Hindawi
International Journal of Distributed Sensor Networks
Volume 2023, Article ID 1362417, 18 pages
https://doi.org/10.1155/2023/1362417

Review Article

Energy Optimization-Based Clustering Protocols in Wireless Sensor Networks and Internet of Things-Survey

Vijayendra K. H. Prasad and Sasikumar Periyasamy

School of Electronic Science, Vellore Institute of Technology, Vellore 632014, India

Correspondence should be addressed to Sasikumar Periyasamy; sasikumar.p@vit.ac.in

Received 2 November 2022; Revised 21 December 2022; Accepted 28 December 2022; Published 13 January 2023

Academic Editor: Antonio Lazaro

Research on popular themes today is mainly concentrated on cutting-edge home applications made up of Internet of Things gadgets. As its principal means of sensing, wireless sensor networks are a component of the Internet of Things. Tracking and monitoring applications benefit from the use of sensor nodes. Every step in the data collection, processing, and transmission processes carried out by wireless sensor nodes takes energy. Small capacity batteries on the sensor nodes in the networks make charging them frequently impractical. Energy optimization is required for sensor nodes since there is no other option but to replace the nodes. Clustering is a well-known and effective solution to increase the energy efficiency of the sensor nodes among the various routing techniques. The closest route between the cluster head node and the base station is thus determined using routing techniques in order to manage energy.

1. Introduction

Ad hoc networks known as wireless sensor networks (WSNs) are crucial in many scientific fields that aim to observe the physical or environmental activities of nature. For instance, sensor nodes in certain locations measure the temperature, humidity, and sound waves [1]. The resources that are available to sensor nodes are exceedingly few. Sensor nodes are naturally sturdy, inexpensive, and small and compact. These tiny sensor nodes, which can transmit data across network nodes, are employed in many remote applications. In Figure 1, it consists of a transceiver, power source, sensing module, ADC, microcontroller, and actuator make up a wireless sensor node. The sensing unit may sense the data utilise the transceiver to broadcast and receive it. The ADC is used to convert analog data to digital data, facilitating communication between the devices. Unprocessed data will be converted into organised data by the CPU, and action signals will be provided by the actuator to the sensor node.

Some of the challenges are energy management, quality of service, and security fault tolerance deployment real-time operation. The sensor node utilizes energy in every process, from sensing the data to processing it and transmitting it. The most challenging limitation by far is energy, as the nodes are, in most cases, powered by batteries [2], which are nonrechargeable in many cases. It requires energy optimization, so clustering is an advanced process to improve the life of the total network. In the clustering process, the sensor nodes form clusters, and the sensor node with rich energy sources is generally elected as a cluster head (CH). When an event or change occurs, the sensor node sends a signal to the cluster head. Then, it will process the data by performing operations like aggregation to further reduce the data redundancy. The data will be sent to the base station, and there are many advantages to clustering, like an improvement in connectivity, a reduction in delay time, and proper load balancing that can be obtained from clustering. Many clustering protocols have been proposed by researchers with various types of optimization techniques that are used to obtain the maximum lifetime of the sensor node. Firefly [3], Grey Wolf [2], Whale Optimization [4], Bat Algorithm [1], and Dragonfly Algorithm [5] are some

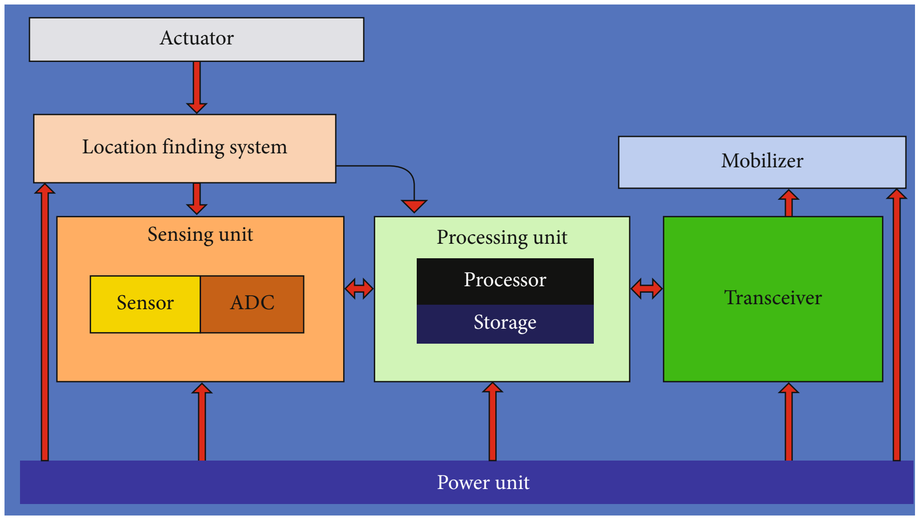

FIGURE 1: Basic components of sensor node.

of the important optimizations. This optimization algorithm optimized the selection process of cluster heads. This help to select the proper cluster head because choosing the correct node to be the cluster head is very important for improving the lifetime because it is responsible for performing many operations in the network.

2. Survey Methodology

This work focuses on the work that was done, and it will be useful for researchers working on the latest trends in IoT and WSN. This survey includes protocols on energy optimization in WSN. Many researchers have concentrated their efforts on clustering because it is a reliable energy optimization scheme. Clustering techniques are classified into subsections, and many researchers rank their protocols according to their operating conditions. Here is an analysis of these clustering protocols covered in the last two decades, starting from where they originated back in 2001, when the first clustering protocol (LEACH) was developed. All the other protocols are derived from and advanced based on those old ones. It is known that, usually, it cannot replace the battery of the sensor node. The researchers were concentrating on improving the energy itself.

3. Clustering Characteristics

The clustering process involves many characteristics and properties to determine a proper cluster formation. There are mainly three characteristics that should be considered here in the process. They are

(1) Cluster properties

(2) Cluster head properties

(3) Clustering process

3.1. Properties of a Cluster. The properties are mainly cluster size, cluster count, and intracluster communication (intercommunication). Cluster size is how nodes form a cluster. The cluster count is how many clusters form in a network, and the intracluster communication can be between the clusters in the network. Intercluster communication is between the group nodes. Which is shown in Figure 2.

3.2. Cluster Head Properties. Cluster head properties are shown in Figure 3, which include mainly node type, the mobility of the cluster, and the role that it chooses to perform. The node which becomes the cluster head is flexible in having the network be homogeneous or heterogeneous in becoming the cluster head, whereas, the mobility of the nodes depends on the requirement of the operation; it can be either mobile or stationary, and the role of the node can be either a relay node which transmits the data or the node which performs the fusion process like data aggregation; the function depends on the operation required in the cluster.

3.3. Clustering Process. The clustering process involves many things, as shown in Figure 4, such as the method for selecting the cluster head, whether centralized or distributed, whether it is a random process or a preset function, or based on the attributes and considering the algorithm complexity, whether it is going to be constant throughout the clustering process or whether it varies according to the requirement and nature of the cluster, whether it is proactive or reactive, and its operation, how it operates either in static or dynamic mode.

Some of the objectives of a clustering process

(1) Scalability

(2) Fault tolerance

(3) Data aggregation

(4) Load balancing

(5) Maximal network lifetime

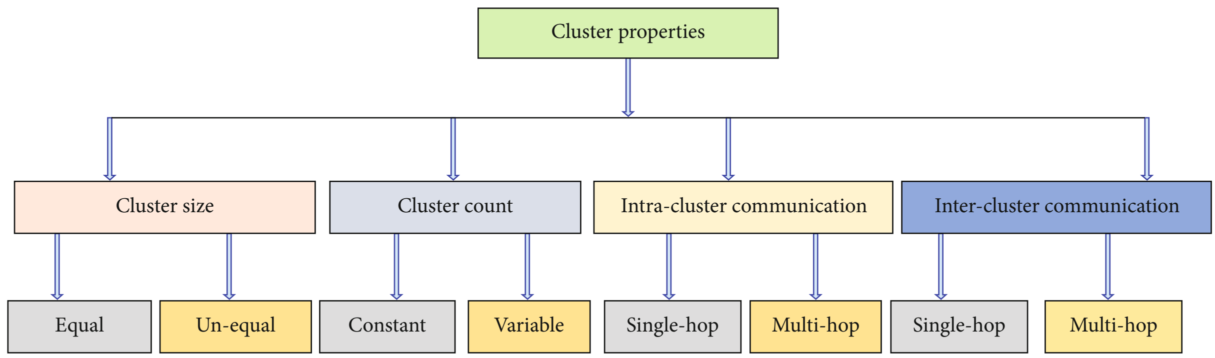

Figure 2: Characteristics of a cluster.

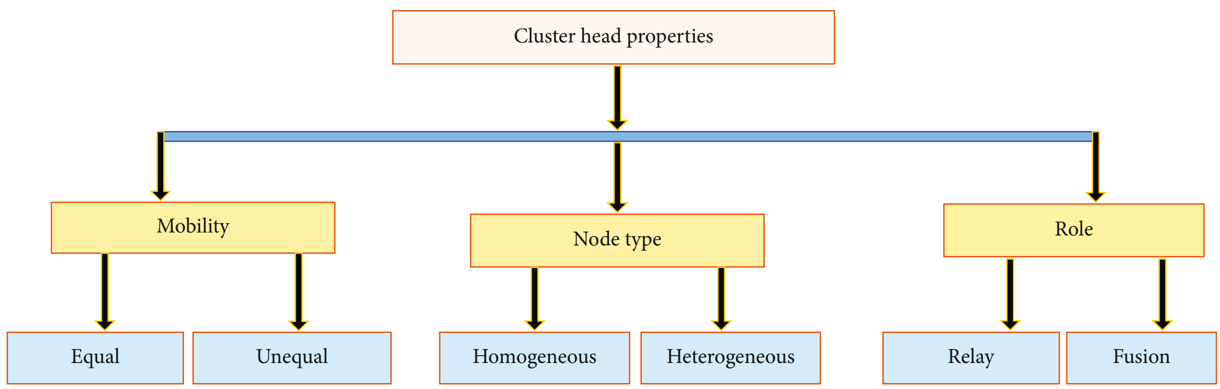

Figure 3: Characteristics of a cluster head.

