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Review Article

A comparative survey on LEACH successors clustering algorithms for energy-efficient longevity WSNs

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ABSTRACT

Wireless Sensor Network (WSN) has appeared as a significant study field integrated with much research in the last two decades. In response to the widespread use of this technology in numerous applications, such as military operations, medical care, automated processes, urban domain and so on. WSN handles conditions where it is challenging or impossible for humans to perform measurement tasks physically and effectively. WSNs are fast-expanding networks incorporating many data communications streams. A WSN is made up of a wide amount of economic sensing device nodes with low energy requirements that have been irregularly placed in a particular region. These sensor node devices periodically sense data and record values before sending them to the sink node (or base station) through other sensor nodes. Some concerns should be addressed, such as preserving the sensor nodes' activity and load balancing as much as possible by wisely distributing the overall energy and the significant duplication problem of generated data where some sensor nodes in the monitor region may provide similar data. These are the WSN's most fundament l issues, necessitating the development of new routing and clustering algorithms. Research has proposed several routing algorithms to respond to these challenges and several optimization methods to decide the best route between the broadcaster and reception nodes. LEACH and its various versions with hierarchical clustering are widely utilized to reduce energy consumption, optimize performance, and lengthen the network's longevity. In this survey, We present an in-depth evaluation of LEACH descendant clustering protocols to respond to the previous challenges. We suggest several optimization methods to decide the best route between the broadcaster and reception nodes. Our qualitatively comparative study and analysis organize LEACH-based routing algorithms into five categories: algorithms for optimizing CH selection, algorithms for optimizing data transmission, algorithms for optimizing both CH selection & data transmission, algorithms executed by fuzzy logic approach, and algorithms that use external energy sources to maximize network energy. Moreover, the survey compares these clustered routing techniques based on these criteria. An examination of algorithms is provided, including information on their goals, categories, strategies, assessments, effectiveness, advantages, and disadvantages. This survey gives academics technical guidance regarding the best way to improve algorithms for routing. The publication concludes with suggestions for additional areas of WSN to investigate.

1. Introduction

WSN is a network of several devices known as nodes that measure environmental events such as temperature, pressure, vibration, pollution, heartbeat, etc. [1]. WSN's primary goals are (1) to monitor and document the events in the identified monitored area, (2) to analyze the correct criterion, and (3) to control this area [2]. Rechargeable or replaced batteries energize sensor nodes in WSN. It is noted that Gathering information, processing, and sending or receiving data packets all need energy. Therefore, the main drawback of WSNs is their considerable use of energy. Several sensor nodes make a wireless sensor network (WSN) that is scattered throughout a given region as well as at only one sink node (Base Station (BS)) [2]. And then use wireless communications to further transfer the information acquired from the monitored region to the sink node (base station) for analysis, as seen in Fig. 1. The routing method [3] determines the best path for data to travel

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from sender to receiver. Routing algorithms in WSNs. Are influenced by (1) the application, (2) the data to be acquired, and (3) the efficient utilization of limited energy. According to [3], a good routing algorithm has significant benefits, such as simplicity, the capacity to develop and adjust under the restricted characteristics of the nodes, and the flexibility to know its level of energy, to mention a few:

Storage memory, computational capabilities, energy, and network bandwidth are provided. A network of sensory-based applications imposes a heavy flow of sensed information data from many sources within a particular area to a specific sink device. Because this study is a survey of LEACH and its derivatives, we shall limit our discussion to hierarchical network architectures. Because of its architecture, hierarchical routing is more energy-efficient and scalable. The entire network is grouped into clusters under this approach, as well as some nodes are designated as particular nodes depending on a list of requirements. Cluster heads (CHs) are certain nodes that gather, combine, and reduce data from nearest neighbours before sending it to the sink node. Because the CH delivers extra benefits to its cluster's residual nodes, it requires more energy than the other nodes. Cluster rotating is a popular technique for balancing energy dissipation inside a cluster. Heintzelman et al. [4] introduced the first hierarchical routing algorithm, LEACH. Clusters are generated in LEACH depending on the signal intensity detected by the sensor.

Several surveys [5–9] were conducted to measure the widespread LEACH clustering hierarchical algorithm and its derivative algorithms. These algorithms employ assorted categories depending on multiple variables and essential factors such as clustering strategy, node mobility, energy efficiency, and adaptability. The present investigation on the LEACH improvement processes is primarily limited to comparisons of a few parameters. As a result, some haven't explored further details about LEACH successor protocols. Reviewing current research on LEACH-based routing algorithms is the aim of this survey. The current paper offers a contemporary analysis of the progress of LEACH clustered routing algorithms. It examines distinct and different LEACH algorithms by utilizing the classification based on many metrics, including energy conservation, clustering methodology, and communication strategy. Both CH choosing and data communication strategies are significant in clustering hierarchical structures based on algorithms for prolonging the lifespan of WSNs. Due to this, the current survey categorized LEACH enhancement techniques into the following five categories:(1) algorithms for clustering that use CH picking to enhance the LEACH protocol; (2) algorithms for strengthening LEACH that uses information transmission approaches;(3) techniques based on both data communication modalities and CH selection. (4) algorithms for optimizing LEACH using Fuzzy rule-based. (5) Algorithms that use external energy sources to develop LEACH. Protocols are then categorized within each class according to various factors, including remaining energy, mobility, centralization, distance, single-hop, multi-hop approach, etc.

The contribution of survey (1) can be described as a comparative study of 36 LEACH descendant clustering routing algorithms with various categories depending on several factors. (2) We invested innovative LEACH descendent strategies in this investigation, focusing on energy effectiveness, distance, remaining energy, communication strategies, one-hop and multi-hop, clustering methodologies, CH selection, deployment, and adaptability. (3)A comparison of this survey with earlier studies has been carried out. (4) the upcoming projects and study scope are addressed. (5) The outcome of this survey would help researchers choose the most practical LEACH algorithm for implementing the related research study. The survey is organized as follows: Section one reviews the introduction on WSN and routing importance. Section two provides an overview of many ongoing surveys. Section three summarizes WSN design aspects and substantial WSN routing types. In Section Four, the current study of LEACH successor algorithms, including the standard LEACH protocol, is introduced. It also gives a comparative analysis of many discussed algorithms and defined routing algorithms for each category. Section Five offers a summary and conclusion of this study's findings, and Section Six presents some directions for future work.

2. Ongoing surveys

The authors described six LEACH-based hierarchical routing algorithms in [5], which solve the non-regular CH allocation that the LEACH algorithm offered. Regarding energy loss, each approach was contrasted with the traditional LEACH protocol. The survey's flaw is that the authors did not categorize the methods they looked at and only included six LEACH grandchildren in their estimations. The survey in [6] studied the energy loss of various LEACH-extracted algorithms. The CH voting

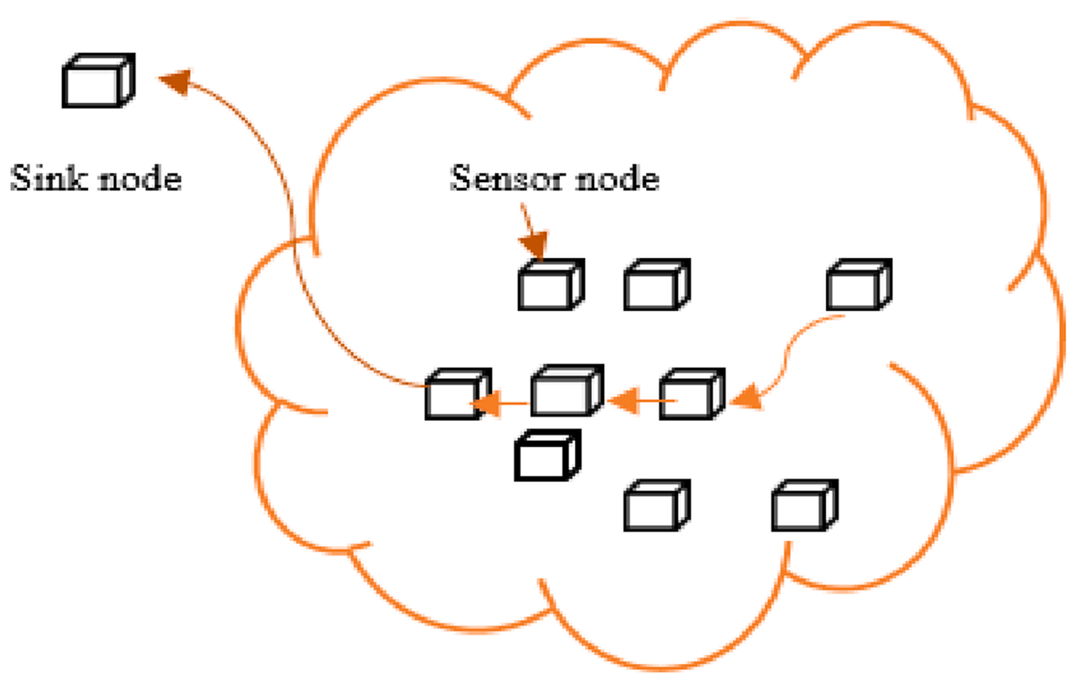

Fig. 1. WSN architecture.

Table 1
A comparison between this survey and previous surveys.

Year	Strengths	Limitations
2016 [5]	Six LEACH-based hierarchical routing algorithms address the LEACH algorithm's non-regular cluster head allocation problem. Each strategy was compared to the conventional LEACH in terms of energy loss.	The authors did not categorize the reviewed techniques, and their assessments only considered six LEACH grandchildren.
2019 [6]	The main aim of this study was the CH election mechanism and the hop count. The authors evaluate these successor algorithms and compare their energy consumption to the LEACH algorithm's.	The inability to categorize these routing algorithms. Only eight LEACH variations are displayed as a result—the authors' comparison of a few parameters. However, certain important parameters are missing.
2019 [7]	The main aim of this study was the CH election mechanism and the hop count. The authors evaluate these successor algorithms and compare their energy consumption to the LEACH algorithm's.	The inability to categorize these routing algorithms. Only eight LEACH variations are displayed as a result—the authors' comparison of a few parameters. However, certain important parameters are missing.
2017 [8]	The survey noted a variety of communications and multi-hop configurations between the Cluster heads and the end endpoint sink node. Depending on the goals and achievements, the authors addressed the upsides and downsides of LEACH and its modifying algorithms.	Authors neglected to check crucial factors, such as remaining energy, adaptability, energy consumption, movement, etc. when reviewing algorithms.
2018 [9]	The algorithms ' data collecting, node mobility, and scalability parameters are compared.	Without categorizing, the authors discussed twelve LEACH-derived algorithms. They did not discuss additional factors or list the upsides and downsides of each mentioned technique.
2021 [10]	Classified LEACH-based protocols based on CH selection, data transmission, and both CH selection and data transmission techniques	Discusses the strengths and weaknesses of LEACH-based protocols but fails to LEACH variants using external energy source and LEACH variants utilize fuzzy logic.
2022 [11]	Bio-inspired algorithms have enhanced CH selection. The algorithms in the study are compared to scalability, data transfer, and durability ratios and considered as performance indicators.	A concise explanation of only ten LEACH-based bio-inspired protocols.
Our survey	This survey gives a comprehensive overview of the LEACH concept as well as a collection of prior investigations. With a focus on the set-up step concerns (CHs picking and cluster construction) and the transmission step considerations, this work presents a thorough categorization of LEACH and its variant algorithms with a qualitative comparison of their operations.	It requires: Investigating authenticated encryption techniques in WSNs that support privacy and network security field. Investigating machine learning integrated with the WSN could be investigated.

process and the number of hops were the main topics of this study. The authors assessed the effectiveness of these successor algorithms using simulation and comparison to the LEACH procedure in terms of energy exhaust. The survey's problem is the lack of categorization of these routing algorithms. As a result, only eight LEACH variations are displayed. The authors compared several parameters. However, certain important parameters are missing. LEACH and several modification protocols were documented in a survey reported in [7]. This survey pointed out various communication methods and multi-hop between the Cluster heads and the endpoint sink node. The authors discussed the benefits and downsides of LEACH and its modification algorithms, relying on the missions and outcomes. Because of this, the authors neglected to check crucial factors when reviewing algorithms, such as remaining energy, adaptability, energy consumption, movement, etc. In [8], LEACH algorithms were analyzed against one another in terms of data gathering, node mobility, and scalability. However, the first drawback of this review is that the authors discussed twelve LEACH-derived algorithms without categorizing them. In addition, they have not brought attention to list the upsides and downsides of each mentioned technique. In [9], the survey summarizes LEACH and its modifications.

Additionally, the authors gave an outline of a few previous surveys and outlined their limitations. They divided the algorithms founded on LEACH into two major classes: Cluster – head choosing and cluster development. Furthermore, these protocols' strengths and drawbacks are given along with their achievements. As an outcome, it has compared different algorithms depending on remaining energy, node position, and complexity. This survey needs to be developed because several network metrics are missing, and the algorithms lack sufficient detail. In [10], the survey Classified LEACH-based protocols based on CH selection, data transmission, and both CH selection and data transmission techniques. The author discusses the strengths and weaknesses of LEACH-based protocols but fails to study bio-inspired and external energy source LEACH variants and LEACH variants' use. In [11], the Author pointed out bio-inspired algorithms that have enhanced CH selection. The algorithms in the study are compared and considered scalability, data transfer, and durability as performance indicators. The survey gives a concise explanation of only ten LEACH-based bio-inspired protocols.

The previous findings generally focused on cluster formation algorithms or cluster head selection criteria or highlighted LEACH-driven algorithms' key contributions, rewards, and limitations. Contrarily, our survey gives an in-depth overview of the LEACH strategy and a compilation of earlier studies. This paper proposes a comprehensive classification of LEACH and its variation algorithms, concentrating on the set-up step considerations (CHs selection and cluster formation) and the transmission step considerations as the two prime stages of executing routing the data packets from the source node to the sink node. The drawbacks of past reviews, as summarized in Table 1 (1), are that they did not categorize the routing algorithms of the reviewed techniques. (2) their assessments only considered few numbers of LEACH grandchildren. (3) The comparison between the reviewed techniques of a few parameters, as certain important parameters are missing. (4) neglected to check crucial factors when reviewing algorithms, such as remaining energy, adaptability, energy consumption, movement, etc. (5) some reviews did not discuss additional factors or list the upsides and downsides of each mentioned technique. In contrast, this work thoroughly categorizes 36 distinct algorithms with a qualitative comparison depending on their operations and effectiveness.

3. Aspects of WSN design

The primary goal of ideal network design is to transport all sensed data from scattered nodes to the sink node using as little energy as feasible. However, WSN challenges to obtaining optimal design are shown in Fig. 2. Several noteworthy aspects of the network's perfect design [2,12]. What are the principal motivations for proposing LEACH different versions protocols for WSNs.

3.1. Hardware limitation& complexity

Each sensor node contains the following: (1) The energy supply (battery). (2) The processing element comprises the memory and CPU modules (3) The sensor element, which varies, refers to the data sensed. (4) The radio transceiver. It's worth mentioning that each preceding component must be compact, low-cost, and energy-efficient. So, the sensor node's structure is distinguished by limited calculating ability and limited memory. As a result, WSNs' global network rate is affected by complexity. As an outcome, designing a low-complexity clustering routing algorithm is vital. To save network energy, the clustered routing algorithm must consider as many factors as necessary with minor complexity.

3.2. Nodes deployment

One of the primary issues in WSN is deployment, a crucial aspect affecting system performance. Devices are deployed at random or in precise locations depending on the application kind of the network. Additionally, sensor nodes can all be fixed or mobile, or even all sensor nodes can be stationary, but the sink node can be portable. In the WSN, both the position and movement of sensor nodes have implications for energy consumption. Some routing systems promote the LEACH strategy without considering the arrangement of the network node's effect. Consequently, node deployment is among the most critical aspects of network design. Various factors must be considered while placing nodes in the network. Coverage, energy, connectivity, and so on are examples of measures.

3.3. Modulation strategies

Wireless communication exposes the entire network to the risk of a rate of error, which substantially impacts the network's functionality and performance. So, WSNs can save energy and improve security by determining the optimum modulation and channel encoding settings. In this regard, a key solution in the physical layer of WSN is optimal modulation with a designed especially coding scheme. Investigators will have prospects to use the coding strategies in LEACH descendant protocols.

3.4. Energy Consumption

The radio channels transmit information inside the network. Additionally, signal strength is inversely proportional to data length moved over the whole network. As a result, the presence of any impediments has an impact on the network's power consumption. Furthermore, routing orientation can also be a multi-hop, single-hop, or a combination of the two. It's important to note that multi-hop orientation outperforms single-hop orientation in extensive networks where sensor nodes are very far apart from sink nodes.

