. The cluster heads' numerical values on the links connecting the nodes are used for illustrating an accurate depiction of the network's grouping.

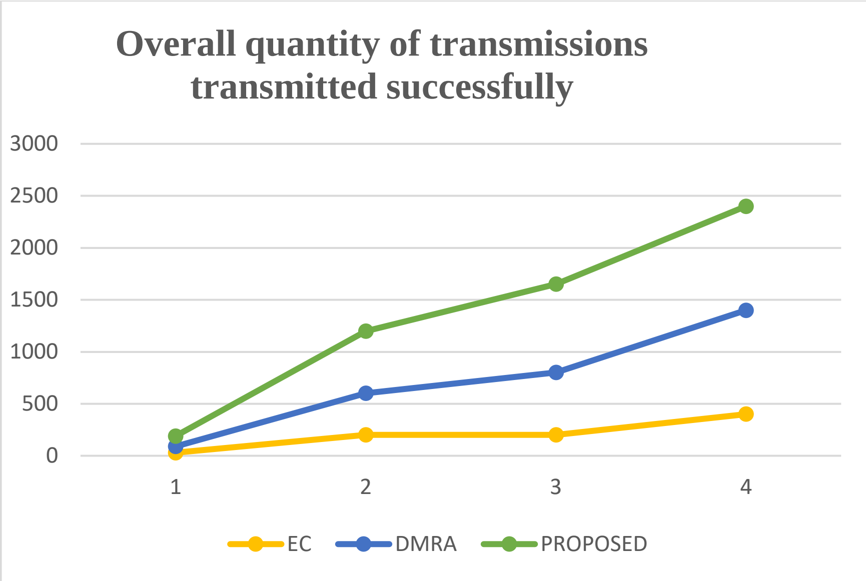

Figure 7. Overall quantity of transmissions transmitted successfully.

In Figure 7, the BS's aggregate number of accepted broadcasts is depicted. The study evaluates the network's capacity using this measure. Knowledge can be transmitted with greater efficiency than with other existing algorithms thanks to the proposed composites routing approach. The proposed method redistributes the cluster master node and nodes which constantly relay data and can equally distribute energy fatigue across different tiers. Energy-efficient Clustering (EC) fails to account for proximity during the relay's choosing operation, whereas Distributed Multihop Routing Algorithm (DMRA) does not consider the remainder of the power of CH nodes. The recommended networking system leverages variable inter-cluster transmission to preserve energy, enabling it to transmit additional data packets to the center station without using the identical beginning storage of energy.

The proposed hybrid routing methodology notably consumes more energy annually if contrasted to other current algorithms. The provided routing approach has a longer lifetime than DMRA and EC and uses fewer resources since it generates unequal groups while minimizing the consumption of energy. Figure 8 displays the overall networks' average energy remained.

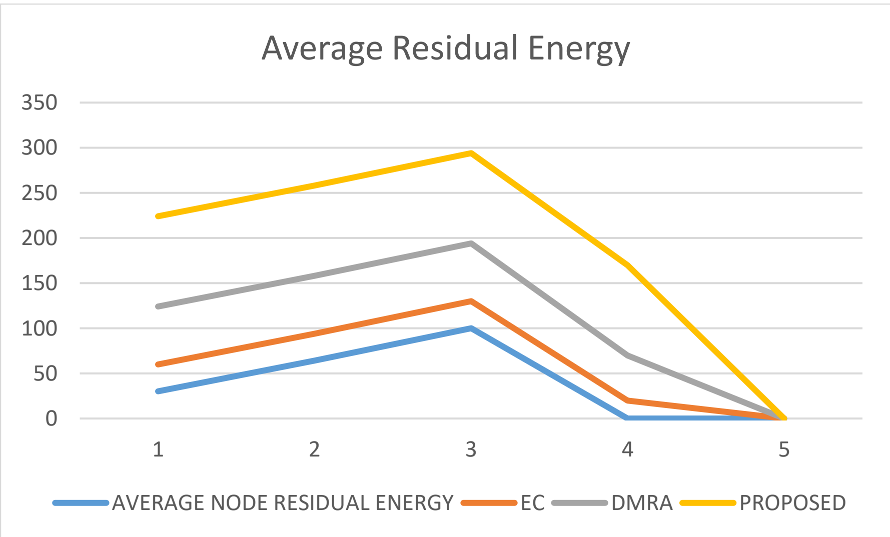

Figure 8. Average residual energy.