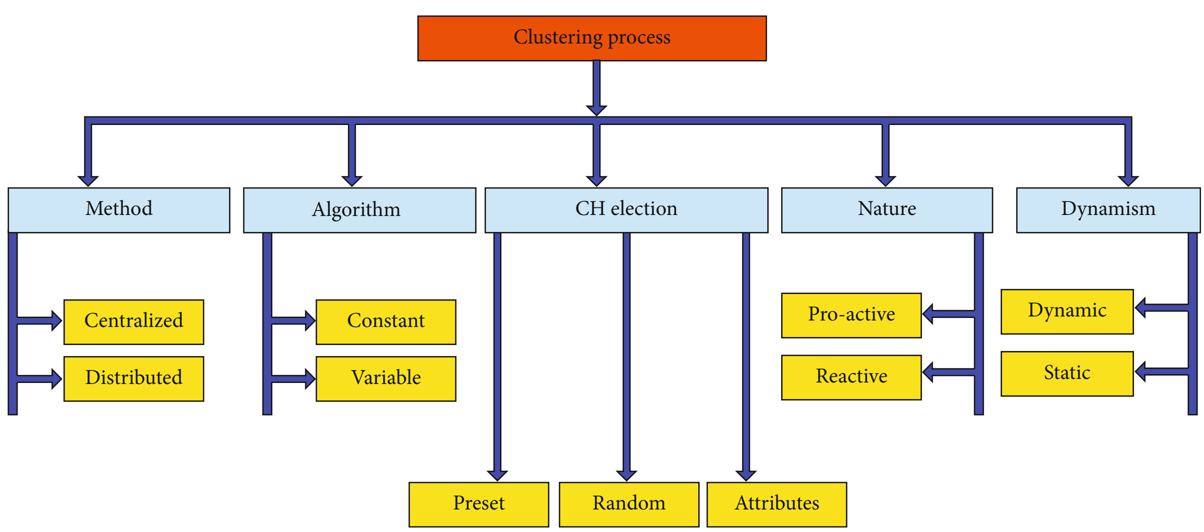

Figure 4: Characteristics of a clustering process.

(6) Stabilized network topology

(7) Increased connectivity

(8) Reducing delay in routing

(9) Avoidance of collision

(10) Sleeping schemes utilization

By considering the above objectives, it can improve the lifetime of the entire network without exhausting the lifetime of the network; hence, if these protocols are to perform some.

4. Classification of Clustering Protocols

The clustering splits into two categories as

(1) Equal clustering

(2) Unequal clustering

4.1. Equal Clustering. In this equal clustering, the nodes form clusters, and the equal name clustering is because the size of the cluster is the same across the network and calculates the number of clusters; here, size refers to the number of nodes in a cluster, in Figure 5, a sample model of equal clustering is shown, and the clustering protocols primarily focus on selecting the cluster head (CH), as it is critical to improving the network's efficiency. There are many methods for CH selection, and researchers have already implemented many protocols based on their ideas, but the optimal solution is still being developed. Equal clustering is classified into three types of clustering.

(i) Probabilistic

(ii) Deterministic

(iii) Preset

4.1.1. Probabilistic Approach. The design obtains the maximum lifetime for the sensor nodes or durability. Here, the probabilistic selection of the cluster head is more random, so it randomly selects the cluster head according to the desired formula. The probabilistic, more specifically, can be categorized as

(1) Random

(2) Hybrid

In the random approach, the design obtains the maximum lifetime for the sensor nodes or durability. Here, the probabilistic selection of the cluster head is more random, so it randomly selects the cluster head according to the desired formula. The probabilistic, more specifically, can be classified as high-energy nodes and selected as cluster heads (CH) using probability techniques. One of the examples of the random protocol is LEACH (low energy adaptive hierarchy) [6], which selects its cluster head randomly and tries to cover all the nodes to become a cluster head accordingly. A hybrid approach selects clusters at random as well as based on a specific formula. In Figure 6, a small list of classifications of protocols is shown.

(1) LEACH (Low Energy Adaptive Clustering Hierarchy) [6]. Key points: it is an application-specific protocol where nodes organize themselves as clusters and using a randomized rotation process, a high-energy cluster head is selected, and the function executes in phases like setup and steady-state. Limitations: it assumes it communicates in the allotted TDMA slot, and all nodes in the network are supposed to be in the range of communication, which affects the scalability of the network.

(2) CCN (Clustering Communication Based on the Number of Nodes) [7]. Key points: in this protocol, it calculates the number of nodes that are nearby to reduce energy consumption. Here, in these four execution stages, take place in Setup Phase, where several nodes are in neighboring, phase 2 determines the CHs, and nodes that try to become CHs send candidacy messages. In phase 3, the nodes that send candidacy messages become CH, and other nodes become non-CH nodes in Phase 4. This creates a TDMA schedule by which CH is executed. Limitations: the main idea behind this is to see a reduction in time delay and energy consumption, but time for calculating the number of nodes and deciding on a cluster head both consume energy.

(3) An Efficient Clustering Strategy Avoiding Buffer Overflow in IoT Sensors: A Bioinspired Approach [8]. Key points: this article mainly concentrates on resource allocation and uses MTCDs (machine-type communication devices). It observes problems like congestion and network overload. MTCD implements a spatial distribution and a Q-learning algorithm that uses the *k*-means algorithm for distributed slot assignments. The main objective of this is to assign the MTCD in a way to reduce intercluster interference, which is obtained by implying a control strategy for slot assignment in the random-access area network. Limitations: previous data flow and cache data of the prior formation of the CH are stored, and thus, they might have an impact on the efficiency.

(4) Clustering Routing Algorithm and Simulation of the Internet of Things Perception Layer-Based and Energy Balance [9]. Key points: it is a clustering algorithm on the IoT, which is an energy-balanced clustering routing algorithm. An energy balance is proposed based on IoT layers. It can achieve the required goal by categorizing the sensor nodes into different types, with N sensors distributed evenly in a square area. The concentration is on areas like the energy balance of network node survival, load balance analysis, total energy consumption, and the number of nodes surviving. This protocol uses a cluster layer aware IoT LEACH classic clustering routing algorithm and considers residual energy and distance between the cluster head and the sink. Limitations: network performance is compared to LEACH [6], and its analysis concentrates only on it. Consideration of the remaining protocols is missing.

(5) Distributed on-Demand Clustering Algorithm for Lifetime Optimization in Wireless Sensor Networks [10]. Key points: the main objective of this research is to maximize the network lifetime. The proposed work includes various processes, namely node deployment, clustering, data collection, and routing. Initially, the nodes were deployed in a distributed manner, and then clustering and CH selection was performed based on the OPTICS clustering algorithm. Here, CH collected the data from the cluster members based on time slots, which allocate the time slot for data transmission. Finally, the collected data was sent to the sink node from CH via the optimal route. Limitations: the random deployment of sensor nodes leads to high energy consumption and poor network management, which increases difficulty during clustering and routing.

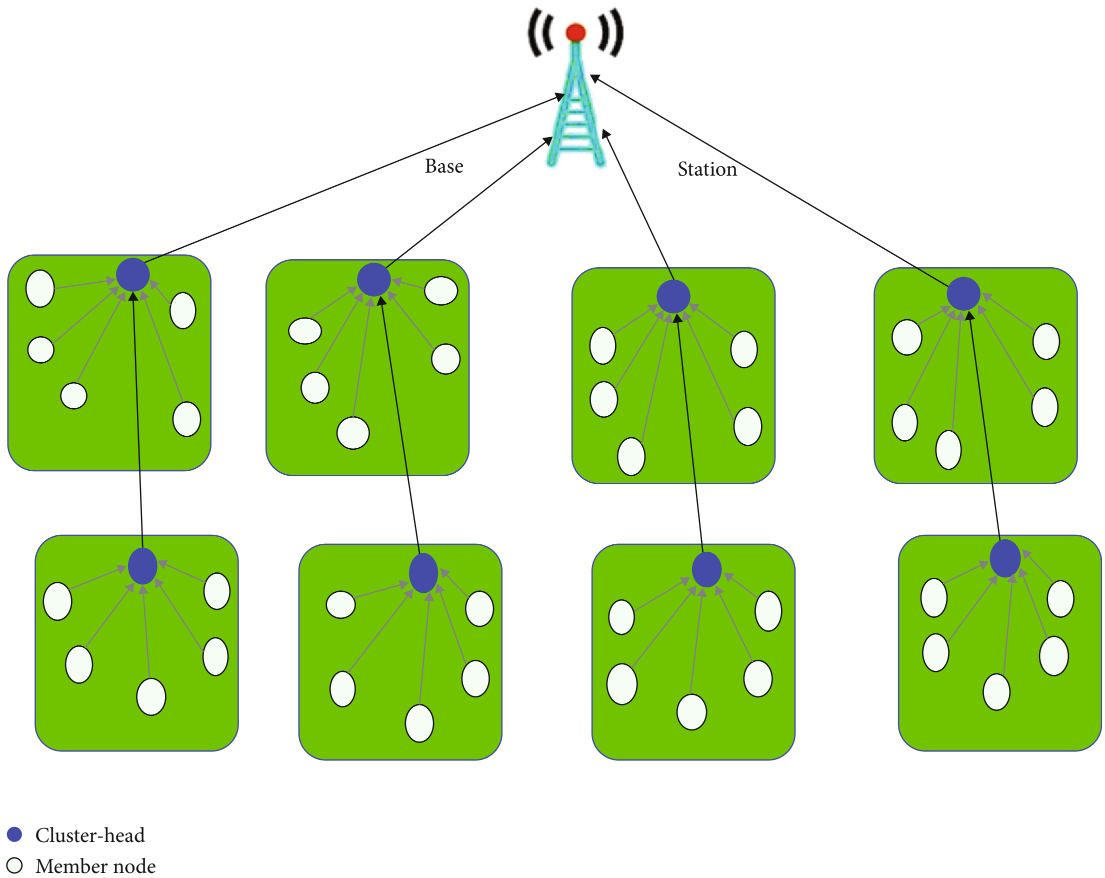

Figure 5: Sample model of equal clustering.

(6) HEED (Hybrid Energy-Efficient Distributed) [11]. Key points: in this protocol, residual energy is considered and calculated during the cluster head selection process, as is neighbor proximity or cluster density, and the concept of temporary (tentative) CHs is considered for protocol operation. Limitations: even though residual energy is taken into account when choosing a cluster head, a node that is not in a cluster or is not being used could be forced to become a cluster head.

(7) ACDA (Autonomous Clustering via Directional Antenna) [12]. Key points: this protocol operates phase-wise, and in the first phase, it determines the primary sensing sectors that perform the sensing task. And in phase 2, cluster heads determine the characteristics of the directional antenna, and in phase 3, the operation of choosing the intercommunication sectors in adjacent clusters and the gateway nodes is determined, and in the last phase, the cluster that forms on all three phases maintains itself as a setup phase. Limitations: without specifying the transmission range of the antenna, it schedules the use of the sensors without considering the power management and directions, and an adaptive method may be required.