3.5. The environment of the monitor area

The Monitor Area Conditions: Sensor nodes must be qualified to cope with any troublesome conditions in the monitoring area.

3.6. Fault Tolerance

A node's equipment failure is unavoidable. As a result, fault tolerance is a significant issue in WSN, which impacts network longevity. The WSN nodes, especially, may be placed in an environment inaccessible to

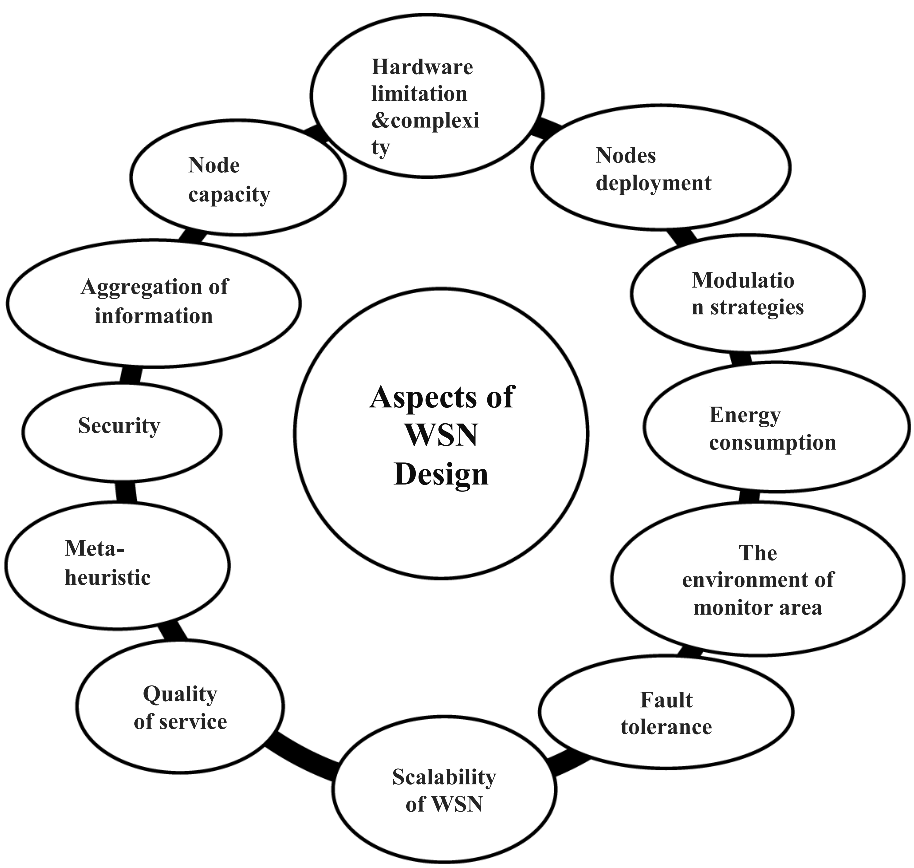

Fig. 2. WSN challenges to optimal design.

humans and remain unattended. Because the CH is in command of forwarding packets from member nodes to the sink node, its failure significantly impacts the overall network. As a result, the clustered routing algorithm additionally includes a fault-tolerance factor. It is vital to prevent errors produced by connectivity breakdowns and node loss. In the event of a CH defeat, it should be clear steps to be followed to reassemble and use another cluster head. The routing aspect needs to respond to the changing situation to protect the sensed data and look for ways to have the data to the sink node.

3.7. Scalability of WSN

The monitor region of a WSN might have a large number of sensor nodes. As a consequence, the routing aspect must deal with many sensor nodes. The network's scalability can be handled through the perfect routing aspect. As a consequence, it enhances data transmission while reducing power consumption.

3.8. Quality of service [13]

Different WSN clustering algorithms have been deemed energy efficiency fundamental to boosting network scalability and lifetime. However, several modern WSN-based systems have constraints that necessitate QoS (Quality of Service). QoS measures such as end-to-end delay, throughput, scalability, reliability, frequency band, response time, ability to adapt, resilience, and other factors are the key concerns in modern WSN-based systems. To address efficiency concerns in WSNs, investigators can design and develop clustering-based energy conservation relevant guidance on QoS.

3.9. Meta-Heuristic [14]

Heuristic algorithms are used in WSNs to discover predictable optimization algorithms. These proposed to inspect the concerns of the clusters, such as CH selection, the CH quantity, node placement, and data gathering [4]. For LEACH successor algorithms, heuristic algorithms constitute a major research challenge. Several modifications can be performed to apply heuristic algorithms in LEACH variant algorithms and lengthen network lifetime. Researchers in the future may design mixed algorithms that incorporate the benefits of different heuristics. The hybrid algorithms consider the percentage of QoS, modulation, coding, and other aspects to maximize WSN performance.

3.10. Security

Encrypting safety in clustering with a sensor node with a limited storage and computation capacity is a valuable contribution to LEACH, but it provides an important limitation in WSN. The CH's vital functions, such as data gathering and transmission to the sink node, make it the most vulnerable equipment. As a result, protocols for authenticating and encrypting data can be employed right at the outset. Keep the CH level up to avoid attacks.

3.11. Aggregation of Information

The CH node is responsible for collecting network information that has been sensed. Thus, there's a chance that some of the information gathered is duplicated. As a result, the cluster head aggregates the sensed data to lower the size of the data communicated to the sink node. Data fusion has been implemented in the network to reduce overall power usage.

3.12. Node Capacity

The goal of node capacity is to allocate specific activities to the node other than sensing data, such as gathering data from other nodes and aggregating it, rather than having all nodes conduct all jobs simultaneously. Additionally, the capacity of nodes prevents excessive energy use. Several types of research demonstrate the importance of the routing aspect in WSN. The routing component refers to the techniques for selecting the best path to transport data from a network's source node to its destination (sink node).

4. Fundamental WSN routing types

In WSN, routes can be reactive, proactive, and hybrid [15]. The reactive pathway detects the pathways routing when they have been indeed required. On the other hand, the proactive pathway routing option is seen before the occurrence occurs and saves the discovered routes in a table for all nodes. The mixed pathway routing method is a mixture of the previous two ways, as is shown in Fig. 3. Regarding the network flow data planning, routing aspects can be classified as flat, hierarchical, or dependent on location routing [12]. All sensor nodes execute the same functions in a flat routing scenario. As a result, there is a lot of data repetition. Hierarchical routing has a feature that creates clusters of sensor nodes. So, it enhances the overall network's energy efficiency. Moreover, it can monitor a wide area and cover many sensor nodes. By performing two steps, hierarchical routing provides more excellent performance. The cluster head is defined as the first step. The CH to/from the sink node routes in the second step. Location-based routing aspects are required for specific applications that require knowing the position of nodes and determining the distance between nodes. The Global Positioning System (GPS) can be a benefit for that. The gains of cluster building in hierarchical routing over flat routing [12] (1) Managing complex networks efficiently. (2) Investing in the concept of data fusion. (3) Prevent traffic collisions. (4) The network's lifespan has been extended. The network comprises clusters of sensor nodes that are clustered together. Each cluster has a unique head responsible for directing communication with the sink node instead of the rest of the cluster's sensor nodes. Each cluster's head gathers information obtained from the other sensor nodes. The data is then aggregated to reduce the amount of information data being transferred

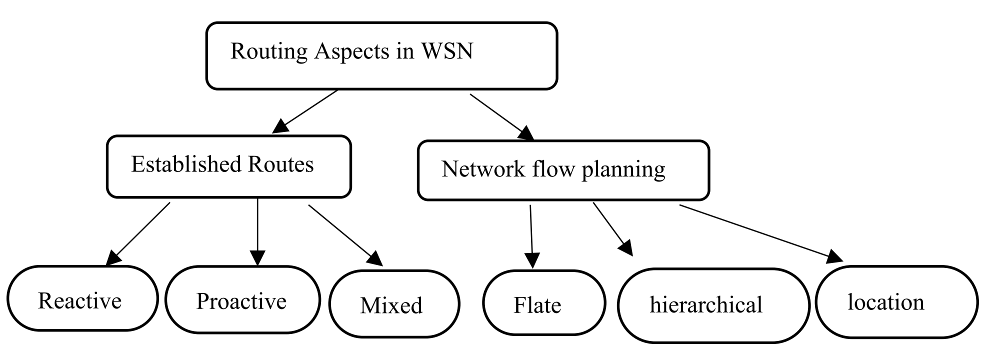

Fig. 3. Protocols for Routing.

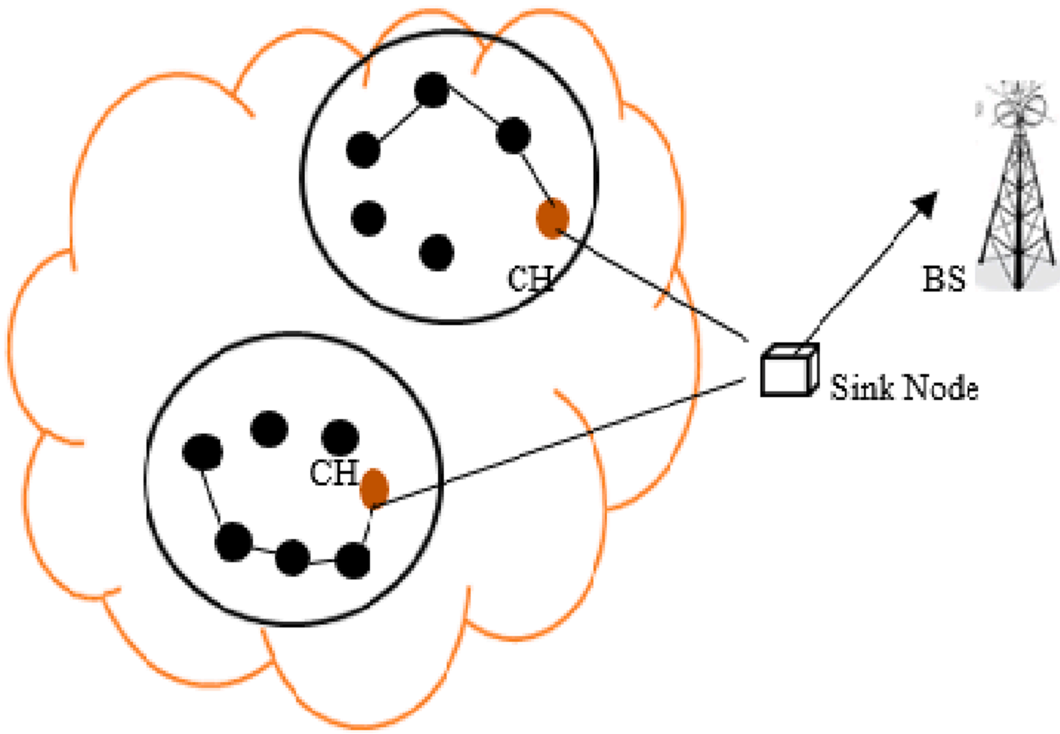

Fig. 4. Creation of clusters.

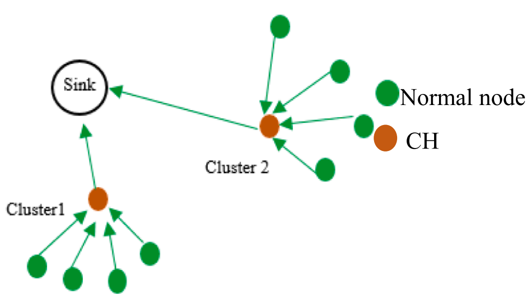

Fig. 5. LEACH architecture.

before being sent to the sink node. As a result, it offers the ability to control the entire network, as seen in Fig. 4. In contrast to flat routing, sensor nodes broadcast their sensed information to the sink node simultaneously. Cluster building uses data fusion to minimize the number of data packets that must be routed through the whole network. The sensor nodes broadcast their detected information to the sink node at different times [16]. Only the head of each cluster can transport data to the sink node in terms of clustering routing. As a result, the clustering routing feature prevented traffic collisions. In addition, the cluster's head shifts round after round to allow an equivalent energy level among the sensing network's participants, prolonging the network lifespan. Several types of research on hierarchical routing algorithms based on clustering algorithms are considered. Network clustering routing is an energy-efficient routing. This routing technique promises energy equilibrium in wireless sensor networks (WSNs).

5. An overview of the LEACH method

Researchers have developed numerous routing algorithms to address energy efficiency constraints and increase network longevity. These methods are based on clustering theory. W.B. Heinzelman proposed LEACH [4], the first and most widely used hierarchical routing algorithm for hierarchical clustering sensor nodes. LEACH suggested that the WSN's energy balance be agreed upon and the total efficiency be optimized [17] by clustering the sensor nodes and randomly electing CH [18]. The LEACH routing structure is shown in Fig. 5 to construct a WSN algorithm that divides sensor nodes into clusters. The LEACH routing algorithm utilizes TDMA for data transmission and reception in a MAC protocol. LEACH is a routing algorithm that uses a cluster structure to create divided clusters from nodes. As a result, each cluster has a cluster head, CH, which aggregates information from its cluster nodes before transmitting it to a sink node [19]. The LEACH algorithm is divided into numerous rounds. Every round has two steps: set-up and steady state, as indicated in Fig. 6(a, b). Clusters are constructed, and TDMA is arranged during the set-up step. The algorithm must first choose a random value n between zero and one in setup. When the chosen value n is smaller than the set limit T(n) in Eq. (1)[4]. The sensor node becomes the CH for the existing round r.

$$T(n) = \begin{cases} \dfrac{per}{1 - \mathrm{per}^{*}\left(\mathrm{r\,mod}\dfrac{1}{\mathrm{per}}\right)}, atn \in S \\ 0o.w \end{cases} \tag{1}$$

When Per denotes the probability of the node being CH, S is the group of nodes that haven't been allocated to CH till 1/per round. Following CH selection, all CH sensor nodes broadcast their status to non-CH sensor nodes using CDMA messages. Following the receipt of broadcast messages from CHs, non-CH sensor nodes utilize the RSS to figure out which CH is the most likely to connect with it. The CH subsequently prepares a TDMA schedule to designate time slots for CH sensor node members, emphasizing that each member node is active and attached to the CH according to the TDMA schedule produced by its CH. It saves energy in the network because the sensor nodes go inactive at times other than their time slots.

They hold their powers in reserve. CH sensor nodes are the sole nodes that connect to the sink node [20]. The Steady stage has a longer duration than the Set-up step because it is made up of many frames [21].

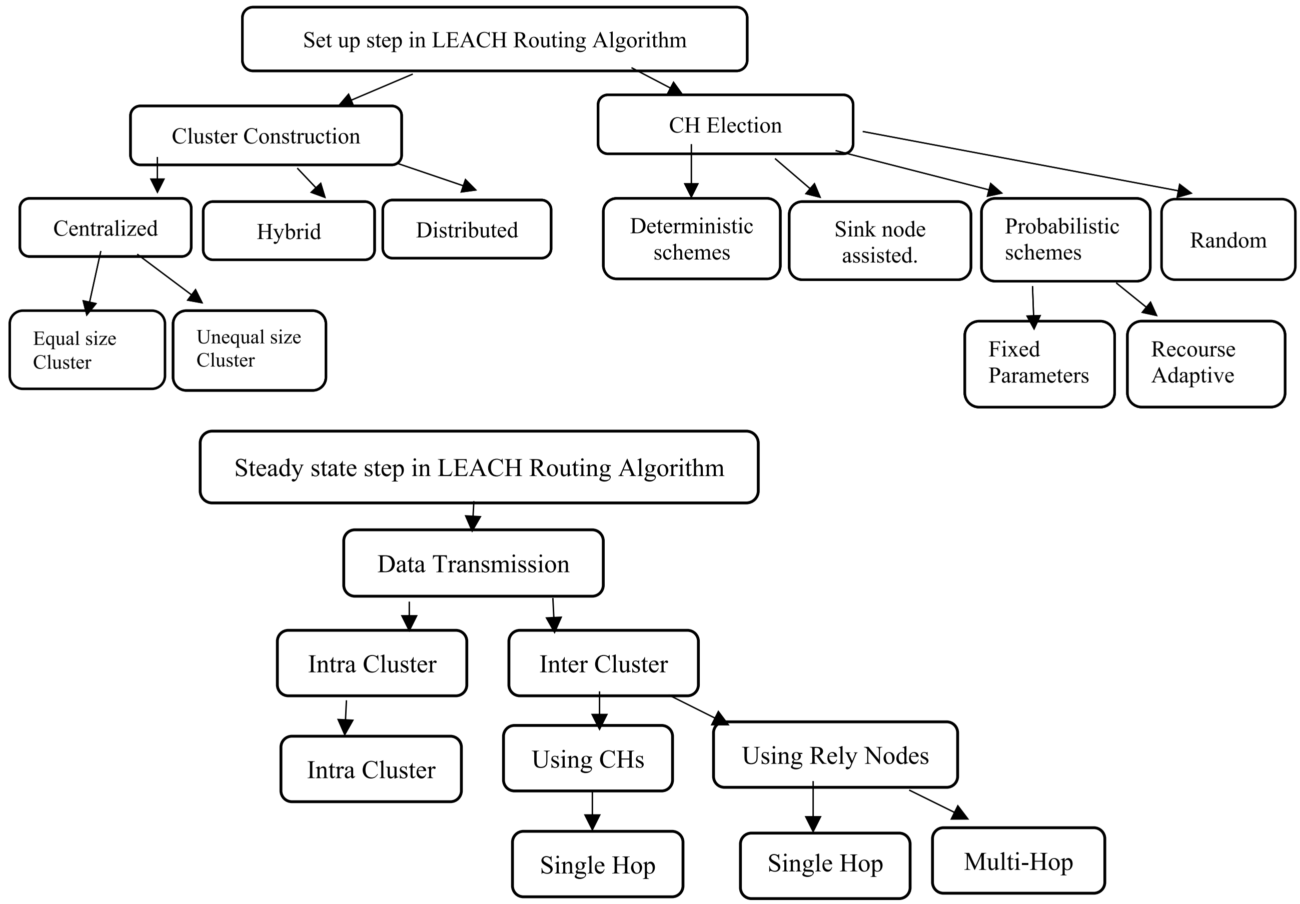

Fig. 6. (a) Set-up step in the LEACH Routing Algorithm. (b) Steady-state step in the LEACH Routing Algorithm.