Figure 9, shows the alteration in node power is depicted. The greatest energy variance is found after particular nodes have used all of their power. The proposed routing approach has the least variation, which suggests that all nodes' energy usage is decreasing simultaneously. The recommended routing system includes power with duration into the CH node revolutions and dynamic relay selection procedures, which not only conserve energy but also regulate the energy load of various stages. Simply said, the suggested routing algorithm balances the demand for traffic while consuming less energy. As a consequence, the suggested approach excels in terms of extending network longevity and enhancing energy efficiency.

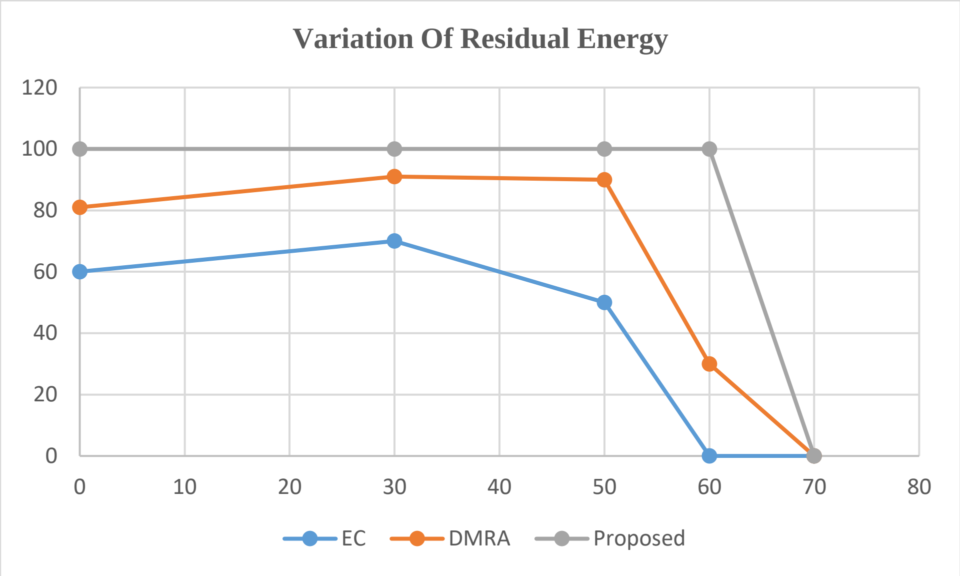

Figure 9. Variation of residual node energy.

6. Conclusions

In this section, it is asserted that the selection of Cluster Heads (CH) in wireless sensor networks (WSNs) can be significantly optimized using a novel approach based on modified fuzzy logic particle swarm optimization. The proposed method employs a modified Fuzzy hybrid PSO algorithm to create groupings, which are then used in the HEED algorithm through a probabilistic approach. By analyzing relevant characteristics and employing optimization techniques, this method enhances the system's performance in terms of throughput, average residual energy, latency, and energy efficiency. Simulation studies demonstrate the superiority of this approach over existing methods, suggesting the potential for a complete transformation in cluster head selection methods. Through this strategy, the WSN network can be improved with the emergence of superior CH. Both the server's presence and throughput experience enhancements due to the proposed upgrades. As a future extension of this research, real-time deployment studies could be conducted. To adapt the method for delay-sensitive applications, modifications would be necessary, and delay could be incorporated as an optimization parameter.

References

[1] A. A. Baradaran and K. Navi, “HQCA-WSN: High-quality clustering algorithm and optimal cluster head selection using fuzzy logic in wireless sensor networks,” *Fuzzy Sets Syst.*, vol. 389, pp. 114–144, Jun. 2020, doi: 10.1016/j.fss.2019.11.015.