(8) Efficient Data Transfer in Clustered IoT Networks with Cooperative Member Nodes [13]. Key points: it operates in multihop communication with the help of the intermediate nodes, and these cooperating member nodes act as cooperators. The problem is choosing the cooperative intermediate nodes for long-haul transmission nodes located near the sink, so they have the opportunity to cooperate and get the benefit. It is an IoT-enabled, socially aware clustering method, and by analyzing the neighbor nodes, Limitations: clusters are formed by taking their IDs and data transmission into account, and the cluster with the highest significant positive score is designated as the CH. Integration of IoT and WSN makes energy consumption higher, so its discussion lags here.

(9) I-SEP: An Improved Routing Protocol for Heterogeneous WSN for IoT-Based Environmental Monitoring [14]. Key points: here, it introduces the intermediate node concept along with normal and advanced nodes, and here, SEP, a variant of the LEACH protocol, is used. A unique threshold strategy makes cluster head selection possible. It avoids unnecessary clusters to save energy. Based on the level of operation of nodes in each iteration, the energy levels are assigned. And to route the data, it uses an advanced technique in the heterogeneous network and controls the energy dissipation. It considers a three-level heterogeneity concerning initial energy node energy. Limitations: this protocol outperforms the standard SEP and other competitive protocols, but it is a stationary design, and the mobile network might have been future work.

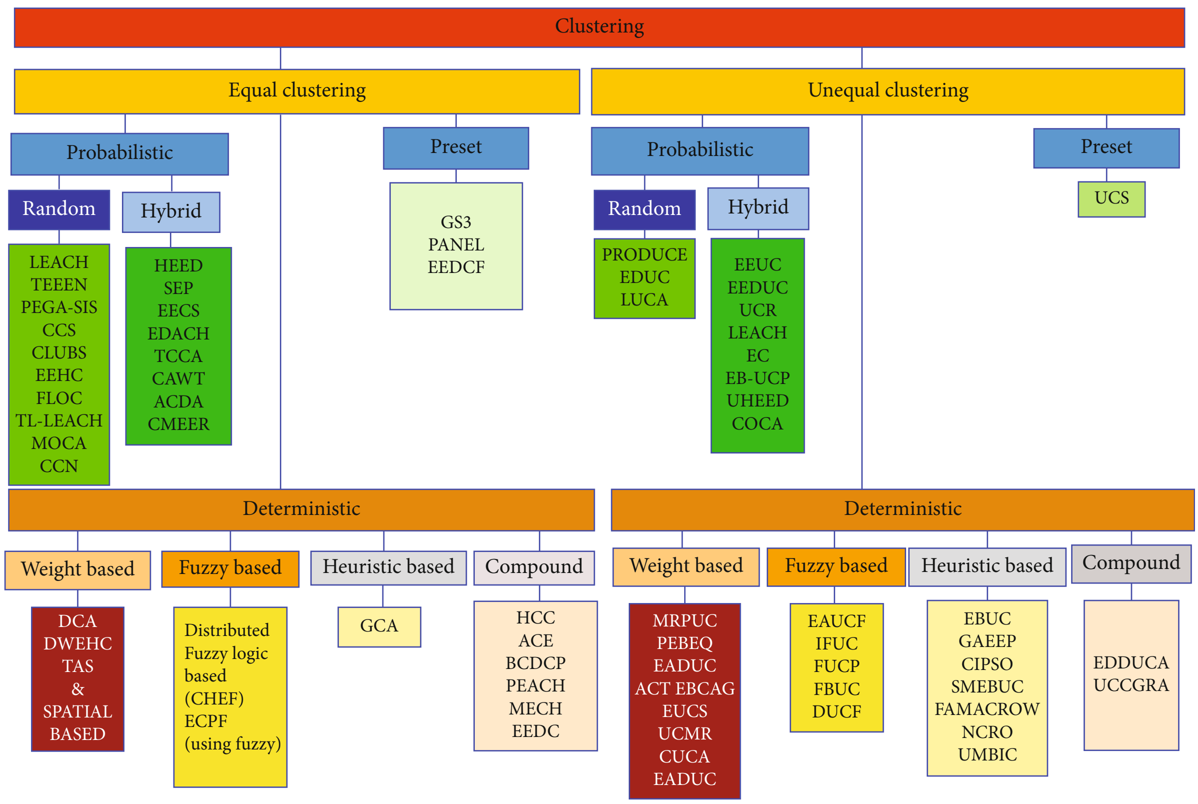

Figure 6: Classification of clustering protocol.

In the following, Table 1, a small analysis of the probabilistic protocols in an equal clustering scenario is conducted.

4.1.2. Deterministic Approach. As the name implies, the approach in this type of clustering is more determined, which means that the cluster head (CH) is determined based on some things like the node's conditions or energy levels, for example, the node's residual energy. In some cases, it also considers location, and in others, it considers the distance from the base station.

(1) DWEHC (Distribution Weight-Based Energy-Efficient Hierarchical Clustering) [27]. Key points: the nodes initially broadcast their (X, Y) coordinates and also calculated the neighbor nodes present nearby, and then the nodes determined how many neighbor nodes were current, and the node with significant weight acted as a temporary cluster head. After each iteration of the rounds, the nodes that still had energy were chosen as real cluster heads, and the nodes that did not have energy were child nodes. Limitations: the selection of a head node in two phases of temporary and real cluster heads and multihop communication may lead to more energy dissipation, which may reduce the overall performance of the network.

(2) A New Blockchain-Based Reinforcement Learning Approach for Distribution and Resource Allocation in Clustered IoT Networks [28]. Key points: this article mainly concentrates on resource allocation. It uses MTCDs (machine-type communication devices). As problems like congestion and network overload exist, it implements a spatial distribution of MTCDs. In a Q-learning algorithm that uses the k-means algorithm for distributed slot assignment, Limitations: the main objective is to assign the MTCD to reduce intercluster interference, which implies a control strategy for slot assignment in the random-access area network. SIR threshold values are the main determinant of the convergence probability. Thus, multiple implementations of various values would be more result-oriented.

(3) Data Transmission Reduction Schemes in WSN for Efficient IoT Systems [29]. Key points: its design reduces unnecessary transmissions and uses two types of schemes: DP (dual prediction) and data compression (DC). It is aimed at exploring new approaches and algorithms for both techniques to improve their performance, where the DP is to exploit the temporal correlation in the collected data from the sensing nodes. A prediction algorithm is executed to collect the data. In DC, it compresses data blocks and assembles them as aggregators, like cluster heads, into smaller sizes so they can be transmitted easily. These are dual prediction algorithms. Limitations: the transmission effect is observed in real-time applications because reducing transmission can affect many things, like bandwidth, energy, and congestion.

(4) CHEF (Cluster Head Election Using Fuzzy Logic) [30]. Key points: every round begins by generating a random number between "0" and "1," and the number should be less than Popt, with the possibility of becoming a cluster head

Table 1: Analysation of probabilistic protocols in equal clustering.

Equal clustering Probabilistic approach Protocol	Year	Key concept	Limitations
Random method			
1. LEACH [6]	2002	Self-organizing cluster head	Scalability
3. PEGA-SIS [15]	2002	Chain formation	Bottleneck
4. CCS [16]	2007	Concentric circles	Global information
5. CLUBS [17]	1998	Fixed integer range [O, R]	Reelection of cluster head
6. EEHC [18]	2003	Volunteer CH	Forced CH
7. FLOC [19]	2004	Inner and outer bands	Waiter timer
8. MOCA [20]	2006	Hop-count	CH-waiting time
9. An efficient clustering strategy avoiding buffer overflow in IoT sensors: a bioinspired approach [8]	2019	MTCDS	Cache data storage
10. CCN [7]	2010	Number of neighbor nodes	Calculation
11. Clustering routing algorithm and simulation of the internet of things perception layer-based and energy balance [9]	2019	Energy balance on IoT layers	Comparison on leach only
Hybrid method			
12. HEED [11]	2004	Neighbor proximity	Idle node as CH
13. SEP [21]	2004	Advanced nodes and ordinary nodes	Coordinates information
14. I-SEP [14]	2020	Intermediate nodes	Stationery design
15. Efficient data transfer in clustered IoT networks with cooperative member nodes [13]	2019	Cooperative member nodes	Integration of IoT
16. EECS [22]	2005	Direct communication	Single hop communication
17. EDACH [23]	2005	Token system for CH	Number of partition segments
18. TCCA [24]	2007	Residual energy	Nonmonitored routing
19. CAWT [25]	2005	Wait-timer	Load balancing
20. ACDA [12]	2013	Phase-wise operation	Power management
21. CMEER [26]	2007	Candidate nodes	Random selection of candidate nodes

calculated by a fuzzy if-then rule, followed by the advertisement of a candidate message, and the node that received the message becomes the cluster head. Energy and the local distance of the node are the two fuzzy parameters for the if-then rule. Limitations: Many external factors may have an impact on the network lifetime, and an optimal fuzzy set is a desirable option.

(5) Refining Network Lifetime of Wireless Sensor Network Using Energy-Efficient Clustering and DRL-Based Sleep Scheduling [31]. Key points: this work proposes zone-based clustering and reinforcement learning-based sleep scheduling in a WSN environment. This work includes three processes: clustering, scheduling, and routing. Initially, zone-based clustering was performed using particle swarm optimization (PSO) and affinity propagation (AP) by considering node degree, distance, and residual energy. Duty cycling was performed based on the Q learning algorithm, which includes three models such as sleep, transmit, and listen. Finally, routing was performed based on ant colony optimization and the Firefly optimization algorithm. Limitations: here, the network was built using a corona structure, which split the network into four parts. Because each part has a huge number of sensor nodes, the real-time environment is very complicated. Hence, the management of sensor nodes was difficult, which resulted in inefficient network management.

(6)GCA (Genetic Clustering Algorithm) [32]. Key points: in this, the main work concentrates on several cluster heads (CH), and it uses a genetic algorithm (GA) in a dynamic approach to determine the cluster head. Limitations: this protocol is intended for cluster load balancing. The central node is in charge here, and the burden may fall on it, and it consumes energy quickly.

(7) An Improved Clustering Algorithm and Its Application in IoT Data Analysis [33]. Key points: many errors that occur during clustering are related to the initial cluster center and rough classification of attributes. The main objective here is to deal with the complicated types of objects in IoT-based applications. It takes into account two types of attributes, numerical and nonnumerical, and determines the initial cluster center using max–min distance, and the

total function includes gradable attributes, categorical attributes, descriptive attributes, mixed data tables, and distance between two mixed data sets, as well as category utility functions. Limitations: more IoT applications-based data sets and the dissimilarity metrics for various attributes can be future research ideas.