During the steady-state step, each normal node utilizes a time slot in the TDMA table to deliver its acquired data to its CH. After CHs have merged the data, it is transmitted to the sink and employs the Code-Division Multiple Access codes (CDMA) to prevent collisions [22]. That is why it is called the data transmission step. And rotational CHs guarantee network energy conservation. Data is conveyed in two distinct forms of communication during the communication session of a WSN: (1) intra-cluster communication and (2) inter-cluster communication. Nodes in the cluster connect with their CH in the intra-cluster within a cluster, while CHs connect with the sink node in the inter-cluster. Transport data within the cluster is always one-hop. Inter-cluster communication, on the other hand, can be one hop or more hops. Considerable hierarchical and clustered routing algorithms were devised utilizing one of the mentioned forms of communication. Fig. 6 illustrates (b) the Steady-state step in the LEACH Routing Algorithm. The work in [23] proposes a simulation of the LEACH algorithm.

5.1. Leach's benefits and drawbacks

A. Benefits are:

)1) The LEACH algorithm clustering feature imposes lower transmission across the network from sensors to a sink node. It lowers the transfer packet amount by constructing clusters, electing CHs, and prolonging the network's lifespan.)2) Since under the LEACH algorithm, of at least once being the CH and repeatedly becoming a member node during its lifespan, the CH's random rotation increases the network lifespan.)3) LEACH promises no node interference since it relies on the TDMA timetable for transferring data. Till sensor nodes are not in their turn to deliver data, they stay in sleep mode. which eliminates intra-cluster collisions. It lengthens the sensor nodes' battery life.)4) LEACH guarantees that no CHs will interfere since it has relied on the CDMA code.)5) Cluster head function of aggregation data eliminates redundant information directly, significantly lowering power usage. A.

B. LEACH flaws, according to [24], are:

LEACH is unsuitable for big networks since it relies on one-hop routing to the sink node. (2) Inadequate time-sensitive applications due to delays. (3) Random selection of CHs affects network energy consumption since LEACH didn't consider various factors, including the CH and the sink node distance or even the energy existing in nodes before using them as CHs. Nodes with lower energy levels have the same possibility of becoming CH as nodes with a well-balanced energy level. After the nodes become CH, they demand considerably more energy than ordinary nodes. (4) Various sizes for each cluster. Cluster selection is random, leading to big groups and smaller pieces with no specific study. (5) Since the data delivered to the sink node might be continuous, event-based, or for inquiry purposes, LEACH is more convenient with continuous data transfer only. Despite this, the CH seems to have more traffic than normal nodes and plays a crucial role in gathering and sending data from its cluster sensor node members. Various routing algorithms based on LEACH have been developed to provide solutions to challenges.

6. The Leach-Based algorithms

The presented review of clustering routing techniques categorization based on LEACH. Using LEACH, we'll look at four different types of routing algorithms. Category A: Algorithms that have been based on CH's choosing. Category B: Algorithms that concentrate on information transmission technologies. Category C: Algorithms focused on both CH selecting and data transport technologies. Category D: Fuzzy rule-based

Table 2
The LEACH-based algorithms.

Category A: Algorithms focusing on Efficient Cluster head selection					**Category B: Algorithms focusing on Efficient Data Transmission**			**Category C: Algorithms focusing on efficient CH election And efficient Information transmission**	**Class D: Fuzzy logic**	**Class E: Using external energy sources**
Algorithms work on Residual Energy issue. for CH selection based on LEACH	**Algorithms work on Centralization issue. to CH selection based on LEACH**	**Algorithms work on Mobility issue. to CH selection based on LEACH**	**Algorithms work on Energy Efficiency to CH selection issue based on LEACH**	**Algorithms work on Distance issue. for CH selection based on LEACH**	**One hop**	**Multi-hop**	**One & multi-hop**	E-LEACH	CHEF	sLEACH Solar Aware-LEACH
LEACH-B	LEACH-C	LEACH-M	VH-LEACH	Improved LEACH	LEACH-F	Cell-LEACH	A-LEACH	BRE-LEACH	EEUC	EHA-LEACH
I-LEACH		LEACH-ME	LEACH-T	EADCR	V-LEACH	O-LEACH	LEACH-TL	EDMHT	EAUCF	EP-LEACH
			TB-LEACH	BN-LEACH	W-LEACH	MH-LACH	L-LEACH		Fuzzy Cluster Head Selection Algorithm based on LEACH	A-sLEACH
					WD-LEACH	MH-LEACH ImpMH-LEACH DynMH-LEACH			FLEEC	

algorithms. Category E: Algorithms that use external energy sources. Several grouped algorithm techniques are covered in categories A, B, C, D, and E. As seen in Table 2.

6.1. Category A: Algorithms focusing on efficient cluster head selection

Adopting CH is one of the essential factors in saving resources and preserving the network's longevity. Various algorithms for finding a CH all follow the same principle of selecting a high-efficiency node in the network to operate as a CH. The considerations made during the research in choosing CH were grouped into various sensor node issues, including remaining energy, centralization, mobility, energy consumption, and location of sensor nodes are all factors to consider.

6.1.1. Algorithms work on residual energy issues for CH selection based on LEACH

6.1.1.1. LEACH B. In [25], the author suggested LEACH-B (LEACH-Balanced) as an approved version of LEACH for wireless sensor networks, relying on selecting the appropriate number of CHs. During the first setup of LEACH, the LEACH-B advances the choice of CH that meets the best amount of CHs, dependent on the leftover power of the node. The algorithm distribution is decentralized [26]. The LEACH-B routing algorithm's three steps are selecting CHs, constructing clusters, and transmitting/receiving data. After choosing CHs for the first time, LEACH-B works similarly to LEACH. Then, LEACH-B includes a step that examines the energy reserves of each sensor node. It's figured out using Eq.2 [25]. For a network of 100 sensor nodes, it is estimated to be between 3 % and 5 % [25].

$$Number\ of\ CHs = N{*}P \tag{2}$$

The network's overall number of sensors is (N), and (P) is defined as the likelihood of being CH. Each node is knowledgeable of its placement and the position of the sink node. Even though the node does not know the location of other nodes [27], a common sensor node with equilibrium energy has become a CH when the number of CHs is fewer than N*P. Furthermore, CHs with energy levels will be discarded, which is not the case with LEACH. LEACH-B ensures a consistent quantity of CHs is distributed in every round [28]. The LEACH-B offers superior results, and LEACH-B has been used to offer superior results and enhance LEACH in the number of live nodes within the time span of the network [25]. Demonstrates the LEACH-B flowchart and simulated and experimental [25].

6.1.1.2. I-Leach: Improved LEACH. I-LEACH is an algorithm that also relies on clustering. Choosing CHs considers several factors, including all the leftover sensory energy of nodes, their placement, and the count numbers of the sensing nodes' neighbours [29]. The I-LEACH algorithm enhances performance and ensures that sensor nodes survive for longer. The optimal quantity of clusters in the network (K_{opt}) is properly considered by the I-LEACH algorithm [27] defined in Eq.3.

$$K_{opt} = \frac{\sqrt{N}}{\sqrt{2\pi}}{*}\sqrt{\frac{\varepsilon fs}{\varepsilon amp}}{*}\frac{M}{dist^2} \tag{3}$$

N denotes the number of sensor nodes deployed in a M *M monitoring area.Where dist is the average distance between CHs to the BS. εfs and $\varepsilon\, amp$ are parameters of the transmission and receiver circuit in free space and multi-path fading, respectively. The algorithm, like B-LEACH, is focused on clustering and involves three steps: identifying CHs, establishing a cluster, and broadcasting and receiving data. The revised threshold equation is the sole basis for CH selection in the LEACH algorithm.

Additionally, other variables that influence the network's longevity are ignored. To address this issue, the I-LEACH algorithm modifies the LEACH threshold by taking into account the power reserves, neighbour's node number, and length of the sink node parameters, as stated in Eqn3.

Table 3
LEACH-based algorithms positives and downsides (Category A):

Routing Algorithm	Strengths	Limitations
LEACH	Exploit TDMA procedures to improve network lifetime. Fairness the energy consumption. It Broadcasted packet reduction. Node energy dissipation reduction.	Cluster head nodes election without conscious decision. Cluster head nodes distribution is nonuniform The nodes count in clusters is not identical to others Transmitting data Uses a single hop.
LEACH-B	Network lifetime is enhanced. Take into consideration the energy remaining of nodes after the first round. The number of cluster heads is symmetric.	Notable overhead cost value
I-LEACH	Cluster head election premise on node remaining energy and nodes location.	The cluster head merges the data collected for transmission cost reduction. That is not easily applicable to nodes that acquire various types of data.
LEACH-C	Network lifetime is enhanced for small networks. Cluster head election premise on node remaining energy. Better Cluster head node distribution is provided by achieving the centralization method. Achieves the optimal number of clusters.	The obstacle of knowing the node's location The sink node is overloaded, were using the Centralization method. Transmitting data Uses the single hop, which creates extra overload
LEACH-M	Support feature of node mobility. Efficient energy is extremely high.	Additional overhead.
LEACH-ME	Support feature of node mobility. Cluster head election premise on the less mobile node.	Additional overhead
VH-LEACH	Cluster head election premise on the node remaining energy. It uses an assistance node (VH) to the cluster head when a calculated threshold arrives.	It brings additional procedures for extra assistant nodes (VH). Transmitting data from cluster heads to sink node uses direct data in one hop.
LEACH-T	Confirms the number of periods in TDMA is conditional on the number of nodes. Achieves the optimal number of clusters.	Cluster head nodes election without conscious decision. Transmitting data from cluster heads to sink nodes uses direct single-hop data.
TB-LEACH	Network lifetime is developed. The cluster head count is symmetric.	Cluster head election premise on a random timer.
Improved-LEACH	Entire network performance improvement Best cluster head election	additional complex calculations

Each node uses the LEACH algorithm to generate a random number between zero and one as an aspect of the CH selection procedure. If this number is below the determined threshold in the current round, it is elected as CH. Immediately after the election of CHs, all nodes are assigned to the CH with the strongest signal. Sensor nodes that closely receive the same inputs greatly impact the overlap issue.

When CH merges its acquired data from member nodes in the data transmission process, the I-LEACH protocol solves this issue, reducing the data transmission fee considerably. CH is the sensor node in the I-LEACH with the most excess energy and is closest to the sink node. The I-LEACH algorithm avoids the drawbacks of the LEACH algorithm, such as cluster size disparity, inadmissible CH distribution, and inadmissible CH selection. [29] Summarizes the simulation and the outcomes. The I-LEACH conserving energy reduction is roughly 62 percent. Increasing About 56 % of the number of packets got received. Also, the network existence increased by at least 65 % [27]. Table 3 shows the benefits and drawbacks of LEACH-based routing algorithms based on residual energy issues to elect CH.

6.1.2. Algorithms work on centralization issues to CH selection based on LEACH

6.1.2.1. Leach-C. The Leach-C or LEACH Centralized routing algorithm best suits wireless sensor networks with central control. It determines the best CH using a centralized approach relying on the sensor nodes' leftover energy. In the set-up step, the nodes update their sensed data directly to the sink node, such as leftover energy and position [30]. LEACH-C is the sink node-based, centrally controlled clustering algorithm [31]. The sink node calculates all sensor nodes' average energy consumption. The existing round's CHs are chosen from sensor nodes with more remaining power than the average. The sink node in the CH election can exploit this latest information to spread sensor nodes in their clusters for every round. Each round's steady phase is similar to LEACH. The LEACH-C algorithm improves upgrades as data communication from/to sink node/sensor nodes is lower than in the original LEACH [32]. It has a good cluster spread and allows to vote in CH elections. Despite the Leach-C routing algorithm offering better cluster splitting built on centralization [30], it is like the original LEACH, which is a single hop that sends data to the sink node via a direct route, ignoring the distance separating the sensors and the sink node, minimizing the network's lifetime [33]. The number of CHs is pre-calculated for all rounds and varies from round to round, unlike the previous LEACH algorithm. Table 3 produced the downsides and benefits of LEACH-C routing algorithms.

6.1.3. Algorithms work on mobility issues TO CH selection based on LEACH

One of the most crucial aspects of WSN is mobility. Mobility can be classified into two kinds: the element side of mobility, which belongs to the movable element, and the movement side of mobility, which corresponds to the type of movement. And there's the design aspect, which covers items like the mobility management approach [34]. In CH selection, node and sink mobility promotes CH election efficiency and, thus, network longevity.

6.1.3.1. Leach-M: Mobile LEACH. LEACH-M [35] extends the original LEACH algorithms and includes a mobility parameter. The set-up phase's sink node is the same as the immobile sink node in the original LEACH; however, the mobility characteristic concerns CHs and member sensor nodes. CHs are determined based on nodes' most negligible attenuation and movement. The CHs that have been detected then broadcast their location to sensor nodes within their transmission area. According to the LEACH-M analysis literature, sensor nodes are first homogeneous, as well as the sensor node's position can be identified using GPS. In spite of the fact that LEACH-M handles the mobility of sensor nodes in the data communication step, the CH selection is identical to that of the initial LEACH using a threshold equation. The mobility of sensor nodes may lead nodes to depart their cluster while passing data to the CH that belongs to it, which is a significant issue in routing algorithms that rely on mobility. The LEACH M algorithm solves this problem by employing a TDMA schedule to check whether nodes are still communicating with CH. In the first of every round, CH verifies the presence or loss of each sensor node via a message sent in response to the request. The nodes that do not respond after two consecutive messages are outside CH's scope. Another concern in the data transmission phase is the relocation of CH or sensor nodes from their cluster, which leads to data loss. When nodes enter their group using the handover procedure, the LEACH-M algorithm allows them to transmit to a new CH.

6.1.3.2. Leach-Me (Mobile Enhanced-Leach). LEACH-ME is an upgrade to the LEACH-M algorithm introduced by the authors in [36]. It chooses CHs from nodes with the lowest mobility compared to their neighbours. Each node contained CH transitions during the steady-state phase of data transmission. The TDMA slot [37] broadcasts different node transitions to CH. The advantage acquired by LEACH-ME is promising in that CHs have the lowest mobility of the rest of the nodes in the entire network, resulting in the least amount of cluster impact. The simulation of the LEACH-mobile and LEACH-C algorithms and the outcomes of algorithm enhancement are documented in [38].

6.1.4. Algorithms work on energy efficiency to CH selection issue based on LEACH

In CH selection, optimal energy performance is a crucial worry in routing algorithms. The wireless network greatly benefits from CHs selection based on which node has the most energy since its longevity is extended. The energy efficiency differs markedly from residual energy. Meanwhile, in routing algorithms based on residual energy aspects, CH overlooks transmission/receiving fees, energy consumption, and many other factors. The energy-efficient clustering algorithms are addressed briefly later.