[2] K. N. Dattatraya and K. R. Rao, “Hybrid based cluster head selection for maximizing network lifetime and energy efficiency in WSN,” *J. King Saud Univ. - Comput. Inf. Sci.*, vol. 34, no. 3, pp. 716–726, Mar. 2022, doi: 10.1016/j.jksuci.2019.04.003.

[3] M. A. Shroud, M. Eame, E. Elsaghayer, A. Almabrouk, and Y. Nassar, “Challenges and opportunities in smart parking sensor technologies,” *International Journal of Electrical Engineering and Sustainability (IJEES)*, vol. 1, no. 3, pp. 44–59, 2023.

[4] M. Emimi, M. Khaleel, and A. Alkrash, “The current opportunities and challenges in drone technology,” International Journal of Electrical Engineering and Sustainability (IJEES), vol. 1, no. 3, pp. 74–89, 2023.

[5] T. A. Alghamdi, “Energy efficient protocol in wireless sensor network: optimized cluster head selection model,” *Telecommun. Syst.*, vol. 74, no. 3, pp. 331–345, Jul. 2020, doi: 10.1007/s11235-020-00659-9.

[6] M. Rami Reddy, M. L. Ravi Chandra, P. Venkatramana, and R. Dilli, “Energy-Efficient Cluster Head Selection in Wireless Sensor Networks Using an Improved Grey Wolf Optimization Algorithm,” *Computers*, vol. 12, no. 2, Art. no. 2, Feb. 2023, doi: 10.3390/computers12020035.

[7] M. Alazab, K. Lakshmanna, T. R. G, Q.-V. Pham, and P. K. Reddy Maddikunta, “Multi-objective cluster head selection using fitness averaged rider optimization algorithm for IoT networks in smart cities,” *Sustain. Energy Technol. Assess.*, vol. 43, p. 100973, Feb. 2021, doi: 10.1016/j.seta.2020.100973.

[8] A. Mirmohammad Sadeghi, N. Bakhshinezhad, and A. Fathi, “Adaptive Particularly Tunable Fuzzy Particle Swarm Optimization Algorithm,” *Iran. J. Fuzzy Syst.*, May 2019, doi: 10.22111/IJFS.2019.4660.

[9] T. M. Behera, S. K. Mohapatra, U. C. Samal, M. S. Khan, M. Daneshmand, and A. H. Gandomi, “Residual Energy-Based Cluster-Head Selection in WSNs for IoT Application,” *IEEE Internet Things J.*, vol. 6, no. 3, pp. 5132–5139, Jun. 2019, doi: 10.1109/JIOT.2019.2897119.

[10] B. Pitchaimanickam and G. Murugaboopathi, “A hybrid firefly algorithm with particle swarm optimization for energy efficient optimal cluster head selection in wireless sensor networks,” *Neural Comput. Appl.*, vol. 32, no. 12, pp. 7709–7723, Jun. 2020, doi: 10.1007/s00521-019-04441-0.

[11] L. K. Tyagi, A. Kumar, C. K. Jha, A. K. Rai, and V. Narayan, “Energy Efficient Routing Protocol Using Next Cluster Head Selection Process In Two-Level Hierarchy For Wireless Sensor Network,” *J. Pharm. Negat. Results*, pp. 4772–4783, Dec. 2022, doi: 10.47750/pnr.2022.13.S10.578.

[12] B. Rambabu, A. Venugopal Reddy, and S. Janakiraman, “Hybrid Artificial Bee Colony and Monarchy Butterfly Optimization Algorithm (HABC-MBOA)-based cluster head selection for WSNs,” *J. King Saud Univ. - Comput. Inf. Sci.*, vol. 34, no. 5, pp. 1895–1905, May 2022, doi: 10.1016/j.jksuci.2019.12.006.

[13] P. S. Rathore, J. M. Chatterjee, A. Kumar, and R. Sujatha, “Energy-efficient cluster head selection through relay approach for WSN,” *J. Supercomput.*, vol. 77, no. 7, pp. 7649–7675, Jul. 2021, doi: 10.1007/s11227-020-03593-4.