(8) Hybridization of Metaheuristic Algorithm for Dynamic Cluster-Based Routing Protocol in Wireless Sensor Networks [34]. Key points: this work proposes cluster-based routing using hybrid optimization for WSN environments. The main objective of this research was to minimize energy and distance during clustering and routing. Initially, clustering was accomplished by devising an optimization algorithm that optimally selects the CH. After complete clustering, routing was initiated by water wave optimization with a hill-climbing algorithm based on distance and energy parameters. Limitations: here, clustering was performed based on the brainstorm optimization algorithm, which considers distance and energy when selecting the optimal CH, which is not sufficient for optimal CH selection and reduces the communication reliability. In addition, static CH selection also leads to energy depletion that increases data loss.

(9) HCC (Hierarchical Clustering Control Scheme) [35]. Key points: this protocol uses a centralized graph cluster algorithm. Any node is capable of initiating the BFS tree in the cluster. In BFS tree clusters, every node tries to find its subtree size and child information in the tree, and the subtree size information aggregates the trees to the root. Limitations: Due to the tree formation, subtree node calculation, and node selection, the network stability of this is questionable.

(10) Dynamic IoT Device Clustering and Energy Management with Hybrid NOMA Systems [36]. Key points: it uses NOMA (nonorthogonal multiple access) to design a superimposed coding, and the transmitter assigns different powers to various IoT devices. A dynamic cooperative framework is used from the fog layer to the IoT device layer using NOMA, designed to reduce system complexity and delay IoT devices. A closed-form power allocation results in each cluster. It solves the power allocation problem in each cluster using NBS and achieves high efficiency and fairness. A downlink NOMA system is considered, which consists of one fog node and multiple IoT devices. Limitations: while designing clustering techniques in the protocol must consider multiple IoT devices.

(11) Collision-Aware Routing Using Multiobjective Seagull Optimization Algorithm for WSN-Based IoT [37]. Key points: this research proposed an optimization algorithm, namely multiobjective seagull optimization, for routing in a WSN-enabled IoT environment. Here, a seagull optimization algorithm was proposed for the clustering and routing process. Initially, CH selection was performed by considering residual energy, network coverage, node degree, and communication cost. After selecting the optimal CH, routing was performed by considering queue length, communication cost, link quality, and residual energy. Limitations: here, optimal routing was performed based on queue length, communication cost, link quality, and residual energy, which selects the optimal path; however, it leads to less throughput and a high packet loss rate due to the lack of physical security of the nodes.

In the following, Table 2 conducts a small analysis of the deterministic protocols in an equal clustering scenario.

4.1.3. Preset. In this approach, before deployment, the base station or sink node decides the cluster formation based on the energy levels, and the clusters are also assigned, and the cluster heads decide themselves, so this method is not very practical in practice, and in many cases, these are deployed in the form of chains or concentric circular shapes based on the requirement.

(1) GS^3(A Distributed Algorithm for Scalable Self-Configuration and Self-Healing) [47]. Key points: there are two types of nodes to be formed in this protocol. One is known as system nodes and perturbations and distributes system nodes. In a 2D plane, two types of nodes are present, small and big nodes, where the large node acts as an access point for the small nodes and initiates the nodes. Self-configurable and self-healing processes. Limitations: while the protocol design is to self-heal, the protocol assumes that nodes are aware of their local position, which in practice may lead to questioning the ability of the protocol.

(2) PANEL (Position-Based Aggregator Node Election Protocol) [48]. Key points: this protocol uses the position of the nodes geographically and selects some nodes as the aggregators, i.e., nodes that have an awareness of their geographical condition; it computes a reference point, and the node nearer to the reference point is selected as an "aggregator." Limitations: This protocol has a process of selecting a reference point, an aggregator, and the aggregator, the cluster head. As a result, the complexity increased significantly, and energy consumption increased.

(3) EEDCF (Energy-Efficient Deployment and Cluster [49]. Key points: this protocol operates by taking into account attributes such as the energy of individual nodes and the signal range of nodes, as well as terrain while implementing it. Two types of nodes are considered that are different in magnitude and have different energies, and they are implemented in grids. Limitations: the suggested protocol is very feasible in general applications like civil applications, but when it comes to complex applications like military or vigilance applications, these are facing challenges.

(4) An Enhanced Heterogeneous Gateway-Based Energy-Aware Multihop Routing Protocol for Wireless Sensor Networks [50]. Key points: this work proposed an energy-efficient routing protocol for the WSN environment. The proposed work includes two phases, such as the setup phase and the steady phase. In the setup phase, the network was divided into four regions based on the distance threshold. The selection of CH was performed by considering regions three and four based on residual energy. For reducing energy

Table 2: Analysation of deterministic type of protocols in equal clustering.

Equal clustering Deterministic approach Protocol	Year	Key concepts	Limitations
Weight based			
22. DCA [38]	1999	Message-driven protocol	Time complex driven
23. DWEHC [27]	2005	Temporary CH	Not considering the power of nodes
24. TASC [39]	2005	2-Hop neighborhood design	Communication messages
25. SPATIAL [40]	2011	Dominator and dominatee	Information representation
26. A new blockchain-based reinforcement learning approach [28]	2019	Spatial distribution of MTCD's	SIR threshold values only
27. Data transmission reduction schemes WSN for efficient IoT systems [29]	2019	Dual prediction (DP) data compression (DC)	It affects bandwidth and energy
Fuzzy based			
28. CHEF [30]	2008	Fuzzy if-then rule	The impact of external factors
29. ECPF [41]	2012	Central and degree of node	Unaware of location
Heuristic-based			
30. GCA [32]	2007	Genetic algorithm	Heavy burden on a central node
31. An improved clustering algorithm and its application in IoT data analysis [33]	2019	Numerical and nonnumerical attributes	Limited attributes consideration
Compound based			
32. HCC [35]	2001	Centralized graph algorithm	Network stability
33.ACE [42]	2004	Clusters spawning	Complexity of messages
34. BCDCP [43]	2005	Base Station operated	Scalability
35. Dynamic IoT device clustering and energy management with hybrid NOMA systems [36]	2019	NOMA for superimposed coding	Lack of multiple IoT devices
36. PEACH [44]	2005	Adaptive cluster formation	Not considering energy level
37. MECH [45]	2006	Back-off timer	Ignoring the energy levels of nodes
38. EEDC [46]	2007	Two-tier hierarchy	Application in WSN is questionable

consumption, a hole-removing algorithm was proposed in this research. Limitations: here, data transmission was performed by considering an energy threshold, which leads to high-security threats because the data was shared through a public channel without considering any security constraints.

In the following, Table 3 conducts a small analysis of the preset protocols in an equal clustering scenario.

4.2. Unequal Clustering. In equal clustering, the formed clusters are equal in size everywhere in the deployed field, so there are possibilities for a situation called a "hotspot problem." So, what is a "hot spot?" The cluster heads located near the base station have a higher burden because they handle more data traffic. The cluster head located near the base station does more data aggregation and processing than the CHs located far from the base station because it transmits data from other cluster heads as well as data that it has collected on its own, which must be processed simultaneously, causing the cluster head to consume more energy.

To overcome the hotspot issue, it uses unequal clustering. In Figure 7, a sample model of unequal clustering is shown. Here, based on the distance from the base station, the cluster's size varies. Suppose it is far from the base station. Its size increases. If it is near the base station, its size decreases, which reduces the hotspot problem. Many present-day protocols focus on designing unequal clustering. It also classifies into three types of clustering approaches like

(1) Probabilistic

(2) Deterministic

(3) Preset

4.2.1. Probabilistic

(1) PRODUCE (Probability-Driven Unequal Clustering Mechanism) [51]. Key points: this protocol concentrates multihop routing on stochastic geometry. The base station is at the center and broadcasts the message "hello" to nodes at a distance of one hop. The node receives the message from BS, approximates its distance, and decides whether to join the cluster or not based on signal strength. Limitations: this protocol considers the ideal conditions, like the ideal mac layer, and it determines the cluster head before the deployment conditions, and the protocol concentrates on comparing with EEUC [52].

Table 3: Analysation of preset type of protocols in equal clustering.

Preset Protocol	Year	Key concepts	Limitations
39.GS^3 [47]	2003	Pertibute and distribute	Assumption of awareness of location
40. PANEL [48]	2007	Aggregators	Increase in complexity
41. EEDCF [49]	2009	Grid-implementation	It cannot be used in complex operations

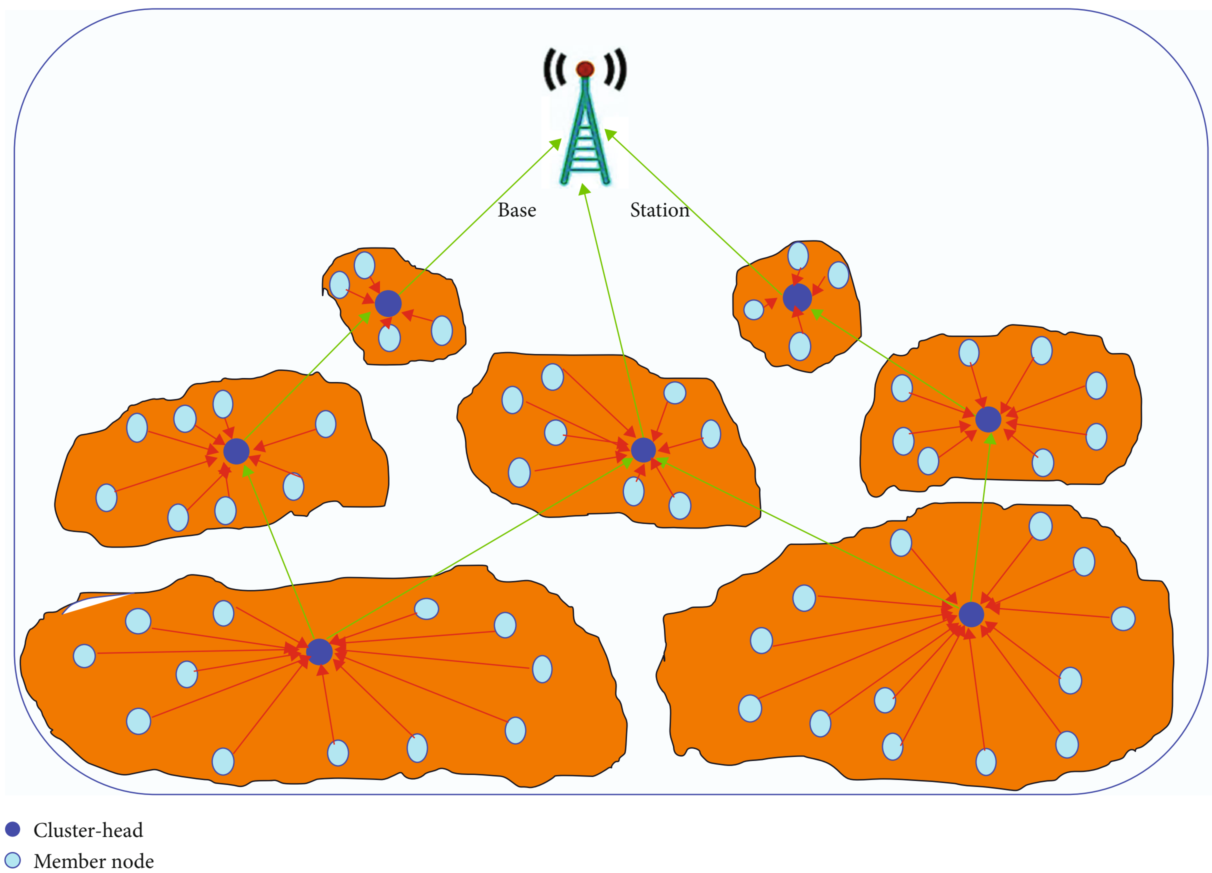

Figure 7: Sample model of unequal clustering.