6.1.4.1. VH-Leach. The authors of [39] developed VH-LEACH, which is an improved version of V-LEACH. The major function of this routing algorithm is the CH election. The VH-LEACH algorithm selects CH with the greatest remaining energy [40]. Then after, construct the clusters and choose which CHs. Each CH acquires all member nodes' remaining energy information. The main CH selects the most energetic vice cluster head (VH). [39]. Until the main CH's remaining power reaches a predetermined threshold, the VH node, sleeping, awakens to take over the CH and elect its own new VH.

6.1.4.2. LEACH-T. LEACH-T is a proposed innovative clustering routing algorithm based on LEACH developed by the authors in [41]. LEACH-T presents a solution for the number of timeslots in TDMA produced in CH determined by the number of member nodes. The LEACH-T algorithm calculates the perfect number of cluster heads in the step of the cluster construction using Eq.4. [41]. It considers the energy left behind at nodes during the data communication stage. The T-LEACH provides CHs with various time periods in the data transmission step /steady-state step [41]. In contrast to a fixed assignment of each CH's time slot, the LEACH-T algorithm assigns slots in TDMA schedules using a dynamic approach. For each CH, the number of cluster members specifies the dynamic process.

$$\mathrm{K_{opt}} = \frac{\sqrt{N}}{\sqrt{2\pi}} * \sqrt{\frac{\varepsilon fs}{\varepsilon amp}} * \frac{M}{dist^2} \tag{4}$$

When the number of member nodes in CH is small, the LEACH-T algorithm assigns a few time slots. Furthermore, the algorithm gives the CH many time slots if the CH's member nodes are big. It's worth noting that if the number of nodes is modest, CHs can communicate to a sink node with one hop or more than one hop; those are options available.

6.1.4.3. TB- LEACH. The algorithm is developed in [42]. It is a time base algorithm for CH voting based on initial LEACH. It enhances the wireless network service life by modifying the original LEACH algorithm. Inside the set-up step, the TB-LEACH algorithm adopts CHs selected according to a random timer rather than randomly chosen CH applied during the original LEACH algorithm. In contrast to LEACH, Each round has a fixed number of CHs, and a counter manages them. At the beginning of every round, all nodes produce a random timer. Once the random timer finishes, the counter seems unable to achieve CH's number. The node then forwards an announcement message to the rest of the nodes, notifying them that it can be CH for this round using CSMA, even though it will not be a CH and will remain a normal node. Following the identification of the CHs, the TB-LEACH algorithm performs the same tasks as the LEACH algorithm. The results and simulation of TB-LEACH are presented in [42], which claims that TB-LEACH improves network lifetime versus the original LEACH. The benefits and drawbacks of energy-efficient algorithms for improving the set-up step in routing clustering algorithms based on LEACH are shown in Table 3.

6.1.5. Algorithms work on distance issues for CH selection based on LEACH

The CH node's location relative to the sink node is a crucial issue that impacts the network's energy usage. Additionally, if the distance is particularly lengthy, it negatively affects network energy usage. Because the CH broadcast sensed and aggregated information to the sink node, thus CH position and the sink position. Improved-LEACH, EADCR, and BN-LEACH algorithms rely on clustering and the distance parameter to determine CHs, which will be discussed below.

6.1.5.1. Improved LEACH. Clustering algorithm Improved LEACH depending on the sensor node's distance for electing CHs in the network. Presented in [43]. It considers two important parameters: node leftover energy and the CH to sink distance. To determine the two metrics, all nodes' leftover energy and the length between CH and sink node, respectively. Use Eqs. (5) and (6) [43]

$$SCRFN1 = \frac{E_{current}}{E_{ini}} \tag{5}$$

$$SCRFN2 = \frac{d_{tosinknode}}{d_{farthestnode}} \tag{6}$$

E_{iai} denotes the node's starting energy, while $E_{current}$ denotes the node's remaining power. The node/sink distance is $d_{tosinknode}$, and $d_{farthestnode}$ is the farthest distance to sink. The network's longevity and scalability have been enhanced by multiplying Eqs (5) And (6) by the weighted number and then taking the summation, which is supplied in Eq.7. Given that w1 + w2 = 1. w1 represents the energy aspect, and w2 represents the distance aspect in Eq.7.

$$SCRFN = w1\left(\frac{E_{current}}{E_{ini}}\right) * w2\left(\frac{d_{tosinknode}}{d_{farthestnode}}\right) * \begin{cases} \dfrac{per}{1 - \mathrm{per}^*\left(\mathrm{r\,mod}\dfrac{1}{\mathrm{per}}\right)}, n \in S \\ 0 o.w \end{cases} \tag{7}$$

6.1.5.2. EADCR. The EADCR algorithm, Energy Aware Distance to CH selection and routing, is introduced in [44]. It is built on the FCM to maximize the wireless sensor network longevity (Fuzzy C-Means). The authors' proposal is inspired by the original LEACH clustering routing algorithm and its rotational function. It considers the nodes' remaining energy and the Euclidean distance between cluster centres and sink nodes. FCM executes clustering at the sink node in the EADCR. The CHs are then determined using a fitness function of each node/sink Euclidean distance, a node/CH distance, the beginning energy, and the node leftover energy, as described in Eq.8. [44]. It's worth noting that cluster members can choose their CHs simultaneously, with the nodes with the best fitness value taking the job.

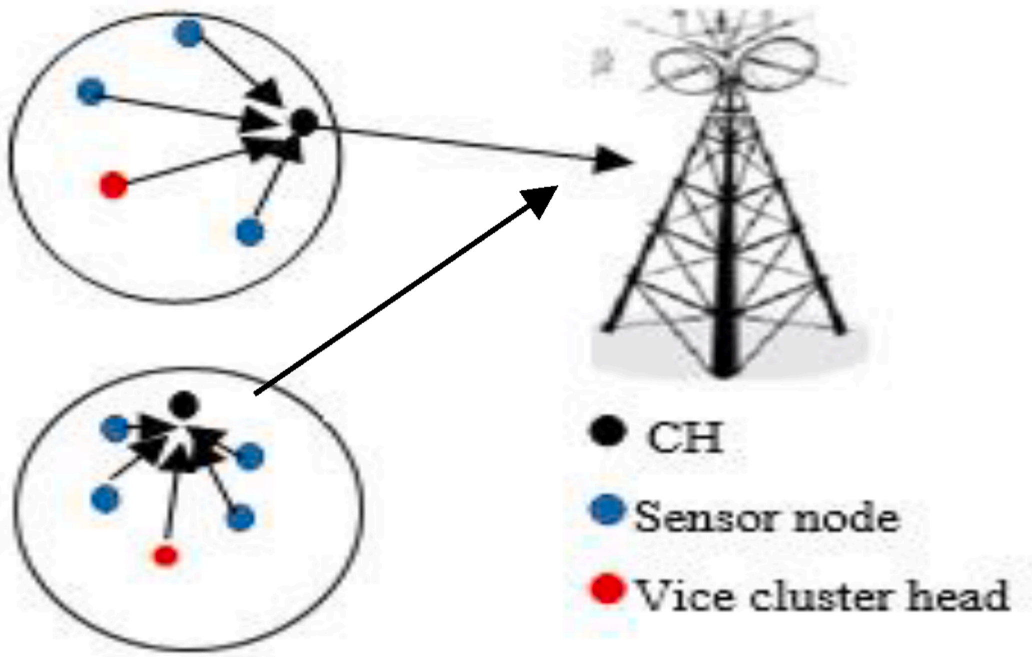

Fig. 7. V-LEACH structure.

$$FCH = \begin{cases} ax_1 + (1-a)x_1, (E_{residual} \geq E_{thd}), (dn2BS > dn2C) \\ x_1, (E\_residual < E\_thd), (dn2BS = dn2C) \\ ax_1 + (1-a)x_2^{'}, (E\_residual \geq E\_thd), (dn2BS < dn2C) \end{cases} \tag{8}$$

As a result, $E_{residual}$ is each node's leftover energy, and E_{thd} is the energy threshold as stated in Eq. (9).

$$Ethd = numberofbits*(E_{elec} + E_{DA})*clustermembersnumbers \tag{9}$$

Where E_{elec} is the energy used to send and get one-bit data, the EDA stands for energy demand over data gathering. $x1$ is the node energy leftover rate to the initial node energy. $x2$ and $x2'$ are expressed in Eq.10. Authors chose the α to be 0.5.

$$x_2 = \frac{d2BS - dn2C}{dn2BS}, x_2^{'} = \frac{dn2C - dn2BS}{dn2C} \tag{10}$$

Sink node/node(n) and sink node/center node euclidean distances are described as *dn2BS*, *dn2C*, respectively.

6.1.5.3. BN-LEACH (Bayesian network –LEACH). BN-LEACH proposal [45]. The BN-LEACH technique is identical to the original LEACH procedure except for the CH selection. The BN-LEACH elects CHs for clusters in the network. Using a Bayesian Network (BN) [45]. Three parameters are taken into account: the node density, their location from the sink node, and their remaining energy. This model calculates the likelihood of a node being CH. The BN-LEACH routing algorithm improves network lifetime by extending the time before nodes die and distributing energy load across the network. CH is chosen by a dynamic area mechanism using a greedy approach to ensure uniform CHs distribution. The cluster is divided into central, distant, and close zones. The central zone has the highest prior probability, the far zone has the lowest, and the near zone has a medium prior likelihood [46].

6.2. Category B: Algorithms focusing ON efficient data transmission

The second critical criterion for improving network performance and extending network longevity is data communication in the WSN. Data transmission and reception between sink nodes and CHs. Likewise, between CHs and their members. The primary concept of any data-transmitting algorithm is to transfer data through a single routing hop, several routing hops, or both.

6.2.1. Single HOP

In the single-hop routing algorithm, The data pathway sent by CHs is a sole hop to reach the sink node.

6.2.1.1. LEACH-F. The LEACH-F algorithm is a fixed number of clusters based on the LEACH technique. It is designed in [47]. As with the LEACH-C method, it is a centralized algorithm that relies on centralized clustering. And arrange itself into clusters and systematically elect CHs. After clusters are constructed, CHs are elected and fixed for all rounds, with no further clustering procedures [48]. As a result, the clusters are fixed, so the chosen CH is only responsible for its cluster. On the other hand, the steady-state step is the same as the original LEACH. Because clusters are fixed at the start of each round, LEACH-F provides insurance to reduce the set-up time. Despite everything, LEACH-F faces obstacles, including the following: (1) If the CH is far away, the nodes may be forced to stay in their clusters. (2)After clusters are established, nodes cannot join or leave the network and cannot modify their behaviour when nodes die. (3)Flexibility and mobility are incongruous with success.

6.2.1.2. V-LEACH. The algorithm is Vice Cluster Head based on the LEACH algorithm. Due to CH, numerous missions require more incredible energy than the other nodes. The authors [49] used the V-LEACH algorithm to reduce energy usage, preventing fixed cluster formation problems and CH death. Fig. 7 shows V-LEACH. A vice-CH node inside the cluster has been selected on the leftover energy of cluster nodes after the clusters have been created. Normal nodes collect and forward collected information to the CH, subsequently send it to the sink during the set-up phase, and then the CHs broadcast the data to the sink node when they have completed their job. If the CH passes away, the vice-CH takes over. Instead of selecting a deceased CH, this algorithm promises excellent efficiency in CH selection by selecting a vice-CH with high

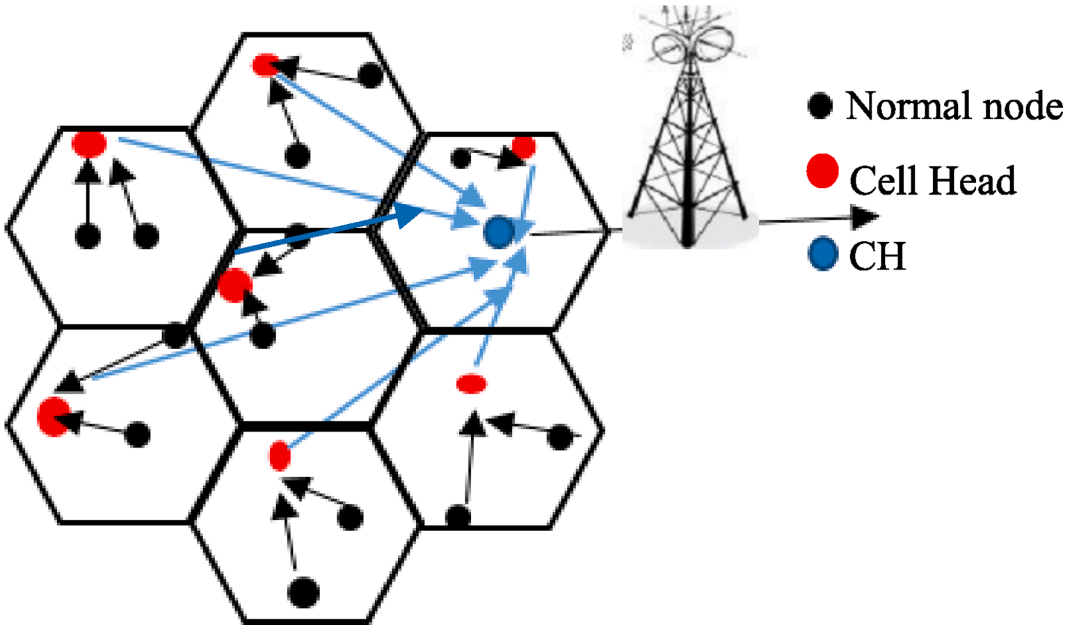

Fig. 8. LEACH-Cell architecture.

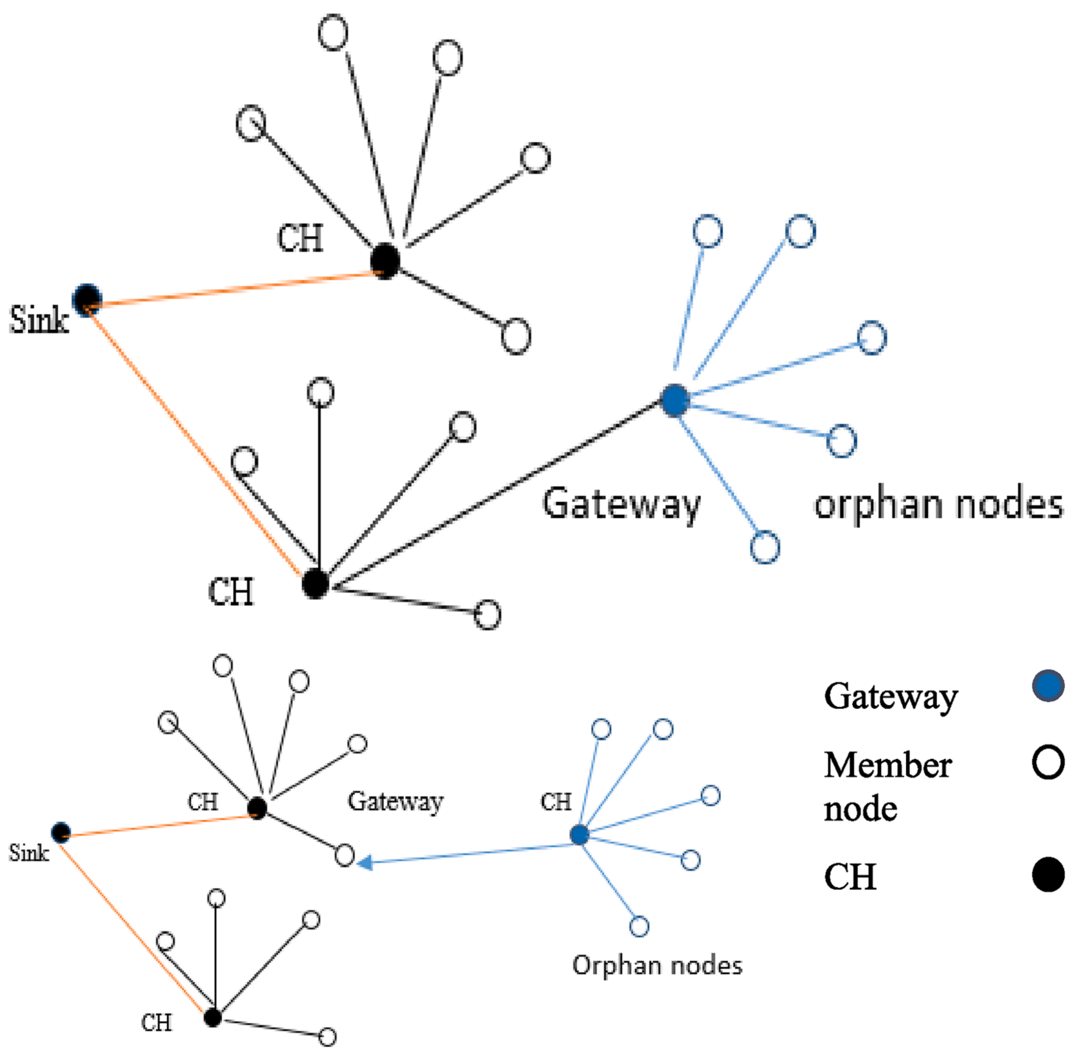

Fig. 9. (a) Option 1 of orphan nodes. (b) Option 2 of orphan nodes solution.

remaining energy. Even if CHs die in any round, the V-LEACH algorithm ensures data transfer to the sink node [50].