[14] H. Ali, U. U. Tariq, M. Hussain, L. Lu, J. Panneerselvam, and X. Zhai, “ARSH-FATI: A Novel Metaheuristic for Cluster Head Selection in Wireless Sensor Networks,” *IEEE Syst. J.*, vol. 15, no. 2, pp. 2386–2397, Jun. 2021, doi: 10.1109/JSYST.2020.2986811.

[15] A. Shankar, N. Jaisankar, M. S. Khan, R. Patan, and B. Balamurugan, “Hybrid model for security-aware cluster head selection in wireless sensor networks,” *IET Wirel. Sens. Syst.*, vol. 9, no. 2, pp. 68–76, 2019, doi: 10.1049/iet-wss.2018.5008.

[16] R. K. Poluru and L. Kumar R, “An Improved Fruit Fly Optimization (IFFOA) based Cluster Head Selection Algorithm for Internet of Things,” *Int. J. Comput. Appl.*, vol. 43, no. 7, pp. 623–631, Aug. 2021, doi: 10.1080/1206212X.2019.1600831.

[17] A. Lipare, D. R. Edla, and R. Dharavath, “Fuzzy Rule Generation Using Modified PSO for Clustering in Wireless Sensor Networks,” *IEEE Trans. Green Commun. Netw.*, vol. 5, no. 2, pp. 846–857, Jun. 2021, doi: 10.1109/TGCN.2021.3060324.

[18] T. A. Alghamdi, “Energy efficient protocol in wireless sensor network: optimized cluster head selection model,” *Telecommun. Syst.*, vol. 74, no. 3, pp. 331–345, Jul. 2020, doi: 10.1007/s11235-020-00659-9.

[19] T. A. Alghamdi, “Energy efficient protocol in wireless sensor network: optimized cluster head selection model,” *Telecommun. Syst.*, vol. 74, pp. 331–345, 2020.

[20] N. Bhalaji, “Cluster formation using fuzzy logic in wireless sensor networks,” *IRO J. Sustain. Wirel. Syst.*, vol. 3, no. 1, pp. 31–39, 2021.

[21] Q. Bai, “Analysis of particle swarm optimization algorithm,” *Comput. Inf. Sci.*, vol. 3, no. 1, p. 180, 2010.

[22] “Energy efficient cluster head using modified fuzzy logic with WOA and path selection using Enhanced CSO in IoT-enabled smart agriculture systems,” May 22, 2023. https://www.researchsquare.com (accessed Jun. 15, 2023).

[23] C. Dudeja, “Fuzzy-based modified particle swarm optimization algorithm for shortest path problems,” *Soft Comput.*, vol. 23, no. 17, pp. 8321–8331, Sep. 2019, doi: 10.1007/s00500-019-04112-1.

[24] D. Mehta and S. Saxena, “Hierarchical WSN protocol with fuzzy multi-criteria clustering and bio-inspired energy-efficient routing (FMCB-ER),” *Multimed. Tools Appl.*, vol. 81, no. 24, pp. 35083–35116, Oct. 2022, doi: 10.1007/s11042-020-09633-8.

[25] V. Narayan, A. K. Daniel, and P. Chaturvedi, “E-FEERP: Enhanced Fuzzy Based Energy Efficient Routing Protocol for Wireless Sensor Network,” *Wirel. Pers. Commun.*, Apr. 2023, doi: 10.1007/s11277-023-10434-z.

[26] D. Yuvaraj, M. Sivaram, A. Mohamed Uvaze Ahamed, and S. Nageswari, “An Efficient Lion Optimization Based Cluster Formation and Energy Management in WSN Based IoT,” in *Intelligent Computing and Optimization*, P. Vasant, I. Zelinka, and G.-W. Weber, Eds., in Advances in Intelligent Systems and Computing. Cham: Springer International Publishing, 2020, pp. 591–607. doi: 10.1007/978-3-030-33585-4_58.

[27] P. Rawat and S. Chauhan, “Particle swarm optimization-based energy efficient clustering protocol in wireless sensor network,” *Neural Comput. Appl.*, vol. 33, no. 21, pp. 14147–14165, Nov. 2021, doi: 10.1007/s00521-021-06059-7.