(2) Hybrid Optimization Algorithm for Security-Aware Cluster Head Selection Process to Aid Hierarchical Routing in Wireless Sensor Network [53]. Key points: this work proposes secure clustering and routing using hybrid optimization methods in a WSN environment. Here, cluster-based routing was performed by using a hybridization of whale optimization and grey wolf optimization, which selects the CH optimally based on distance, energy, security, and delay. The security of the CH was calculated by qualitative fuzzy logic, which provided five classes of security, such as low, very low, medium, high, and very high. Limitations: here, trust values were calculated based on fuzzy logic, which provides only an approximate result that reduces security. In addition, the calculated trust values were stored in a public manner, which leads to poor security because it can easily be compromised by attackers.

(3) EEUC (Energy-Efficient Unequal Clustering) [52]. Key points: this protocol is used for data gathering applications periodically, it uses a localized competition to select the head nodes, and it is a message-driven process, and the tentative cluster heads are elected, and from that, CH node which is deserving, tries to be the final cluster head, and they broadcast compete_head_message, and if it receives a better signal, it sends quit_election_message and joins as a regular node. Limitations: the protocol, however, has promising features, but the scalability of the network is unaddressed.

(4) COCA (Constructing Optimal Clustering Architecture) [54]. Key points: this protocol carries out the process in several repetitive rounds. At the beginning of each communication round, the reconstruction of clusters occurs, and the cluster heads are reselected. Here, a message is broadcasted

Table 4: Analysation of probabilistic protocols in unequal clustering.

Unequal clustering Probabilistic approach Protocol	Year	Key concept	Limitations
Random method			
1.PRODUCE [51]	2008	Centered base station	Predetermined cluster head
2. EDUC [56]	2008	Timer based operation	Single hop message
3. LUCA [57]	2011	Random back-off timer	Sleep of nodes
Hybrid method			
4. EEUC [52]	2005	Compete_head_message	Scalability
5. EEDUC [58]	2008	Waiter time	Noise-signal intervention
6. UCR [59]	2009	Beacon signal	Noise error
7. LEACH (UNEQUAL) [60]	2010	AOW (adaptive on weight)	Not for small applications
8. ECC [61]	2011	Probability scale of CH	Delivery speed
9. EB-UCP [62]	2009	Compete_message	Many assumptions
10. UHEED [63]	2012	Competition radius formula	Energy consideration
11. COCA [54]	2013	Reselection of clusters	Frequency of cluster head rotation

to construct a basic cluster topology for certain transmission rounds and cluster head selection. Nodes transmit their residual energy first, then use signal strength to calculate distance. They join by pairing with the nearest node. Limitations: the selection of a CH, formation of clusters, and design of routing did not address the decision on cluster head rotation frequency, and finding an optimal value for large-scale networks is another challenge that is also a limitation.

(5) An Enhanced Energy Proficient Clustering (EEPC) Algorithm for Relay Selection in Heterogeneous WSNs [55]. Key points: in this work, the authors propose an approach to increasing the energy efficiency of WSNs by performing clustering-based relay selection. Initially, network construction is performed with static and mobile nodes. After constructing the network, cluster head selection was performed. Static nodes broadcast their information to all mobile nodes. Mobile nodes select the suitable cluster head based on its location and level of energy. Relay node selection was performed using an enhanced energy-efficient algorithm. Limitations: here, static nodes are selected as relay nodes to transmit aggregated data to the base station. However, a lack of transmitting power and the network's static nature increase energy consumption and cause transmission delays, lowering the packet delivery rate.

In the following, Table 4 conducts a small analysis of the probabilistic protocols in an unequal clustering scenario.

4.2.2. Deterministic (Unequal)

(1) MRPUC (Multihop Routing Protocol with Unequal Clustering) [64]. Key points: it operates in rounds that follow the distributed method and phases, like the setup of the cluster and multihop routing and formation, and sees the transmission in each stage. During deployment, the base station broadcasts a BS-ADV message, and the nodes calculate distance; nodes with the highest residual energy will be preferable as a CH. Limitations: though the protocol outperforms the HEED by 251%, it lags behind the optimal parameter configuration. The discussion of this is missing here.

(2) DLUC (Double Leveled Unequal Clustering with considering Energy Efficiency and Load Balancing in Dense IoT Networks) [65]. Key points: the main aim is to design a new clustering model to choose the best node to be a cluster head by calculating the remaining energy available. Here, the members are defined at two levels, and the gateways are changed based on their previous energy consumption and background work. The algorithm also uses two types of clusters, like small and big clusters, and two kinds of data packet transmission, like CTPR (control packet transmission range), and considers DTPR (data packet transmission range) in designing the algorithm, and this tries to create big clusters rather than small ones, and here, it calculates the proportional threshold of average energy (PIAE); it also uses an adaptive scheme and operates in super frames, with the formation of cluster heads at the beginning of each superframe. Limitations: for better performance, the protocol should consider the coverage of the nodes and the nodes' mobility.

(3) EAUCF (Energy Aware Fuzzy Unequal Clustering Algorithm) [66]. Key points: it is a competitive and distributive algorithm that makes local decisions in order to determine the competition radius, like distance and consider residual energy. Using the Mamdani method for fuzzy rules, each tentative CH changes dynamically based on its competition radius and derives output as the tentative CH's competition radius. Limitations: even though it works well, this protocol is based on the idea that stationary nodes are more important than mobile nodes.

(4) FBUC (Fuzzy Logic Base Unequal Clustering) [67]. Key points: it is a distributive type of clustering and operates in rounds like LEACH. Every round selects a cluster head

Table 5: Analyzation of deterministic protocols in unequal clustering.

Unequal clustering Deterministic Protocol	Year	Key concept	Limitations
Weight based			
12. MRPUC [64]	2008	BS-ADV message	Lags optimal parameter
13. PEBECS [75]	2009	PID (partition flag bit)	Network lifetime
14. EADUC [56]	2011	Neighbor node information	Supports only short-distance operation
15. EBCAQ [76]	2012	Gradient values	Data packet loss
16. EUCS [77]	2013	Overhead reduction	No real-time scenario
17. UCMR [78]	2008	Node centrality	Scalability due to node centrality
18. CUCA [79]	2015	Overlapping cluster heads	Single-hop communication
19. EADUC (improved) [80]	2016	Competition radius with neighbor nodes	Relay node selection
20. DLUC [65]	2019	CTPR and DTPR	Node's mobility
Fuzzy based			
21. EAUCF [66]	2010	Mamdani's method for fuzzy rules	Assumption of stationary nodes
22.DUCF [81]	2016	Chance calculation	Data redundancy
23. IFUC [82]	2012	Neighbor discovery message	Intercluster routing
24. FUCP [83]	2015	Novel cluster head algorithm	Endpoint residual energy
25. FBUC [67]	2016	An arbitrary number of node	FND calculator for the first node dies
Heuristic-based			
26. EBUC [69]	2010	Particle swarm optimization	Lack of knowledge of the number of clusters
27. GAEEP [84]	2014	Genetic algorithm	Instability
28. IPSO [85]	2015	Global and local optima	Algorithm complexity
29. FJAPSO [70]	2018	SDSN (software defined sensor nodes)	Control node selection
30. SMEBUC [86]	2015	Local search	Path loss
31. An efficient preference-based sensor selection method in the internet of things [71]	2019	MCDA	Complexity
32. FAMACROW [87]	2014	SETUP_MSG	ACO algorithm
33. OPEN [4]	2017	Path routing algorithm	Timer system
34. NCRO [88]	2016	Energy function	Delay of nodes
35. UMBIC [89]	2016	MOIA (multiobjective immune algorithm)	Communication costs
Compound based			
36. EDDUCA [73]	2016	Message length	Only homogeneous networks
37.UCCGRA [90]	2016	Vote base system	Challenges in real-time operations
38. AGCA [91]	2018	Load distribution model	Lags in a large-scale operation

based on an arbitrary number for each node. If the threshold values assigned were more than the number, then it could be a tentative CH. The main difference between the EAUCF and this algorithm is that the two variables considered fuzzy are distance and residual energy. Still, it includes the node degree because the competition radius automatically decreases when the node degree increases and the final CH is high. Limitations: electing a tentative CH. The network initializing and the FND (first node die) and the LND (last node die) should extend the network lifetime.

(5) Fuzzy Clustering Algorithm for Enhancing Reliability and Network Lifetime of Wireless Sensor Networks [68]. Key points: this work proposes fuzzy-based clustering for enhancing the network lifetime in WSN. Initially, this research presents the energy model and then performs clustering using fuzzy mechanisms by considering node degree, node energy, and distance. After complete clustering, CH selection is performed by considering node energy, node concentration, and centrality. In this way, this research reduced energy consumption and increased network lifetime. Limitations: here, cluster construction is performed by using fuzzy rules and limited metrics, which are not enough for stable clustering. In addition, fuzzy logic always does not provide an optimal solution, which leads to instability in clustering.