6.2.1.3. The W-LEACH. In [52], the authors introduced a centralized enhancement algorithm depending on LEACH called the W-LEACH (Weighted-LEACH) algorithm, where the sink node is a distinctive node that takes charge of choosing active and sleeping nodes in the network. The WLEACH algorithm composes two steps like the original LEACH, while in the set-up step, the authors modify the probability number of CH percentage in the original LEACH to be the highest possible percentage of CHs. In the set-up step, at every round, W- LEACH determines a weight number Wi referred to each node without considering whether the node is taken as CH in past rounds or not [50]. Wi is defined by using two fundamental factors: residual energy of the node and density of nodes. Wi is used to elect the best nodes to be CH. Nodes that have the highest Wi have the highest opportunity to be CH. after CHs are constructed, each node is attached to the nearest CH. The value of Wi is calculated by applying Eq.11 and 12.[51].

$$T(i) = \begin{cases} e_i * d_i if d_i > d_{threshold} \\ d_i otherwise \end{cases} \tag{11}$$

$$d_i = \frac{1 + numberofalivenodesinranger}{n} \tag{12}$$

In conclusion, *d*i indicates the density of one-by-one node, the available range of node i is pointed by r, the residual energy of node i is shown by e (i), and $_{dthresh}$ displays the density threshold for a set of nodes in extremely low-density locations [51].

6.2.1.4. WD-LEACH. The author of [52] improves W-LEACH to WD-LEACH (decentralized W-LEACH), a decentralized algorithm. It extends the WSN's longevity. It divides the network into two segments based on node density information. Active nodes and sleeping nodes are the two types of nodes. Decentralized WD-LEACH, like LEACH and W-LEACH, performs its functions in two steps at each round: set-up and steady-state. Cluster heads are chosen, and clusters are grouped through the set-up phase. Each node that is not CH can identify its neighbour and the distance between them based on the density of nodes [53]. Nodes with a lower density stay alive as long as possible. [52] As an outcome, each node can be active or sleep in each round. In conclusion, WD-LEACH decentralized uses sensor node density to determine if a sensor node is active or asleep. In addition, the method permits some active sensor nodes in each cluster to broadcast their data to their CH in each round. As a result, the W-LEACH decentralized algorithm offers a significant increase in WSN life and a reduction in excessive CHs data. Despite this, it has downsides, such as that it can only execute in networks with the same accumulated data. In [52], a WD-LEACH schema is described. Table 3 shows the benefits and drawbacks of routing algorithms that use a single hop to route data.

6.2.2. MULTI-HOP

Through data routing, the multi-hop mechanism reduces energy usage for the entire network. The data path from CHs to the sink node is classified in this way.

6.2.2.1. LEACH-CELL ALGORITHMS. In [54], the authors extend the coverage of the WSN by employing LEACH-Cell algorithms. A cluster is formed by seven nearby cells. Sensor nodes are embedded in each cell, as illustrated in Fig. 8. Moreover, the algorithm elects cell heads that perform the function as a CH in the original LEACH. The algorithm in the cell head generates a TDMA schedule. Then, for each node member in the cell, allocate time slots. After that, the algorithm collects data from cell members and sends it to their CH in periods designated to them in the TDMA schedule. The CH is in charge of collecting data from cell heads and forwarding it to the sink node in the most efficient way. The cells and clusters are static for the duration of the WSN's existence. However, the CHs and cell heads are dynamically modified within the cluster and cells [54]. The main goal of the LEACH-Cell algorithm is to reduce network communication costs [55]. The algorithm turns off the cell's member node transmission while the cell head broadcasts the collected data to CH. [55] shows the pseudo-code used for new cell-head CH selection. The algorithm flaw emerges when some nodes cannot join a CH due to LEACH's random Cluster head selection, resulting in a few CHs being chosen on a specific network surface. Furthermore, orphan nodes that aren't connected to any CHs can't send data to the sink node. That significant task.

6.2.2.2. O-LEACH (ORPHAN-LEACH). The authors of [56] upgraded the LEACH-Cell algorithms to O-LEACH (Orphan-LEACH). O-LEACH can be used to send data from orphan nodes to the sink node. It provides two options. First, any member node in the cluster should be labelled as the CH for orphan nodes and serve as a gateway. The gateway member node takes the orphan node's measured data and sends it to the cluster head to which it is attached. As seen in Figs. 9a, 9b. The O-LEACH algorithm provides a second solution. If the amount of orphan sensor nodes exceeds the amount of nodes attached to the CH, orphan nodes must form their cluster. The approach is to create a separate cluster for orphan nodes with their CH. The first orphan node to reach the gateway is selected as the administrator for a particular cluster of orphan nodes, as seen in Fig. 9b [56]. Orphan nodes can connect to sink nodes using either of the two solutions. The multi-hop routing mechanism from sensor nodes to sink nodes provides a better transmission range.

6.2.2.3. MHLEACH: (MULTI HOP BASED ON LEACH). The authors in [57] propose the MHLEACH algorithm. It determines the best path for data transfer from CH to the sink node. Transitional CHs are used. The multi-hop connections between CHs and sink nodes are at the heart of this routing system. The MHLEACH algorithm has two steps: initialization and steady state. The set-up step creates clusters in the same fashion as the initial LEACH. Each CH sends a message announcing its new status as CH.Furthermore, relying on the strength of the received signal, each node generates a Table for probable routes to different CHs. After the cluster is created, CHs broadcast their routing tables to the sink node. The sink node checks to see whether any CHs are in the path of another one. The sink node then loads the investigated tables back into their source CHs [57]. Suppose CH refuses to accept data packets. The source CH attempts other routes from its routing table. In [58] it shows a simulation and results for the MHLEACH algorithm.

6.2.2.4. MHLEACH: (Multi Hop Based on LEACH). The authors in [55] propose the MHLEACH algorithm. It determines the best path for data transfer from CH to the sink node. Transitional CHs are used. The multi-hop connections between CHs and sink nodes are at the heart of this routing system. The MHLEACH algorithm has two steps: initialization and steady-state. The set-up step creates clusters in the same fashion as the initial LEACH. Each CH sends a message announcing its new status as CH. Furthermore, relying on the strength of the received signal, each node generates a Table for probable routes to different CHs. After the cluster is created, CHs broadcast their routing tables to the sink node. The sink node checks to see whether any CHs are in the path of another one. The sink node then loads the investigated tables back into their source CHs [55]. Suppose CH refuses to accept data packets. The source CH attempts other routes from its routing table. [56] shows a simulation and results for the MHLEACH algorithm.

6.2.2.5. The MHA-LEACH (Multi-HOP Algorithm-LEACH). [59] Describes the MHTLEACH algorithm. It is an algorithm that is based on the original LEACH. Instead, CHs broadcast data to sink nodes in real-time [60], and the algorithm divides the entire monitoring area into two sections based on the pathway between CHs and the sink node. In the

Table 4
The benefits and drawbacks of LEACH-based procedures (Category B).

Routing Algorithm	Strengths	Limitations
LEACH-F	Using centralization gives a greater distribution of CHs. Reduces the time it takes to set up.	Clusters are predetermined at the start. There is no re-clustering process. Adding or removing nodes inside clusters is impossible once they have been established.
V-LEACH	In the occurrence that the main CH drops dead, the Vice-CH takes over. Extend life expectancy. When the current CH dies, voting for a new CH is unnecessary.	Whenever the CH gets too away from the sink node, it dies early. Vice CH will receive additional treatment.
W-LEACH	Low usage of energy	CH is randomly chosen.
WD-LEACH	Designing active and sleep network nodes Only some sensor nodes are allowed to communicate with the CH.	This method will not be successful in networks where the data collected differs.
LEACH-Cell	The network has excellent coverage. It Increased energy savings.	CHs and cell heads were all randomly selected. Overloading control packets is produced by several types of heads (CHs and cell heads).
O-LEACH	The BS can receive data from orphan nodes. The network has good coverage.	CHs are picked at random. In a single hop, communicate with the BS.
MH-LEACH		
MHT-LEACH	A significant degree of energy efficiency Between CHs, various hop is used. CHs are divided into two sets relying on their distance from the sink node.	Selects CHs without considering energy. The number of CHs in each turn may differ. CHs near the network's edge spend extra energy on only two levels. Clusters do not all have the same number of nodes.
IMHT-LEACH	It adopts the multi-hop strategy between CHs. The CHs are divided into multiple levels.	CHs are picked at random. Only considers the path to the sink node.
DMHT-LEACH	Relying on the distance to the sink node, it partitions the entire network into multiple layers. The distance and remaining energy create each CH's routing table. When the cost function changes, the pathway will change.	CHs are randomly chosen. Each period may have a different number of CHs.
A-LEACH	Prolong the duration of stability. Reduces the likelihood of nodes failing.	CHs selection randomly Data transmission is based on a single hop. CAG nodes are paid extra attention.
LEACH-TL	There are multiple CHs. When choosing the secondary CH, the remaining energy and distance are considered.	Data is sent from CHs to the sink node in one hop. The rate of overhead is rising.
L-LEACH	It is well-suited to huge networks. It uses the most efficient amount of hops. The load on the network is controlled.	Only the distance is taken into account. CHs with low residual energy are more likely to perish fast.

set-up step, the CHs are chosen, and the cluster is built in the same way as in the original LEACH. When a length separates the CH, and the sink node is less than d0, the CH is considered in the inner section. The nodes in that section can communicate with the sink node directly. The CH will be considered in the outer section [61] if its location is equal to or longer than d0. Any CH in the outer portion can create its routing tables using advertisement messages from the inner CHs [62]. As a result, the outer CHs choose the shortest route from their routing table. It sends its data one of two ways: straight to the sink node or through one of the inner CH, using the shortest route length between the CH and the sink node. This algorithm's key benefit is that it balances the energy in the network. Its process mechanism [63–66] promises to balance network energy. However, the fundamental disadvantage of this approach is that it is ineffective in big networks [64]. [59] shows the flowchart and steps for the algorithm.

6.2.2.6. IMPMHA-LEACH (IMPROVED MULTI-HOP ALGORITHM-LEACH). The authors of [61] attempt to address the MHA-LEACH issue by incorporating discoveries into the ImpMHA-LEACH algorithm. ImpMHA-LEACH is the name of the proposed algorithm (Improved Multi-Hop -LEACH). CHs have routing tables for transferring their data over the shortest path in the IMHT-LEACH algorithm, just as in the MHT-LEACH algorithm [66]. The data path in this algorithm is from the outer section to the next, and so on, until the closest section to the sink node [62]. As a result, the development separates the entire network into multiple pieces rather than only two [63,66]. Any segment must be $d0/2$ in diameter to reach the sink node. To obtain clearance: The distance to the sink node in section one is less than $d02$. The distance to the sink node in section two is less than d0 but equal to or greater than $d0/2$. Section three is the distance to the sink node, which is less than 3 $d0/2$ but equal to or longer than d0. The IMHT-LEACH algorithm promises to improve the network's energy balance and lifetime [63]. The IMHT-LEACH method overcomes the MHT-LEACH algorithm's limitation of being able to apply to huge networks [67]. The IMHT-LEACH algorithm stages and flowchart are shown in [63] as a result of splitting the network into multi-sections.

6.2.2.7. DYNMH-LEACH (DYNAMIC MULTI-HOP LEACH). In [68], the author described a dynamic method known as the DynMH-LEACH algorithm. The goal of this algorithm is to improve ImpMHA-LEACH. The suggested algorithm considers the current round's leftover energy [68]. To route the transferred data between CHs and sink nodes, the algorithm first performs static stages similar to ImpMHA-LEACH. Importantly, it can modify its routing information dynamically in the same round. [69]. To accomplish its goals, the DynMHA-LEACH algorithm has four phases. (1) The first step is to put everything up. To choose CHs and build clusters, it uses the original LEACH algorithm. To begin, each CH must create its TDMA table schedule. As a result, each CH's TDMA table contains the distribution of member nodes. Included within CH's TDMA schedule are all the neighbours—the consequence of this step. The CH nodes and member nodes are placed throughout the network, split into portions based on their distance from the sink node. It should be noted that each portion is $d/2$. (2)The second step is to advertise. CHs broadcast messages in the advertisement step to announce their information, such as identification marks, position, length to the sink node, and remaining power [66]. (3) CHs generate their routing tables in the

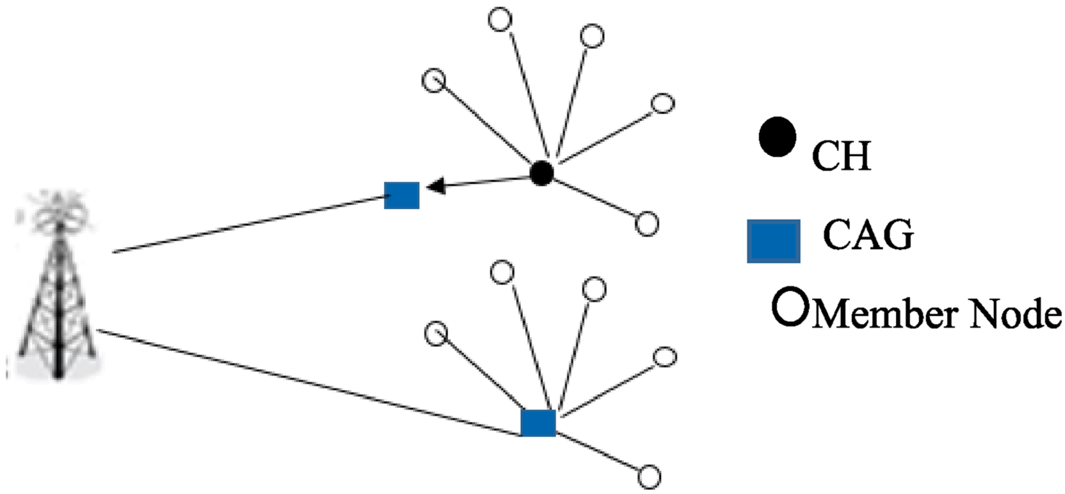

Fig. 10. Advanced-LEACH architecture.

third step based on the information about the CH position gathered in the previous step. These routing tables are arranged from the closest portion to the farthest portion. (4) The routing step is the final step in the DMHT-LEACH algorithm. After constructing routing tables, the algorithm sorts the routing tables in this step. CHs can choose the best path to send data to the sink node based on the distance between the CH and the sink node and the residual energy of CH neighbours. As previously mentioned, the four processes to establish the algorithm are set ups, advertisement, selection, and routing. Also, Eq.13 and 14 determine the cost of route regulation in the routing tables [66]. As a result, the distance and energy costs for the Next cluster head NCH are C_{NCHP}, C_{NCHE}, respectively.

$$C_{NCH}(i) = C_{NCHP}(i) + C_{NCHE}(i) \tag{13}$$

$$C_{NCHP}(i) = \frac{D_i^2}{SCH_{D-BS} - NCH_{ID-BS}} \tag{14}$$

D_i, it is the source cluster head SCH length to the next cluster head NCH. SCH_{D-BS} is the distance between the source cluster head (SCH) and sink. NCH_{ID-BS}, is the length of the next cluster head NCH to sink. In the current round, SCH has chosen i as a member node in the neighbouring set to CHs. And α is the relative weight. The DynMHA-LEACH algorithm's main characteristic is that it implements a dynamic mechanism. For transferring data, consequence paths for routing may be modified several times depending on the computed cost equation for transferring data between each CH and sink node. Table 4 lists the pluses and minuses of algorithms. The multi-hop routing approach sends data from Cluster heads to the sink node.

6.2.3. SINGLE AND MULTI-HOP

A single and multi-hop possibility is a classification of data flowing from the CH to the sink node.

6.2.3.1. ADVANCED-LEACH (A-LEACH) ALGORITHM. The authors in [70] presented the Advanced-LEACH (A-LEACH) algorithm. To strengthen the original LEACH, it is heterogeneous energy. Because the CHs nodes in the original LEACH exhaust a lot more power than the other nodes. The goal of the A-LEACH algorithm is to give the network a more remarkable life. Because of the heterogeneity characteristic, the method promises to reduce the probability of nodes being defeated. As a result, the network's stability will improve [70]. The A- LEACH method, like the classic LEACH algorithm, has two steps in each round. Aside from that, it employs a clock for synchronization and thus to notify the start of turns. The CAG nodes in the described algorithm are those with a lot of energy. The CAG nodes can be used as gateways or CHs. Each node calculates the likelihood of being a CH during the set-up phase. The collected data in CH will be disseminated from CH to the sink node using one of two techniques in the steady state step. The two techniques rely on data being broadcast from nodes through the nearest CAG gateway node. If such a node is a CAG gateway, it can also broadcast the data, as seen in Fig. 10. The decentralized algorithm is one of the A-LEACH features that build upon that original LEACH. As a result, the clusters are built independently of the sink node. The algorithm combines data being sent to the sink node. As a result, the volume of data transferred and the expense of doing so are greatly reduced. Given that all nodes have died,

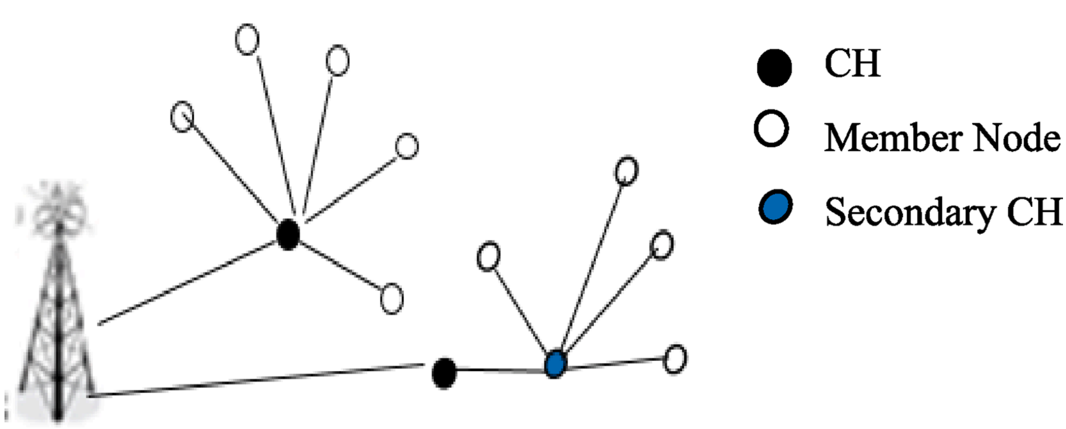

Fig. 11. CH ○ Member Node Secondary CH.

the CAG nodes continue to broadcast data to the sink node.

The algorithm's most notable characteristic is its significant reduction in energy use. As a result, the CHs' life is extended, and the sensed data is transferred to the sink node, extending the network's life.

6.2.3.2. LEACH-TL. The authors of [21] presented the LEACH-TL algorithm to optimize the energy challenge balance in the original LEACH, produced by a random selection of CHs. As a reason, the CHs will have less energy left after the first round. Accordingly, if choosing a CH at random, choose a node that has low leftover energy or one that is distant from the sink node. It means the node will die sooner, and the network will lose data felt by the node. The LEACH-TL algorithm promises to balance the WSN's energy usage. In each cluster, the algorithm procedure is to choose two CHs. one for combining the measured data gathered from cluster member devices. It's known as secondary CH. Then, broadcast the acquired sensed data to the cluster's other CH, which is in charge of forwarding them to the sink node. It's known as the main CH. First, based on the LEACH algorithm, the LEACH-TL algorithm is used to choose CHs and build clusters. Second, either when the CH's energy remains below the average or the distance between it and the sink node surpasses the average. See, for example, Eqs. (15) and (16) [21]. As a result, this CH requires an assistance CH, referred to as a secondary CH, with remaining high energy. When the CH's residual energy is higher than the calculated average, the cluster will not quite need an assistance CH, also known as secondary CH.

$$E_{ave}\sum_{i=1}^{N}E_{cur}(i) \tag{15}$$

$$d_{ave}\sum_{i=1}^{N}d_{i} \tag{16}$$

Hence, $E_{cur}(i)$ is the Cluster Head's current energy, while E_{ave} is the Cluster Head's average energy. The d_i, *and* d_a are the distance between the CH/the sink node and the average distance, respectively. The algorithm illustrated in Fig. 11. [38] covers the evaluation and outcomes of the LEACH-TL algorithms.

6.2.3.3. ENERGY BALANCED –LEACH. Another multi-hop routing algorithm was given in [71]. However, the distance between sink nodes/CHs is simply a factor. The capacity to adjust in huge networks distinguishes the algorithm from the original LEACH. It necessitates the utilization of the most hops achievable. Depending on the distance, CHs send data to the sink node in a single hop or many hops. When CHs are close to the sink, the measured data is broadcast directly to the sink node.

Furthermore, remote CHs from the sink node can use the shortest pathways to transport data through multi-hop paths. Each round of the algorithm consists of two phases, similar to LEACH. The first step is to elect the CHs and build all clusters. The algorithm promises an even distribution of energy among the nodes. Because all sensor nodes have the same amount of power, the LEACH-L algorithm may cover a more extensive network than the Mobile-LEACH algorithm. Table 4 shows the pluses and minuses of routing algorithms that use one hop and more than one hop approaches to broadcast cluster heads collected data to the sink node.

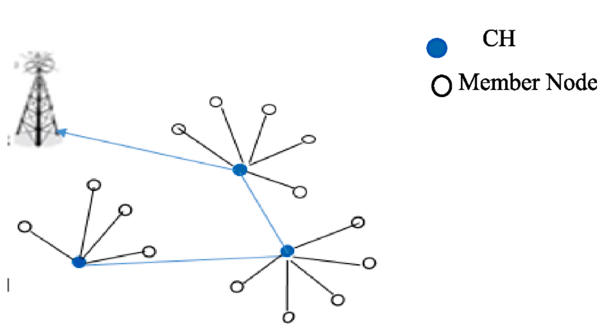

Fig. 12. Check.

6.3. Category C. ALGORITHMS FOCUSING ON EFFICIENT CH ELECTION AND EFFICIENT INFORMATION TRANSMISSION

We have two fundamental difficulties, as previously described in clustering routing schemes. One is a well-executed CH election. The second aspect is efficient data transmission. Both of these concerns have a significant impact on network lifespan. A need for refinements and litters and ongoing research to extend the WSN's life span through progress in these two areas.

6.3.1. E-LEACH (ENHANCED-LEACH)

$$T_{new}(n)=\begin{cases}\dfrac{P_{head}}{1-P_{head}*(rmod(1/P_{head}))}*\dfrac{E_{curr}}{E_{inial}}, n\in G\\ 0 otherwise\end{cases} \tag{17}$$

Hence

$$P_{head}=\sqrt{\frac{N}{2\pi}\sqrt{\frac{E_{fs}}{E_{mp}}}\frac{M}{d_{toBS}^{2}*N}} \tag{18}$$

The authors of [72] build on the original LEACH. The authors enhance the original LEACH by adjusting the set-up step, which is responsible for the CH election, and the steady-state step, which is in charge of data transfer. The leftover energy is taken into account by the E-LEACH in its set-up state [48]. Following the first round, the election of CHs is determined by the remaining energy of nodes. Nodes with higher residual energy have a higher chance of becoming CH [48]. The authors of [72] use Eq.17 and 18 to determine the threshold.

The algorithm chooses a random value n between zero and one in the setup. When the chosen value n is smaller than the set limit $T_{new(n)}$ in Eq. (17). The sensor node becomes the CH, For the existing round r. When P_{head} denotes the probability of the node being CH, G is the group of nodes that haven't been allocated to CH till 1/per round. E_{inial} denotes the node's starting energy, while E_{curr} denotes the node's remaining power. N denotes the number of sensor nodes deployed in a M *M monitoring area. Where $d_{to\ BS}$ is the average distance between CHs and the BS. ε_{fs} and ε_{amp} are parameters of the transmission and receiver circuit in free space and multi-path fading, respectively. The E-LEACH improves the steady-state step of the original LEACH by transmitting data to the sink node in the one-hop method. The E-LEACH algorithm chooses a CH with remaining high power, namely.

a root-CH. A root-CH collects data from CHs and broadcasts the aggregated data to the sink node. Furthermore, CHs discover the best route between CHs /root CH. The E-LEACH algorithm is shown in Fig. 12.

6.3.2. BRE-LEACH

The authors proposed the Balanced Residual Energy development on the original LEACH [20]. It promises increased WSN longevity, stable time intervals, and lower energy consumption costs. As a result, CH has to collect sensed data from nodes in its cluster. As a result, CH energy depletes faster than that of other nodes. Furthermore, the CH election is based on a random method in the LEACH algorithm. The LEACH algorithm ignores one of the most important challenges that affect the network's life, namely the remaining energy of CHs. Because CHs may conclude their lives and then lose their sensed data, the residual energy of CHs causes a network energy imbalance. The BRE-LEACH algorithm is suggested as a solution to the original LEACH defect. It considers the energy that is leftover in the account Eq. (19) [20] is used by BRE-

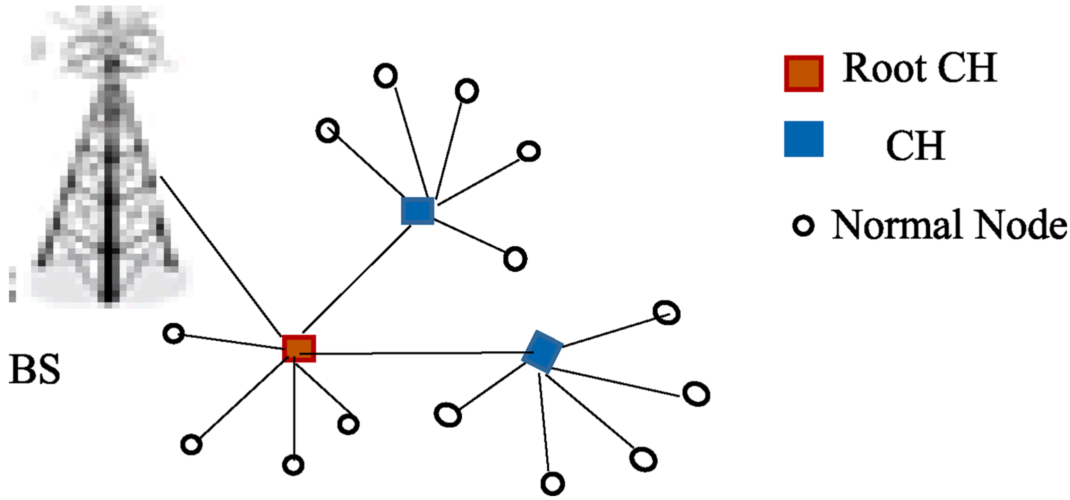

Fig. 13. Balanced Residual Energy LEACH architecture.

Table 5
The upsides and downsides of LEACH-based strategies (Category C).

Routing Algorithm	Strengths	Limitations
E-LEACH	It is bringing the network's energy consumption into balance. CHs are selected based on the node's remaining energy.	Choosing CH based on energy may be further away from the BS. Regardless of the distance to the sink node, selects a root-CH based solely on energy.
BRE-LEACH	It promotes the network's longevity. It gives the determination of CH based on residual energy. Based on the quantity of energy left and the distance to the sink node, choose a parent CH.	Clusters do not have the same node count. The number of CHs may not be the same at each round.
EDMHT-LEACH	In CHs picking, the residual energy is considered. The highest number of sensor nodes in clusters is specified. The network is divided into multiple layers. Data is transmitted dynamically.	In intra-cluster communication, a single hop is used.

LEACH to estimate the threshold.

$$T_1(n) = \begin{cases} \dfrac{P}{1 - P^*(rmod(1/P))} * \dfrac{E_{res}}{E_0}, n \in G \\ 0 otherwise \end{cases} \tag{19}$$

As a result, p is the total number of CH possibilities in the network. The remaining energy of nodes and the initial energy, respectively, are E res and E $_0$. Finally, G represents nodes that were not selected as CH in the previous 1/P rounds. The BRE-LEACH algorithm, like the original LEACH, works in rounds. The BRE-LEACH algorithm performs four steps in each round. The first step is to set up. In the second step, there's the TDMA schedule. The choice of Root CH is the third step. The fourth step is executed inside the data communication process. First, CHs are based primarily on node residual energy. Then, regarding the strength of the received signal, all sensor nodes join to CHs. A TDMA schedule is also sent to cluster member nodes by respective CH nodes. The BRE-LEACH algorithm then identifies CH as the root CH defined by two conditions:

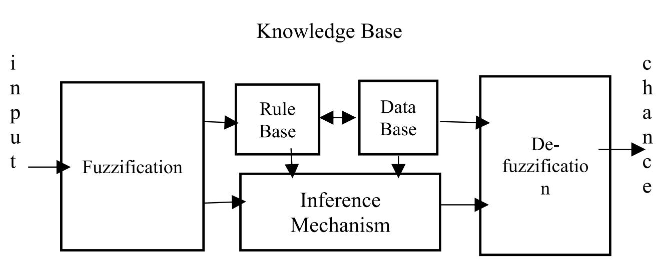

Fig. 14. Diagram of the Fuzzy Logic-based Process framework.

the node's remaining energy being higher than the average. Second, the distance between the node and the sink node is shorter than average. The root CH reassembles data from all other cluster heads before broadcasting these data to the sink node. Furthermore, nodes, not root-CHs, use a multi-hop approach to get to the father CH. Fig. 13 depicts the Balanced Residual Energy LEACH algorithm. Simulation and findings in [18] show how the BRE LEACH algorithm optimizes the original LEACH. It lowers the amount of spent energy and extends the sensing environment lifetime by 55.73 percent. The downside of random CH election in the DMHT-

6.3.3. EDMHT-LEACH

The authors of [69] improved the DMHT-LEACH algorithm and introduced a new one called Enhanced Dynamic Multi-Hop based on LEACH. It uses novel procedures to choose CH and create clusters. The algorithm improves the dynamic technique for choosing the optimal pathways. The EDMHT algorithms, like IMHT and DMHT, divide the entire network into many portions based on the distance from the sink node. Each section has a radius of d02. The algorithm has four steps, just like DMHT. The algorithm approach is as follows:

The CH election is initially determined by computing Eq.20 [69], which relies on nodes' leftover energy $E_{residual}$.

$$T(i) = \begin{cases} \max\left(\dfrac{p}{1 - p^*(rmod(1/p))} * \dfrac{E_{residual}}{E_{max}}, T_{min}\right), n \in G \\ 0 otherwise \end{cases} \tag{20}$$

As a result, the EDMHT algorithm claims to conserve energy. N_0 is the number of nodes in each restricted cluster. It is assigned in Eq. (21) [69].