(6) EBUC (Energy Balanced Unequal Clustering) [69]. Key points: here, the base station possesses the nodes' information and computes the node's energy level to select the cluster

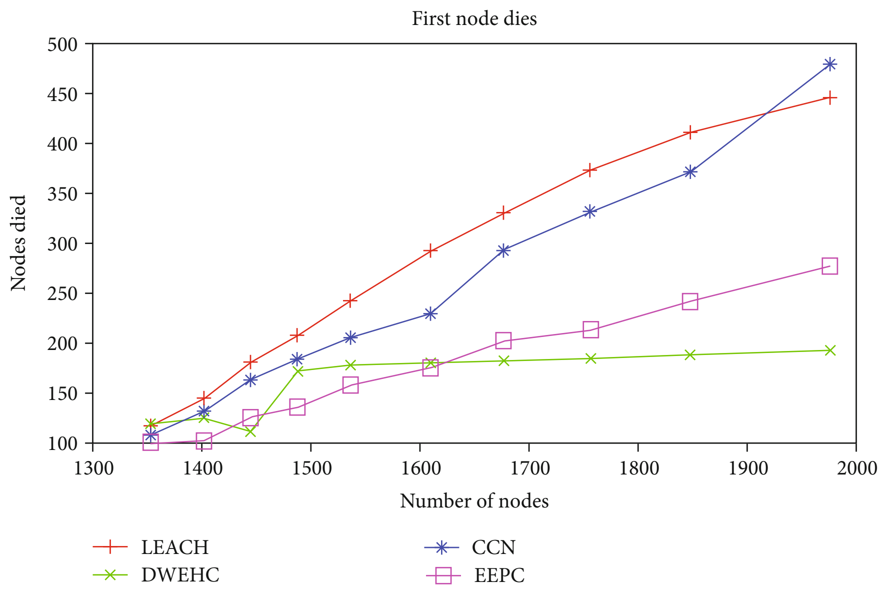

Figure 8: Comparison analysis of first node dies.

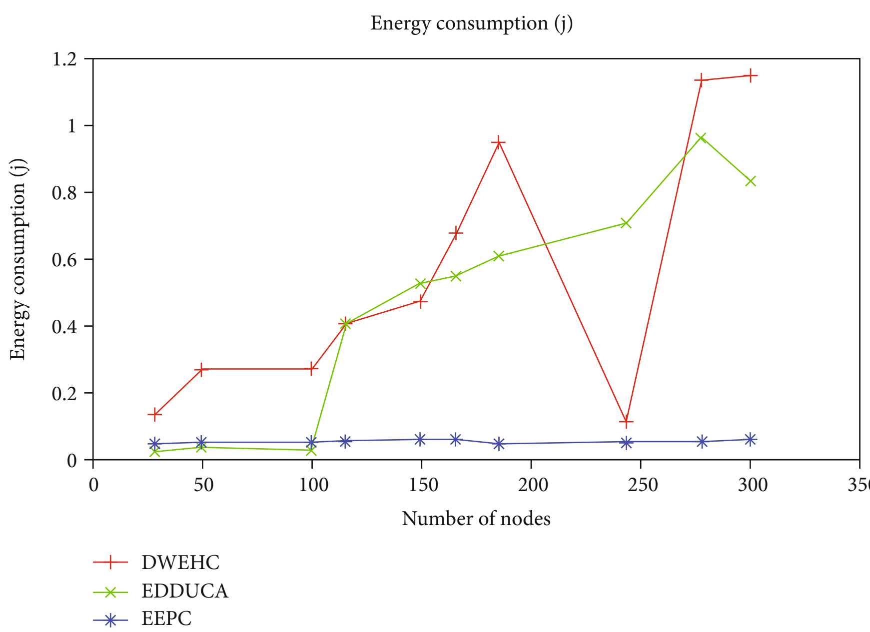

Figure 9: Comparison of energy consumption.

heads. And next, it runs the PSO (particle swarm optimization) algorithm for choosing the cluster heads. Limitations: the protocol does not know how many clusters there are, and the consideration of continuous time in the network is missing before the occurrence of FND (first node death).

(7) FJAPSO (Fork Join Adaptive Particle Swarm Optimization) [70]. Key points: here, it proposes an FJAPSO (fork-join adaptive particle swarm optimization) algorithm, which is a two-level optimization routing algorithm. In this algorithm, instead of regular nodes, it proposes SDSNs (software-defined sensor nodes), which are innovative in management and are organized into clusters. Each will contain a CN (control node) and a normal node and execute in iterations. In each iteration, the particles are forked into subatomic particles and again merged after the execution of the algorithm, and a fitness function with energy and a trade-off distance of CN will be considered for the optimization of a cluster. Limitations: selection of the control node during an iterative process of merging the particles and merging them back may consume energy, which is challenging.

(8) An Efficient Preference-Based Sensor Selection Method in the Internet of Things [71]. Key points: it uses a multicriteria decision analysis algorithm (MCDA) and a technique for prioritization by similarity to an ideal solution (TOPSIS)

with a wide range of usage that is low in complexity. It is used to improve a fast nondominated sorting algorithm and retrieve sensor resources in static two-dimensional space by constructing an R tree and using attributes such as the sensor attribute, the objective function, and the retrieving structures. Sensor dataset size can be reduced based on sensor attributes. "N" copies are related to "n" sensor attributes, implying a nondominated model. Front of the data set, which reduces time and space complexity. Limitations: the complexity of semantic algorithms is semantically based here in this protocol, and cross-platform sensing of data might have improved the quality of the work.

(9) A Coherent Approach for Dynamic Cluster-Based Routing and Coverage Hole Detection and Recovery in Bilayered WSN-IoT [72]. Key points: in this, the authors proposed an approach to perform routing, detection of coverage holes, and recovery based on clustering in WSN-IoT. Initially, sensor nodes are clustered using the k-means clustering algorithm. After cluster formation, the selection of the cluster head step was performed based on calculating the weights of the nodes by considering parameters such as distance and residual energy. Maintenance of clusters by cluster merging and cluster splitting was performed using the entropy function when the cluster size was large. Limitations: cluster head selection is performed by considering residual energy and distance for weight calculation. However, these parameters are not enough to select the cluster head efficiently, which leads to poor cluster head selection and a high packet loss rate.

(10) EDDUCA (Energy Degree Distance Unequal Clustering Algorithm) [73]. Key points: message length k and the distance between nodes are directly proportional to transmission. The main idea of EDDUCA is to reduce energy consumption and balance it to perform the protocol and derive the required goals of the operation. The method of the "Sierpinski gasket," which is also known as the "Sierpinski triangle," is used. Limitations: the protocol has many advantages when compared to many other protocols, but the network has a limitation in that it is designed based on homogeneous networks only.

(11) Q-Learning-Based Data-Aggregation-Aware Energy-Efficient Routing Protocol for Wireless Sensor Networks [74]. Key points: this work proposes a reinforcement learning algorithm for data aggregation and routing in a WSN environment. The main aim of using reinforcement learning (i.e., Q learning) was to reduce the reward and take the necessary actions. Initially, the sensor node collected the data by using multimode operations to reduce energy consumption. Following that, data aggregation was carried out to reduce redundancies in temporal and spatial data during routing. The aggregated data was sent forward to the sink nodes by selecting an optimal path with a smaller hop count. Limitations: the Q learning algorithm was used for data aggregation and routing in this case, which takes a long time to update Q values, increasing latency and potentially leading to routing failure.

In Table 5, the analysis of the deterministic protocols in unequal clustering is done and compared their feasibilities.

5. Results and Discussion

Here, an analysis of the protocols is conducted because there have been many proposed ideas for improving the efficiency of the sensor nodes by clustering techniques over the past decade, but it is observed that all these protocols concentrated on the death of the first node in the clusters. In Figure 8, an analysis of protocols for the first node dies. In this, a small comparison of some of the mentioned protocols is observed, when first node dies.

Because energy efficiency is dependent on the cluster heads and the number of clusters, in Figure 9, a comparative analysis of the energy consumption of different protocols is shown. These protocols primarily focus on determining the cluster heads and the number of clusters., and many protocols primarily propose that if it reduces the time of transmission, they are accepted, and some suggest that it increases the overall life by reducing the hop count and some significant distance between the clusters, and some protocols consider residual energy for the cluster head and the recharging of the battery. While considering many parameters, the energy consumption of the nodes will also be a key factor to observe in their performance.

6. Conclusions

Even though there are many ways to implement protocols in wireless sensors, it is still hard to find the best energy-optimization solution in wireless sensor networks because protocols are made to improve performance. A significant contradiction is that the battery in the sensor cannot be recharged in most cases, so, the design of the protocols concentrates more on how to reduce energy consumption. This has become the only choice for the researchers, and so the algorithms are designed accordingly. The major issues in existing works are as follows:

(i) Instability in clustering

(ii) Low network lifetime

(iii) High data loss

(iv) Less security

(v) Poor network management

(vi) Ineffective data collection

(vii) Increased response time

Also, the concentration on coverage holes while implementing and detecting them and the usage of machine learning and artificial intelligence can enhance performance and handle the problems mentioned above.

Data Availability

Data sharing does not apply to this article as no datasets were generated or analyzed during the current study.

Conflicts of Interest

There are no conflicts of interest regarding the publication of this article with any of the authors.

References

[1] N. Bacanin, U. Arnaut, M. Zivkovic, T. Bezdan, and T. A. Rashid, "Energy efficient clustering in wireless sensor networks by opposition-based initialization bat algorithm," in *Computer Networks and Inventive Communication Technologies*, S. Smys, R. Bestak, R. Palanisamy, and I. Kotuliak, Eds., vol. 75 of Lecture Notes on Data Engineering and Communications Technologies, Springer, Singapore, 2022.

[2] M. Zivkovic, N. Bacanin, T. Zivkovic, I. Strumberger, E. Tuba, and M. Tuba, "Enhanced Grey wolf algorithm for energy efficient wireless sensor networks," in *2020 Zooming Innovation in Consumer Technologies Conference (ZINC)*, pp. 87–92, Novi Sad, Serbia, 2020.

[3] M. Zivkovic, N. Bacanin, E. Tuba, I. Strumberger, T. Bezdan, and M. Tuba, "Wireless sensor networks life time optimization based on the improved firefly algorithm," in *2020 International Wireless Communications and Mobile Computing (IWCMC)*, pp. 1176–1181, Limassol, Cyprus, 2020.

[4] N. Bacanin, M. Antonijevic, T. Bezdan, M. Zivkovic, and T. A. Rashid, "Wireless sensor networks localization by improved whale optimization algorithm," *Proceedings of 2nd International Conference on Artificial Intelligence: Advances and Applications. Algorithms for Intelligent Systems*, G. Mathur, M. Bundele, M. Lalwani, and M. Paprzycki, Eds., Springer, Singapore, 2022.

[5] M. Zivkovic, T. Zivkovic, K. Venkatachalam, and N. Bacanin, "Enhanced dragonfly algorithm adapted for wireless sensor network lifetime optimization," in *Data Intelligence and Cognitive Informatics. Algorithms for Intelligent Systems*, I. Jeena Jacob, S. Kolandapalayam Shanmugam, S. Piramuthu, and P. Falkowski-Gilski, Eds., Springer, Singapore, 2021.

[6] W. B. Heinzelman, A. P. Chandrakasan, and H. Balakrishnan, "An application-specific protocol architecture for wireless microsensor networks," *IEEE Transactions on Wireless Communications*, vol. 1, no. 4, pp. 660–670, 2002.