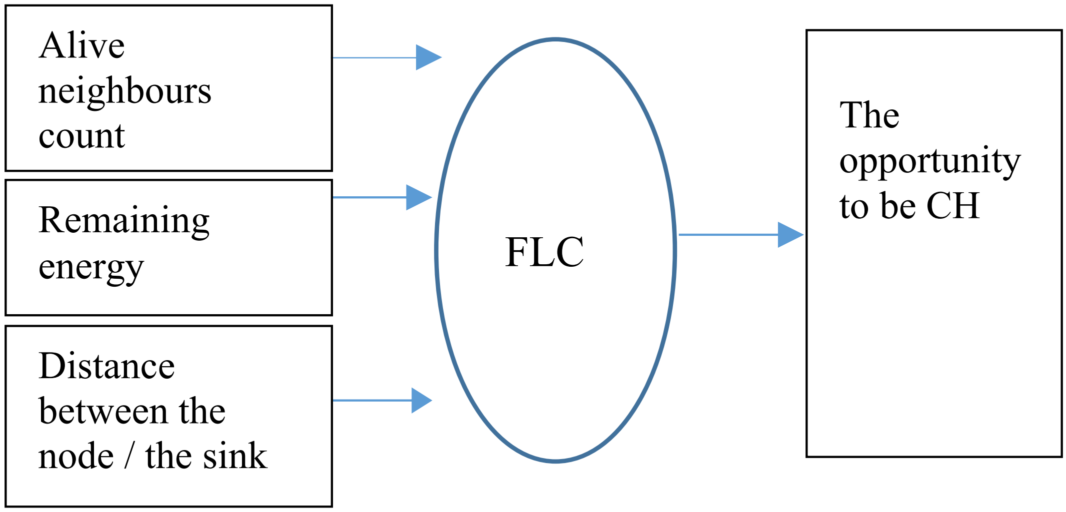

Fig. 15. The FLC that achieves the clustering in FCHS.

$$N_0 = \frac{Numberofsensornodes}{NumberofCHs} \tag{21}$$

It's worth noting that some nodes that can't deal with one of the CHs throughout the set-up process are referred to as IN (Independent Nodes). After the cluster is built, each node realizes its responsibilities in the network. Cluster heads and independent nodes build tables of possible routes depending on the advertisement signal received. The routes are selected and identified based on the cost equation. As a result, the shorter paths in the routing tables of CHs and INs are chosen as direct paths from the CH or IN/sink node, like the DMHT method. It's worth noting that the routes can dynamically switch to another route in the current round. Independent nodes can communicate with the sink node and transfer their detected data using EDMHT algorithms even though the EDMHT-LEACH algorithm has significantly improved over the classic LEACH algorithm. It faces difficulties, such as the fact that it is similar to the LEACH algorithm in intra-cluster transmission. Only in inter-cluster [73] can it change routes dynamically. [69] Illustrates the EDMHT-LEACH flowchart algorithm. Table 5 Summarizes the upsides and downsides of algorithms that improve the original LEACH by using CH choosing and data transfer algorithms.

6.4. CATEGORY D. ALGORITHMS FOCUSING ON FUZZY LOGIC

Fuzzy logic is in the power of decision and experience, and it uses probabilistic characteristics to mimic people. Furthermore, It can be used in real-time processes [74]. The wireless sensor network is a sceptic's environment. As a result, some algorithms necessitate Fuzzy Logic technology, which entails sophisticated computations and memory. Because of their flexibility and low mistake rate, fuzzy logic algorithms for CH selection are more successful and efficient. As seen in Fig. 14, the Fuzzy Logic method requires four steps to complete. (1) The fuzzifier performs the fuzzification step. The algorithm first inserts unambiguous values before distorting them into a fuzzy group (2) The rule evaluation step is known as the Fuzzy Rule Base. The algorithm stores Rule IF THEN in this stage. (3) Fuzzy Inference Engine step: the algorithm mechanism holds input and uses the IF-THEN rule to construct a fuzzy set in this stage. (4) Defuzzification step: The algorithm turns the fuzzy group and returns clear values in this stage. The fuzzy logic controller is the name of this block (FLC). To choose the CH, Mamdani's Fuzzy Inference approach is used in nearly all Fuzzification strategies. The authors used Fuzzy Logic (FL) to merge it into the whole network to increase the wireless sensor network's lifetime. It promises that CHs are elected successfully. Popular Fuzzy Logic-based Clustering Algorithms are covered below see Fig. 15.

6.4.1. CHEF: CH ELECTION BASED ON FL

The CHEF algorithm is presented by the authors in [75]. CHs election utilizes Fuzzy Logic. The algorithm employs two input parameters: energy and radius length between the existing cluster head in the current round and its cluster members defined by a predetermined fixed radius. As a result, sensor nodes that are closer and have more energy than

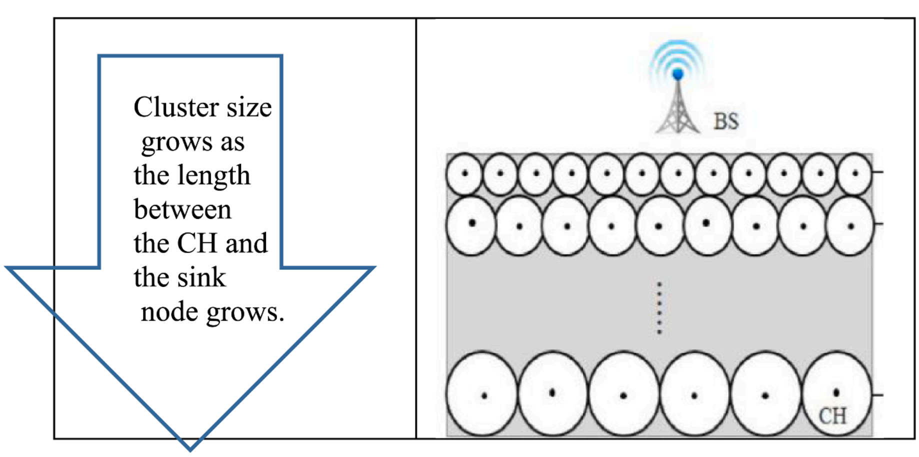

Fig. 16. At WSN, the clustering structure is asymmetrical.

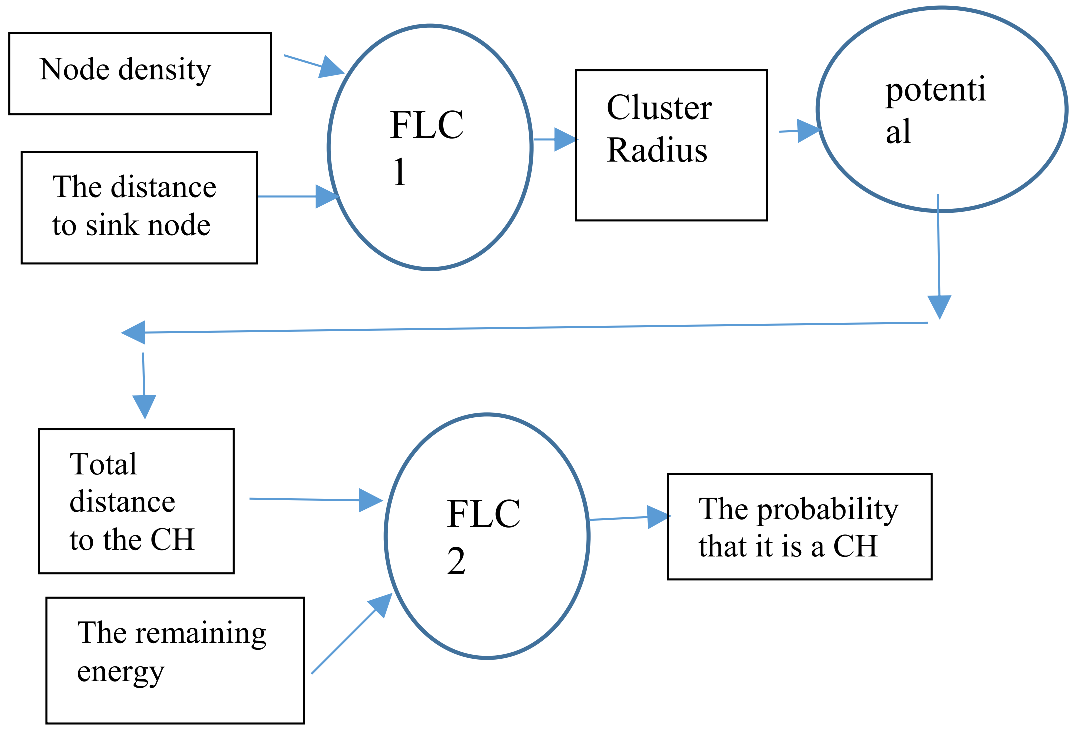

Fig. 17. The Fuzzy-Logic algorithm in (FLEEC).

others choose to be CH. In [74], CHEF simulations and findings show gains of up to 22.7 percent over the original LEACH. However, there are still problems with the CHEF algorithm, such as the fact that it is not ideal for networks larger than 200 m by 200 m and more [75,76].

Additionally, sensor nodes cannot determine their location without a GPS device [74]. An algorithm for asymmetrical clustering is suggested [75] to promote a proper energy balance. Because clusters adjacent to the sink node have more traffic congestion, the energy falls out quickly.

6.4.2. EEUC: ENERGY EFFICIENT UNEQUAL CLUSTERING

The EEUC algorithm [75] grouped the sensor nodes into uneven clusters. The clusters closest to the sink node are the smallest nodes number. The algorithm proposal introduces clusters far from the sink node, including a larger number of member nodes. Contrary clusters near the sink node will include a smaller number of member nodes. To solve the problem of congested traffic that affects tight clusters and consumes more energy from the farthest [77]. LEACH is used in the EEUC algorithm. It chooses CH randomly by each node, selecting an integer between zero and one as the original LEACH. This random number determines whether or not a node will be CH. [78] The EEUC computations and results demonstrate that it outperforms the original LEACH. It improves the quantity of active sensor nodes over the original LEACH.

6.4.3. EAUCF: ENERGY-AWARE UNEQUAL CLUSTERING BASED ON FL

Authors in [78] defined that for temporary CH, there are two requirements for a large competition radius. The first is that the temporary CH's residual energy is significant. The second factor is the significant length between the temporary CH to the sink node. And vice versa. If there is more than a temporary CH in the competition radius of a particular CH, their remaining energy is compared to which forwarded. As a result, the temporary CH with the lowest remaining energy is eliminated from the competition [77]. [78] Shows the findings and simulations where the EAUCF algorithm outperforms in the number of sensor nodes that are still operational in the original LEACH, CHEF and EEUC algorithms at the same number of rounds. The EAUCF algorithms concentrated on intra-cluster density only. The algorithm does not take the node level into account, which impacts cluster communication density, which in turn impacts energy consumption and network lifetime [76].

6.4.4. FCHS: FUZZY CLUSTER HEAD SELECTION LEACH-BASED ALGORITHM

Fuzzy logic is a more specific and suitable strategy than others, which is the optimum CH election for each cluster in the network if more than one input is factored in and only one output is defined. In [79], the three inputs that affect the production in this algorithm are the number

Table 6
The pluses and minuses of LEACH-based approaches (Category E).

Routing Algorithm	Strengths	Limitations
S LEACH	**Certain nodes are powered by solar cells, and these nodes serve as cluster heads.**	**Additional harvesting equipment increase expenses. And total dependence on light duration time**
EHA-LEACH	**Energy efficiency is achieved by using. The max–min optimization approach.**	**Additional complications as well as more lateness time**
EP-LEACH	**A greater number of energy-potential sensor nodes used to be cluster heads.**	**Extra difficulty and extra lag time**
A-S LEACH	**The convex shape has the greatest number of nodes utilized for clustering, and solar energy-responsive nodes are chosen as cluster heads.**	**increased complexity and more delayed time**

of surviving neighbours, the node's leftover energy, plus the length between the node and the sink node. Furthermore, as seen in Fig. 16, the algorithm output is a chance. The elected CH has the highest residual energy level, the most living neighbours, and the shortest distance to the sink node [76]. The FCHS algorithm utilizes the same set-up procedures as the original LEACH in each round. CH is selected at random. It achieves random CH by assigning each node a number between 0 and 1. When this number is less than the calculated threshold, it will be considered CH. In addition, the fuzzy algorithm's output, the chance, is evaluated for each Concurrent CH. Also, notify any other concurrent CHs in the competition's radius. As a result, Concurrent CH contains a record of all CHs and their chances. The CH node is then selected as the most robust node. As a result, other nodes within its contribution range connect to the CH as normal nodes.

Furthermore, the elected CH node constructs TDMA tables to assign each connected normal node a distinct time slot. The normal nodes broadcast the detected data to the elected CH node in their designated time windows. Furthermore, normal nodes sleep in the time slots of other nodes to save energy [76]. The results and simulations show that the FCHS algorithm enhances the energy nodes consumed (J) compared to the original LEACH, CHEF, EEUC, and EAUCF by nearly 44 %, 43 %, and 27 % for every round [75].

6.4.5. FLEECE: (FL-BASED ENERGY-EFFICIENT CLUSTERING)

Such as the LEACH-based FCHS algorithm. The authors of the LEACH-based FLEEC algorithm [77] emphasize that when more than one factor is used to determine a specific parameter, fuzzy logic is superior to other methods. It's worth remembering that the length between any sensor device in the network and the sink node can be measured by the received signal intensity (RSS). A "hot spot problem" occurs, in which clusters of the same size are formed regardless of distance from the sink node. The closest cluster to the sink node consumes more energy, as seen in Fig. 16. Two steps are required for the formation of distinct clusters.

The node density and the length from the sensor device to the sink are the first fuzzy logic controller (FLC) input parameters. In addition, the first FLC's output is the cluster Radius observed in Fig. 17. The radius of each CH determines the overall length between neighbours. The FLC's second input parameters are the remaining energy and the overall length of the CH, and its output is the likelihood of nodes being CH. The FLEEC algorithm is divided into the following sections [77]:

(1) Estimate cluster size: use the sink node to transmit a hello message to all nodes. Consequently, each node determines its distance to the sink node based on the intensity of RSS signals. Furthermore, each node sends an (ACK) acknowledgement message to the sink node, which includes the node's ID, remaining energy, and distance. In addition, the sink node calculates the dispersed density based on data collected from each node. FLC 1 estimates the relevant cluster radius to all sensor nodes. After that, the sensed data is stored in the node's memory. (2) Estimate the probability of a CH: Once the cluster radius has been defined, all nodes must send exploring messages to learn about their neighbours and receive acknowledgement messages in response to their exploring messages. As a result, the nodes may estimate the distance between themselves and their neighbours using RSS. FLC 2 estimates the likelihood of being CHs using the stored fuzzy sets. (3) Estimate CH: Each node sends a greeting message to its neighbours in its competition radius, confirming that it holds each CH and ID. The CH with the highest probability is elected as the CH during information exchange, while the others are considered normal nodes. If a node receives many ADV advertisement messages from various CHs, it assesses which CH is best suited to send a join request message. The results and findings are depicted in [77]. The FLEEC algorithm outperforms the CHEF algorithm- the most prevalent fuzzy-logic-based algorithm- and the original LEACH regarding energy usage.

6.5. CATEGORY E: ALGORITHMS FOCUSING ON USING EXTERNAL ENERGY SOURCES

Wireless sensor networks often have many battery-powered nodes that acquire, analyze, and send data widely dispersed and cooperatively. It is difficult, if not impossible, to renew the spent batteries due to the complex environment and different applications. Energy harvesting technologies have recently addressed this difficulty, allowing the node to recharge by attaching an energy harvesting module due to its harvesting capability. Various investigations have been conducted on harvesting energy from the surroundings, such as sun, wind, and thermoelectricity. Additional energy sources to the nodes for energy harvesting are a practical approach to extending the network lifetime of the WSN. Solar power is used in centralized and distributed clustering algorithms where some sensor nodes are aided by power obtained by harnessing the energy of the sun's rays. All nodes forward their remaining power and solar power level to the solar-conscious centralized clustering sink node. Typically, the sink node selects higher-energy solar-powered sensor nodes. The solar-conscious LEACH network's longevity depends entirely on the sun's time &its intensity. The pluses and minuses of LEACH-based approaches (Category E) are shown in Table 6 .

6.5.1. S LEACH (SOLAR AWARE-LEACH)

The solar-conscious LEACH network is suggested in [80]. The idea is that during the steady-state step, when the sun is only accessible for a short time, the nodes powered by batteries take the role of the CH, and the rest of the nodes deliver data with a flag. When the solar-powered node's energy rises, it can take over the part of CH. Solar-powered nodes have a strong chance of becoming the CH in solar-conscious distributed clustering. Simulation and discussions compared to the LEACH and LEACH-C algorithms, providing solar-powered to the selected nodes and choosing them as CH delivers superior longevity and enhances the performance.