[7] N. Shigei, H. Morishita, and H. Miyajima, "Energy-efficient clustering communication based on the number of neighbors for wireless sensor networks," in *International Multi-Conference on Engineers and Computer Scientists (IMECS)*, Hong Kong, 2010.

[8] H. Ranida, A. Zibouda, A. Adamou, and G. Mourad, "An efficient clustering strategy avoiding buffer overflow in IOT sensors: a bio-inspired based approach," *IEEE Access*, vol. 7, pp. 156733–156751, 2019.

[9] X. Yan, Y. Zhanwei, and L. Lingling, "Clustering routing algorithm and simulation of internet of things perception layer based on energy balance," vol. 7, IEEE Access, 2019.

[10] A. Ghosal, S. Halder, and S. K. Das, "Distributed on-demand clustering algorithm for lifetime optimization in wireless sensor networks," *Journal of Parallel and Distributed Computing*, vol. 141, pp. 129–142, 2020.

[11] O. Younis and S. Fahmy, "Distributed clustering in ad-hoc sensor networks: a hybrid, energy-efficient approach," in *IEEE INFOCOM 2004*, Hong Kong, 2004.

[12] Y.-C. Chen and C.-Y. Wen, "Distributed clustering with directional antennas for wireless sensor networks," *IEEE Sensors Journal*, vol. 13, no. 6, pp. 2166–2180, 2013.

[13] B. Seema, N. Yao, A. Carie, and S. B. H. Shah, "Efficient data transfer in clustered IoT network with cooperative member nodes," *Multimedia Tools and Applications*, vol. 79, no. 45-46, pp. 34241–34251, 2020.

[14] B. Trupthi, M. Sushantha, S. Umesh, S. Mohammed, and A. G. Mahmoud, "I-SEP: an improved routing protocol for heterogeneous WSN for IoT-based environmental monitoring," *IEEE Internet of Things Journal*, vol. 7, no. 1, pp. 710–717, 2019.

[15] C. S. Lindsey Raghavendra, "PEGASIS: power-efficient gathering in sensor information systems," in *Proceedings, IEEE Aerospace Conference*, Big Sky, MT, USA, 2002.

[16] S. Jung, Y. Han, and T. Chung, "The concentric clustering scheme for efficient energy consumption in the PEGASIS," in *The 9th International Conference on Advanced Communication Technology*, Gangwon, Korea (South), 2007.

[17] R. Nagpal and D. Coore, "An algorithm for group formation in an amorphous computer," in *International Conference on Parallel and Distributed Computing Systems (PDCS)*, Louisville, Kentucky, USA, 1998.

[18] S. Bandyopadhyay and E. Coyle, "An energy efficient hierarchical clustering algorithm for wireless sensor networks," in *IEEE INFOCOM 2003. Twenty-second Annual Joint Conference of the IEEE Computer and Communications Societies (IEEE Cat. No.03CH37428)*, San Francisco, CA, USA, 2003.

[19] M. Demirbas, A. Arora, and V. Mittal, "FLOC: fast local clustering service for wireless sensor networks," in *Workshop on Dependability Issues in Wireless Ad Hoc Networks and Sensor Networks (DIWANS/DSN)*, Florence, Italy, 2004.

[20] A. Youssef, M. Younis, M. Youssef, and A. Agrawala, "WSN16-5: Distributed formation of overlapping multi-hop clusters in wireless sensor networks," in *IEEE Global Communications Conference (GLOBECOM)*, San Francisco, CA, USA, 2006.

[21] G. Smaragdakis, I. Matta, and A. Bestavros, "SEP: a stable election protocol for clustered heterogeneous wireless sensor networks," in *International Conference on the Sensor and Actor-Network Protocols and Applications (SANPA)*, Boston, USA, 2004.

[22] M. Ye, C. Li, G. Chen, and J. Wu, "EECS: an energy efficient clustering scheme in wireless sensor networks," in *PCCC 2005. 24th IEEE International Performance, Computing, and Communications Conference, 2005*, Phoenix, AZ, USA, 2004.

[23] K. T. Kim and H. Y. Youn, "Energy-driven adaptive clustering hierarchy (edach) for wireless sensor networks," in *Embedded and Ubiquitous Computing – EUC 2005 Workshops. EUC 2005*, T. Enokido, L. Yan, B. Xiao, D. Kim, Y. Dai, and L. T. Yang, Eds., vol. 3823 of Lecture Notes in Computer Science, Springer, Berlin, Heidelberg, 2005.

[24] S. Selvakennedy and S. Sinnappan, "An adaptive data dissemination strategy for wireless sensor networks," *International Journal of Distributed Sensor Networks*, vol. 3, no. 1, 40 pages, 2007.

[25] C. Wen and W. Sethares, "Automatic decentralized clustering for Wireless Sensor Networks," *EURASIP Journal on Wireless*

Communications and Networking, vol. 2005, Article ID 248089, 2005.

[26] T. Kang, J. Yun, H. Lee, I. Lee, H. Kim, and B. Lee, "A clustering method for energy-efficient routing in wireless sensor networks," in *Proceedings of the 6th WSEAS Int. Conf. on Electronics, Hardware, Wireless and Optical Communications*, Corfu Island, Greece, 2007.

[27] P. Ding, J. Holliday, and A. Celik, "Distributed energy-efficient hierarchical clustering for wireless sensor networks," in *Distributed Computing in Sensor Systems. DCOSS 2005*, V. K. Prasanna, S. S. Iyengar, P. G. Spirakis, and M. Welsh, Eds., vol. 3560 of Lecture Notes in Computer Science, Springer, Berlin, Heidelberg, 2007.

[28] F. Hussain, R. Hussain, A. Anpalagan, and A. Benslimane, "A new block-based reinforcement learning approach for distributed resource allocation in clustered IoT networks," *IEEE Transactions on Vehicular Technology*, vol. 69, no. 3, pp. 2891–2904, 2019.

[29] J. Abdallah, S. Ayman, and I. Mohamed, "Data transmission reduction schemes in WSNs for efficient IoT systems," *IEEE Journal in Selected Area Communications*, vol. 37, no. 6, pp. 1307–1324, 2018.

[30] J.-M. Kim, S.-H. Park, Y.-J. Han, and T.-M. Chung, "CHEF: cluster head election mechanism using fuzzy logic in wireless sensor networks," in *2008 10th International Conference on Advanced Communication Technology*, Gangwon, Korea (South), 2008.

[31] R. S. Sinde, F. Begum, K. N. Njau, and S. F. Kaijage, "Refining network lifetime of wireless sensor network using energy-efficient clustering and DRL-based sleep scheduling," *Sensors*, vol. 20, no. 5, article 1540, 2020.

[32] S. Mudundi and H. H. Ali, "A new robust genetic algorithm for dynamic cluster formation in wireless sensor networks," in *Proceedings of Wireless and Optical Communications*, Montreal, Quebec, Canada, 2007.

[33] Y. Xuanxia, W. Jiafei, S. Mengyu, K. Huafeng, and N. Huansheng, "An improved clustering algorithm and its application in IoT data analysis," *Computer Networks*, vol. 159, pp. 63–72, 2019.

[34] S. T. Al-Otaibi, A. Al-Rasheed, R. F. Mansour, E. Yang, G. P. Joshi, and W. Cho, "Hybridization of metaheuristic algorithm for dynamic cluster-based routing protocol in wireless sensor networksx," *IEEE Access*, vol. 9, pp. 83751–83761, 2021.

[35] S. Banerjee and S. Khuller, "A clustering scheme for hierarchical control in multi-hop wireless networks," in *Proceedings IEEE INFOCOM 2001. Conference on Computer Communications. Twentieth Annual Joint Conference of the IEEE Computer and Communications Society (Cat. No.01CH37213)*, Anchorage, Alaska, USA, 2001.

[36] S. Xiaoqing, Y. Chungang, C. Danyang, Z. Nan, and F. Richard, "Dynamic IoT device clustering and energy management with hybrid NOMA systems," *IEEE Transactions on Industrial Informatics*, vol. 14, no. 10, pp. 4622–4630, 2018.

[37] P. Jagannathan, S. Gurumoorthy, A. Stateczny, P. B. Divakarachar, and J. Sengupta, "Collision-aware routing using multi-objective seagull optimization algorithm for WSN-based IoT," *Sensors*, vol. 21, no. 24, article 8496, 2021.

[38] S. Basagni, "Distributed clustering for ad hoc networks," in *Proceedings Fourth International Symposium on Parallel Architectures, Algorithms, and Networks (I-SPAN'99)*, Perth/Fremantle, WA, Australia, 2007.

[39] A. S. R. Virrankoski, "TASC: topology adaptive spatial clustering for sensor networks," in *IEEE International Conference on Mobile Adhoc and Sensor Systems Conference, 2005*, Washington, USA, 2005.

[40] Y. Ma, Y. Guo, X. Tian, and M. Ghanem, "Distributed clustering-based aggregation algorithm for spatial correlated sensor networks," *IEEE Sensors Journal*, vol. 11, no. 3, pp. 641–648, 2011.

[41] H. Taheri, P. Neamatollahi, O. Younis, S. Naghibzadeh, and M. Yaghmaee, "An energy-aware distributed clustering protocol in wireless sensor networks using fuzzy logic," *Ad Hoc Networks*, vol. 10, no. 7, pp. 1469–1481, 2012.

[42] H. Chan and A. Perrig, "ACE: an emergent algorithm for highly uniform cluster formation," in *Wireless Sensor Networks. EWSN 2004*, Lecture Notes in Computer Science, vol 2920, H. Karl, A. Wolisz, and A. Willig, Eds., Springer, Berlin, Heidelberg, 2004.

[43] S. D. Muruganathan, B. R. I. MaDC, and A. O. Fapojuwo, "A centralized energy-efficient routing protocol for wireless sensor networks," *IEEE Communications Magazine*, vol. 43, no. 3, pp. S8–13, 2005.

[44] K. Kim and H. Youn, "Peach: proxy-enable adaptive clustering hierarchy for wireless sensor network," in *International Conference on Wireless Network (ICWN)*, Las Vegas, Nevada, USA, 2005.

[45] R.-S. Chang and C.-J. Kuo, "An energy efficient routing mechanism for wireless sensor networks," in *20th International Conference on Advanced Information Networking and Applications - Volume 1 (AINA'06)*, Vienna, Austria, 2006.

[46] M. Yu, K. K. Leung, and A. Malvankar, "A dynamic clustering and energy-efficient routing technique for sensor networks," *IEEE Transactions on Wireless Communications*, vol. 6, no. 8, pp. 3069–3079, 2007.

[47] H. Zhang and A. Arora, "Gs^3: scalable self-configuration and self-healing in wireless sensor networks," *Computer Networks*, vol. 43, no. 4, pp. 459–480, 2003.

[48] L. Buttyan and P. Schaffer, "PANEL: position-based aggregator node election in wireless sensor networks," in *2007 IEEE Internatonal Conference on Mobile Adhoc and Sensor Systems*, Pisa, Italy, 2007.

[49] T. Kaur and J. Baek, "A strategic deployment and cluster-header selection for wireless sensor networks," *IEEE Transactions on Consumer Electronics*, vol. 55, no. 4, pp. 1890–1897, 2009.

[50] F. Jibreel, E. Tuyishimire, and M. I. Daabo, "An enhanced heterogeneous gateway-based energy-aware multi-hop routing protocol for wireless sensor networks," *Information*, vol. 13, no. 4, p. 166, 2022.

[51] J. H. Kim, C. S. Hussain, W. C. Yang, D. S. Kim, and M. S. Park, "PRODUCE: A probability-driven unequal clustering mechanism for wireless sensor networks," in *22nd International Conference on Advanced Information Networking and Applications - Workshops (aina workshops 2008)*, pp. 928–933, Gino-wan, Japan, 2008.

[52] C. Li, M. Ye, G. Chen, and J. Wu, "An energy-efficient unequal clustering mechanism for wireless sensor networks," in *IEEE International Conference on Mobile Adhoc and Sensor Systems Conference, 2005*, pp. 597–604, Washington, DC, USA, 2005.

[53] D. L. Reddy, C. Puttamadappa, and H. N. Suresh, "Hybrid optimization algorithm for security aware cluster head selection process to aid hierarchical routing in wireless sensor

network," *IET Communications*, vol. 15, no. 12, pp. 1561–1575, 2021.

[54] H. Li, Y. Liu, W. Chen, W. Jia, B. Li, and J. Xiong, "COCA: constructing optimal clustering architecture to maximize sensor network lifetime," *Computer Communications*, vol. 36, no. 3, pp. 256–268, 2013.

[55] K. Guleria, A. K. Verma, N. Goyal, A. K. Sharma, A. Benslimane, and A. Singh, "An enhanced energy proficient clustering (EEPC) algorithm for relay selection in heterogeneous WSNs," *Ad Hoc Networks*, vol. 116, article 102473, 2021.

[56] J. Yu, Y. Qi, and G. Wang, "An energy-driven unequal clustering protocol for heterogeneous wireless sensor networks," *Journal of Control Theory and Applications*, vol. 9, no. 1, pp. 133–139, 2011.

[57] S. Lee, H. Choe, B. Park, Y. Song, and C. K. Kim, "LUCA: an energy-efficient unequal clustering algorithm using location information for wireless sensor networks," *Wireless Personal Communications*, vol. 56, no. 4, pp. 715–731, 2011.

[58] J. Yu, Y. Qi, G. Wang, Q. Guo, and X. Gu, "An energy-aware distributed unequal clustering protocol for wireless sensor networks," *International Journal of Distributed Sensor Networks*, vol. 7, no. 1, Article ID 202145, 2011.

[59] G. Chen, C. Li, M. Ye, and J. Wu, "An unequal cluster-based routing protocol in wireless sensor networks," *Networks*, vol. 15, no. 2, pp. 193–207, 2009.

[60] P. Ren, J. Qian, L. Li, Z. Zhao, and X. Li, "Unequal Clustering Scheme Based LEACH for Wireless Sensor Networks," in *2010 Fourth International Conference on Genetic and Evolutionary Computing*, pp. 90–93, Shenzhen, China, 2010.

[61] D. Wei, Y. Jin, S. Vural, K. Moessner, and R. Tafazolli, "An energy-efficient clustering solution for wireless sensor networks," *IEEE Transactions on Wireless Communications*, vol. 10, no. 11, pp. 3973–3983, 2011.

[62] T. Z. D. Yang, "An energy-balancing unequal clustering protocol for wireless sensor networks," *Information Technology Journal*, vol. 8, pp. 57–63, 2009.

[63] E. Ever, R. Luchmun, L. Mostarda, A. Navarra, and P. Shah, "UHEED – an unequal clustering algorithm for wireless sensor networks," in *Proceedings of the 1st International Conference on Sensor Networks*, Rome,Italy, 2012.

[64] B. Gong, L. Li, S. Wang, and X. Zhou, "Multihop routing protocol with unequal clustering for wireless sensor networks," in *2008 ISECS International Colloquium on Computing, Communication, Control, and Management*, pp. 552–556, Guangzhou, China, 2008.

[65] F. Marjan and G. Akbar, "Double leveled unequal clustering with considering energy efficiency and load balancing in dense IoT networks," *Wireless Personal Communications*, vol. 106, pp. 1183–1207, 2019.

[66] H. Bagci and A. Yazici, "An energy aware fuzzy unequal clustering algorithm for wireless sensor networks," in *International Conference on Fuzzy Systems*, pp. 1741–1749, Barcelona, Spain, 2010.

[67] R. Logambigai and A. Kannan, "Fuzzy logic based unequal clustering for wireless sensor networks," *Wireless. Networks*, vol. 22, no. 3, pp. 945–957, 2016.

[68] S. Lata, S. Mehfuz, S. Urooj, and F. M. Alrowais, "Fuzzy clustering algorithm for enhancing reliability and network lifetime of wireless sensor networks," *IEEE Access*, vol. 8, pp. 66013–66024, 2020.

[69] C. J. Jiang, W. R. Shi, M. Xiang, and X. L. Tang, "Energy-balanced unequal clustering protocol for wireless sensor networks," *The Journal of China Universities of Posts and Telecommunications*, vol. 17, no. 4, pp. 94–99, 2010.

[70] N. Kumar and D. P. Vidyarthi, "A green routing algorithm for IoT-enabled software-defined wireless sensor network," *IEEE Sensors of Journal*, vol. 18, no. 22, pp. 9449–9460, 2018.

[71] Z. Zengwei, T. Yanyan, C. Yuanyi, Z. Fengle, and C. Dan, "An efficient preference-based sensor selection method in internet of things," *IEE ACESS Journal.*, vol. 7, pp. 168536–168547, 2019.

[72] J. K. Jain, "A coherent approach for dynamic cluster-based routing and coverage hole detection and recovery in bi-layered WSN-IoT," *Wireless Personal Communications*, vol. 114, no. 1, pp. 519–543, 2020.

[73] A. B. F. Guiloufi, N. Nasri, and A. Kachouri, "An energy-efficient unequal clustering algorithm using 'Sierpinski Triangle' for WSNs," *Wireless Personal Communications*, vol. 88, no. 3, pp. 449–465, 2016.

[74] W. Yun and S. Yoo, "Q-learning-based data-aggregation-aware energy-efficient routing protocol for wireless sensor networks," *IEEE Access*, vol. 9, pp. 10737–10750, 2021.

[75] Y. Wang, T. L. X. Yang, and D. Zhang, "An energy efficient and balance hierarchical unequal clustering algorithm for large scale sensor networks," *Information Technology Journal*, vol. 8, pp. 28–38, 2009.

[76] T. Liu, Q. Li, and P. Liang, "An energy-balancing clustering approach for gradient-based routing in wireless sensor networks," *Computer Communications*, vol. 35, no. 17, pp. 2150–2161, 2012.

[77] M. Mohamed-Lamine, "New clustering scheme for wireless sensor networks," in *2013 8th International Workshop on Systems, Signal Processing and their Applications (WoSSPA)*, pp. 487–491, Algiers, Algeria, 2013.

[78] D. C. Jinwala, D. R. Patel, and K. S. Dasgupta, "Optimizing the Block Cipher Resource Overhead at the Link Layer Security Framework in the Wireless Sensor Networks," in *Proceedings of the World Congress on Engineering 2008*, London, UK, 2008.

[79] N. Mazumdar and H. Om, "Coverage-aware unequal clustering algorithm for wireless sensor networks," *Procedia Computer Science*, vol. 57, pp. 660–669, 2015.

[80] V. Gupta and R. Pandey, "An improved energy aware distributed unequal clustering protocol for heterogeneous wireless sensor networks," *Engineering Science and Technology, an International Journal*, vol. 19, no. 2, pp. 1050–1058, 2016.

[81] B. Baranidharan and B. Santhi, "DUCF: distributed load balancing unequal clustering in wireless sensor networks using fuzzy approach," *Applied Soft Computing*, vol. 40, pp. 495–506, 2016.

[82] S. Mao, C. Zhao, Z. Zhou, and Y. Ye, "An Improved Fuzzy Unequal Clustering Algorithm for Wireless Sensor Networks," *Mobile Networks and Applications*, vol. 18, pp. 206–214, 2013.

[83] S. Gajjar, A. Talati, M. Sarkar, and K. Dasgupta, "FUCP: fuzzy based unequal clustering protocol for wireless sensor networks," in *2015 39th National Systems Conference (NSC)*, pp. 1–6, Greater Noida, India, 2015.

[84] M. Abo-zahhad, S. M. Ahmed, and N. Sabor, "A new energy-efficient adaptive clustering protocol based on genetic algorithm for improving the lifetime and the stable period of wireless sensor networks," *International Journal of Energy, Information and Communications*, vol. 5, pp. 47–72, 2014.

[85] S. K. Salehian and S. Subraminiam, "Unequal clustering by improved particle swarm optimization in wireless sensor network," *Procedia Computer Science*, vol. 62, pp. 403–409, 2015.

[86] X. Fan and F. Du, "Shuffled frog leaping algorithm-based unequal clustering strategy for wireless sensor networks," *Applied Mathematics and In9formation Sciences*, vol. 3, pp. 1415–1426, 2015.

[87] S. Gajjar, M. Sarkar, and K. Dasgupta, "FAMACRO: fuzzy and ant colony optimization BASED MAC/routing cross-layer protocol for wireless sensor networks," *Procedia Computer Science*, vol. 46, pp. 1014–1021, 2014.

[88] P. C. Srinivasa Rao and H. Banka, "Novel chemical reaction optimization based unequal clustering and routing algorithms for wireless sensor networks," *Wireless Networks*, vol. 23, no. 3, pp. 759–778, 2016.

[89] S. Nabil and M. Abo-Sahhad, "An unequal multi-hop balanced immune clustering protocol for wireless sensor networks," *Applied Soft Computing*, vol. 43, pp. 372–389, 2016.

[90] H. Xia, R.-h. Zhang, J. Yu, and Z.-k. Pan, "Energy-efficient routing algorithm based on unequal clustering and connected graph in wireless sensor networks," *International Journal of Wireless Information Networks*, vol. 23, pp. 141–150, 2016.

[91] J. Zhang, X. Feng, and Z. Liu, "A grid-based clustering algorithm via load analysis for industrial internet of things," *IEEE Access*, vol. 6, 2018.