6.5.2. EHA-LEACH (ENERGY HARVESTED AWARE LEACH)

An Energy Harvesting WSN is a wireless sensor network supplied by energy-harvesting devices that can recover energy from the external area and produce power (EHWSN)[81]. Conventional routing algorithms cannot be used efficiently in EHWSNs since the nodes can recharge their batteries. Consequently, determining how to route the gathered data employing the energy harvested successfully has become an arduous task that profoundly affects the effectiveness of EHWSNs. Authors in [81] are utilizing energy-harvested nodes in the entire network to enhance the efficiency of LEACH and bring in a new algorithm. The CH is likelier to become a node with the highest capability for energy obtained and low energy usage. Eq.22 expresses the overall energy E_h obtained by node c in the time [0, T].

$$Eh = (c, 0 \le t \le T) = \beta^* \int_0^T ph(c,t)dt - \int_0^T pleak(c,t)dt \tag{22}$$

The gathered power ratio of node c in the network area is $p_h(c, t)$, and the energy losses of node c at time t are p_{leak} (c, t). T represents the time: an hour, a day, or even a week. CH picking algorithms to enhance primary LEACH in the clustering step by factoring the node's harvesting assessment and energy-exhaustion situation. Eq.23 expresses the gain valuable equation F (c) of a node c.

$$F(u) = \frac{exp^{\frac{(E(u,0)+Eh(u,0<t<T)-M)}{A}}}{1 + exp^{\frac{(E(u,0)+Eh(u,0<t<T)-M)}{A}}} \tag{23}$$

Where M and A express the mean and variance for the energy of each node in the network, respectively and these are obtained using Eq.24.

$$\begin{cases} M = \sum_{c\in C}(E(c,0) + Eh(c,0<t<T) - M)|C| \\ A = \sum_{c\in C} \frac{E}{(c,0) + Eh(c,0<t<T) - M)^2|C|} \end{cases} \quad (24)$$

Each node creates a number between 0 and 1 at random, similar to LEACH, and then compares it to a predetermined threshold in the algorithm. Node c considers itself a cluster head for the current round if the created number by the node is below the predefined threshold. The predefined threshold depends on the required percentage of CH nodes. The procedure is similar to LEACH after the CHs are identified. It surpasses LEACH's energy efficiency and network longevity due to the energy Harvesting nodes and lower energy usage. In comparison to LEACH, the authors get 29.19 % more rounds. The algorithm's fundamental flaws are its higher cost and complexity.

6.5.3. EP-LEACH

By utilizing EH-WSN [82], Energy potential-LEACH [83] has increased the longevity of LEACH. Algorithm. The network member sensors in an EH-WSN network feature with restore LEACH procedure, and LEACH is the CH choosing method. In comparison to LEACH, it has two changes. In the first adjustment, sensor nodes with a higher potential for energy gathering ought to have a higher likelihood of becoming CHs. Battery power, and they draw energy from the environment to power those batteries. The only difference between the EP and the second alteration is that a node can turn into a CH multiple times. Therefore, The old LEACH threshold can be rebuilt based on these two adjustments. In this case, $T_G(y)$ represents the likelihood of choosing node G as a CH at slot y, as seen in Eq.25

$$T_G(y) = \frac{F_G(y)}{\sum_{r\in D_G} F_r(y)} * M * |Q_G| \quad (25)$$

The EP assignment for the EH-WSN is called $F_G(y)$, and it has a value range of 0 to 1. One denotes the sensor node has enough energy to keep as a CH, whereas zero means its energy is entirely depleted. The ideal number of clusters for the network is M. Eq.26 can be used to calculate $Q_G(i)$, which stands for the Q neighbour nodes of node G.

$$Q_{G=[rD(r,G)<D_t]} \quad (26)$$

Where the length between nodes r and G are expressed as D (r, G), Dt is the minimum distance between two neighbour sensors considered. The steady stage resembles LEACH in structure. In terms of network longevity, Energy potential-LEACH with energy harvesting performs better than LEACH. Price will be a challenge with this network type since the nodes gather the energy. In addition, Compared to LEACH, the algorithm is complex and has data overhead.

6.5.4. A-S LEACH (ADVANCED SOLAR AWARE LEACH)

The author in [84] upgrades sLEACH (Solar aware LEACH) to A-sLEACH. A heuristic method to choose a cluster head inside a cluster, an economical radio energy modelling, a Carrier Sense Multiple Access (CSMA) that eliminates collisions, the scanning method for picking the cluster head, and the Sequential Data Priority Mechanism (FIFO) are the five novel strategies that the authors have offered. (1) A cluster's N sensor nodes come together to form a convex hull with the most sensor nodes possible. (2) An advertisement text carrying CH Identification (3) The CH collates the data it receives using the optimized strategy First In First Out precedence before sending it to the following scale of CH in the path of the sink node. (4) The present round CH picks solar-supported nodes to be cluster heads for the following stage. A-sLEACH employs a key goal, the smallest route data collection strategy. In addition, CH choosing also uses a metaheuristic optimization strategy. This algorithm outperforms LEACH in terms of energy savings and has a 19.58 percent longer operational longevity over sLEACH. The system uses many procedures to show a considerable rise in expense and complication.

7. Discussion

7.1. Leach-based algorithms (Category A) benefits and negative side

One of the key aspects of resource conservation and longevity network lifespan is the deployment of CH. The same basic idea underlies all CH-finding algorithms: choosing a high-efficiency node to act as a CH. The criteria considered during the research for selecting the best CH were categorized into different sensor node cases, including the amount of leftover energy, centralization, mobility, energy consumption, and position of the sensor nodes. In general, it can be said that LEACH Utilizes TDMA solutions concerning energy use to lengthen the lifespan of networks. It minimized broadcast packets and node energy dissipation. The limitation of LEACH is Cluster head nodes pick one another without analyzing it, the distribution of cluster head nodes is not regular, the cluster nodes ratio differs from those of other clusters, and it sends data utilizing one hop. According to Algorithms, work on Residual Energy issues as stated in Table3 for CH selection based on LEACH.it is found that the network longevity is increased in LEACH-B because of considering the nodes' remaining energy After the first round, and the cluster head count is symmetrical. The limitation of L LEACH-B is increasing overhead cost value. Another algorithm is Based on the nodes' location and remaining energy; the cluster head chosen is I-LEACH. To cut down on transmission costs in I-LEACH, the cluster head integrates the data that has been gathered, but That isn't easy to apply to nodes that gather different kinds of data. LEACH-C is also Based on the node's remaining energy; the cluster head is elected.in addition, LEACH-C effectively scatters the Cluster head nodes when the centralization technique is achieved. The optimum number of clusters has been attained. LEACH-C Network durability is increased for small networks based on the node's remaining power. LEACH-C's problem is that it doesn't know where the node is. The sink node is overwhelmed because the centralization technique is being used. Data transmission only utilizes one hop, which increases the overload. LEACH-M Support feature of node mobility, Efficient energy is extremely high in this algorithm. But gives Additional overhead to the network. LEACH-ME also Supports the feature of node mobility. It has benefited the Cluster head election premise on the less mobile node. But it also gives Additional overhead.VH-LEACH offers important advantages. Cluster head election is premised on the node's remaining energy. The algorithm uses an assistance node (VH) to the cluster head when a calculated threshold arrives. The major drawbacks are additional procedures for extra assistant nodes (VH) and Transmitting data from cluster heads to sink node using direct data in one hop. LEACH-T's substantial advantage is that it Confirms the number of periods in TDMA, conditional on the number of nodes. It achieves the optimal number of clusters. The main disadvantages are the Cluster head nodes election without conscious decision and Transmitting data from cluster heads to sink node using direct data from the single hop. TB-LEACH Network lifetime is developed. But its drawback is the Cluster head election premise on a random timer.

7.2. Leach-based algorithms (Category B) benefits and negative side

Transfer of information in the WSN is the second essential condition for enhancing network performance and expanding the network's lifespan, sending and receiving data between sink nodes and CH And between CHs and their constituents. Any information-transmitting algorithm's key idea is to send data via one, multiple, or many routing hops. LEACH-F Using centralization, which gives a greater distribution of CHs. Reduces the time it takes to set up. However, clusters are predetermined at the start, there is no re-clustering process, and adding or removing nodes inside clusters is impossible once they have been established. When the main CH drops dead in V-LEACH, voting for a new CH is unnecessary. The Vice-CH takes over. It offers Extended life expectancy. The limitation of V-LEACH is Whenever the CH gets too away from the sink node, it dies early, and Vice CH will receive additional treatment. The profit of W-LEACH is Low usage of energy. But CH is randomly chosen. WD-LEACH Design active and sleep network nodes. Only some sensor nodes are allowed to communicate with the CH. The negative aspect of WD-LEACH is that the data collected in networks differ; this method will not be successful. The gain of LEACH-Cell The network has excellent coverage and Increased energy savings. The downsides in this algorithm are CHs and cell heads were all randomly selected, and the Overloading of control packets is produced by several types of heads (CHs and cell heads). In O-LEACH, The BS can receive data from orphan nodes. Its problems are CHs are picked at random and communicate with the BS In a single hop. In MHT-LEACH, A significant degree of energy efficiency Between CHs, and various hops are used, and CHs are divided into two sets relying on their distance from the sink node. It has many limitations. Selecting CHs without considering energy, The number of CHs in each turn may differ, and CHs near the network's edge spend extra energy on only two levels. Clusters do not all have the same number of nodes. IMHT-LEACH adopts the multi-hop strategy between CHs, and The CHs are divided into multiple levels. It has many flaws, such as the fact that CHs are picked randomly and only consider the path to the sink node. DMHT-LEACH algorithm has some advantages. It partitions the entire network into multiple layers, Relying on the distance to the sink node. The distance and remaining energy create each CH's routing table. When the cost function changes, the pathway will change. Negative aspects: Each period may have a different number of CHs, and CHs are randomly chosen. A-LEACH Prolongs the duration of stability and reduces the likelihood of nodes failing. A-LEACH complications CHs selection randomly, Data transmission is based on a single hop, and CAG nodes are paid extra attention. In LEACH-TL, There are multiple CHs. When choosing the secondary CH, the remaining energy and distance are considered. Its problems are that Data is sent from CHs to the sink node in one hop, and the overhead rate is rising. L-LEACH It is well-suited to huge networks. It uses the most efficient amount of hops. The load on the network is controlled. The downsides are that only the distance is taken into account, and CHs with low residual energy are more likely to perish fast, as mentioned in Table four.

7.3. Leach-based algorithms (Category C) benefits and negative side

As previously said in clustering routing methods, we face two basic challenges. One is a smoothly run CH election. Data transmission efficiency is the second factor. Both issues significantly impact the longevity of the network. Refinements, litter, and continued research are required to increase the WSN's lifespan through development in these two areas. E-LEACH balances the network's energy consumption, selected based on the node's remaining energy. It has many flaws: Choosing CH based on energy may be further away from the BS. It selects a root-CH based solely on energy Regardless of the distance to the sink node. BRE-LEACH promotes the network's longevity. It gives the determination of CH based on residual energy. It chooses a parent CH Based on the quantity of energy left and the distance to the sink node. The negative aspect is that The Clusters do not have the same node count. The number of CHs may not be the same at each round. In EDMHT-LEACH CHs picking, the residual energy is considered. The highest number of sensor nodes in clusters is specified. The network is divided into multiple layers. Data is transmitted dynamically. Its limitation is in intra-cluster communication; a single hop is used.

7.4. Leach-based algorithms (Category D) benefits and negative side

Fuzzy logic is the optimal CH selection for each cluster in the network when more than one input is considered but only one output is specified. In CHEF, CHs election utilizes Fuzzy Logic. Nodes that are closer and have more energy than others choose to be CH. It gains over the original LEACH. The disadvantage of CHEF is that it is not ideal for networks larger than 200 m by 200 m. Without a GPS device, sensor nodes seem unable to determine their location. Clusters adjacent to the sink node have more traffic congestion, and the energy falls out quickly. The improvement of EEUC Solves the problem of congested traffic by construction. It has no equal clusters. The clusters close to the sink node have lowered the number of nodes.

Equilibrate energy use and address the "hot spot problem." Less memory and computing costs are needed because the proposed fuzzy procedures have been modified. Network lifetime is enhanced. EAUCF gives the biggest residual energy and length between the temporary CH and the sink node in the competition radius of a particular CH. EAUCF has many downsides. It Ignores the node's degree, causing the clusters to suffer high transmission density. It affects the life of the wireless network overall and requires more energy. FCHS has flaws. It ignores the node's degree, causing the clusters to suffer high transmission density. It affects the life of the wireless network overall and requires more energy. FLEEC has many benefits. It uses Fuzzy logic, which is superior to other methods. The length between the nodes and the sink node is calculated using the received signal intensity (RSS). Use two fuzzy logic functions to calculate the likelihood of CH. It considers the node density, the length from the node to the sink node, the remaining energy, and the overall length of the CH. The algorithm outperforms the CHEF and the original LEACH in terms of energy usage. The algorithm drawback is that A "hot spot problem" occurs, in which clusters of the same size are formed regardless of distance from the sink node, as the closest cluster to the sink node consumes more energy.

7.5. Leach-based algorithms (Category E) benefits and negative side

The benefits of S LEACH are that Certain nodes are powered by solar cells, and these nodes serve as cluster heads. The limitation of S LEACH is that Additional harvesting equipment increases expenses And total dependence on light duration time. EHA-LEACH offers energy efficiency that is achieved by using the max–min optimization approach. The limitation of the algorithm is that Additional complications and more lateness time. EP-LEACH advantage is A greater number of energy-potential sensor nodes used to be cluster heads. But it gives Extra difficulty and extra lag time. The positive impact of A-S LEACH is the convex shape has the greatest number of nodes utilized for clustering, and solar energy-responsive nodes are chosen as cluster heads. The drawback of the algorithm is increasing complexity and more delayed time.

7.6. The difference between the original LEACH and the leach-based algorithms

CHEF exploits Fuzzy Logic in choosing CHs. A predetermined fixed radius &the energy are the inputs to the fuzzy function. Device nodes that are closer and have more energy than others choose to be CH. EEUC groups the sensor nodes into uneven clusters. To solve the problem of congested traffic that affects tight clusters and consumes more energy from the farthest, the clusters closest to the sink node are the smallest node numbers. EAUCF defines temporary CH. The temporary CH's residual energy and the length between the temporary CH and the sink node would be significant for a large competition radius. If there is more than a temporary CH in the competition radius of a particular CH, their remaining energy is compared, and the one with the stronger energy is chosen. In FCHS, The CH node is selected as the strongest node. The fuzzy algorithm's output is evaluated for each Concurrent CH. Concurrent CH contains a record of all CHs and their chances. The elected CH has the highest residual energy level, the most living neighbours, and the shortest distance to the sink node. The elected CH node constructs TDMA tables to assign each connected normal node a time slot. in FLEEC, the length between any sensor in the network and the sink node can be measured by the received signal intensity (RSS). The node density and the length from the sensor to the sink are the first fuzzy logic controller (FLC) input parameters. In addition, the first FLC's output is the cluster Radius observed. The radius of each CH determines the overall length between neighbours. The FLC's second input parameters are the remaining energy and the overall length of the CH, and its output is the likelihood of nodes being CH. In S LEACH, The nodes powered by batteries take the role of the CH, and the rest of the nodes deliver data with a flag. When the solar-powered node's energy rises, it can take over the part of CH. Solar-powered nodes have a strong chance of becoming the CH in solar-conscious distributed clustering. Member sensors in an EHA-WSN network feature restore battery power, and they draw energy from the environment to power those batteries. The CH is likelier to become a node with the highest capability for energy obtained and low energy usage. In EP-LEACH, the sensor nodes with a higher potential for energy gathering ought to have a higher likelihood of becoming CHs, and a node can turn into a CH multiple times. In A-S LEACH, With a scanning process in a cluster, the sink chooses the CH. The five novel strategies offered are a heuristic method to choose a cluster head inside a cluster, an economical radio energy modelling, the scan-founded method for Cluster head choosing, a FIFO priority strategy for information collection, and CSMA for eliminating collision. In A-LEACH, Using CAG nodes increases stability, saves energy, and reduces the risk of node failure. LEACH-B assures that each round generates a relatively close amount of CHs. LEACH-C relies on node position and leftover energy. The sink node builds clusters and then votes CHs using a centralized algorithm. LEACH-Cell partitions into portions, i.e., cells produced by clustering with seven surrounding cells. Each cluster has a CH. There is a cell head for every cell.in E-LEACH The ideal is that CH (with the maximum residual energy) is chosen to combine additional CH data before transmitting it to the sink, relying on node residual energy. The centralizing method is used to choose CHs and construct clusters in LEACH-F, and Clusters are permanent when generated at the start. LEACH-M exploits the nodes' and CHs' mobility to transport data to the sink. So, it works effectively in mobile environments. CHs are the sensor nodes that have the least mobility compared to their neighbours in LEACH-ME.In I-LEACH, The leftover energy is subsequently added to the threshold equation and adjusted. The number of neighbours, the quantity of energy left, and the placement of nodes all influence the selection of CHs. As a result, it takes into account the number of clusters that are the best. LEACH-TL generates two types of CHs: main and auxiliary. When the main CH's residual energy is lower than the average value and/or its distance from the sink node is higher than the average, the auxiliary cluster head assumes the tasks of the cluster head. It transmits gathered data to the main cluster head, while the main cluster head solely transmits with the sink node. V-LEACH When a CH goes, it is replaced by a vice CH. In VH-LEACH CHs are picked based on residual energy, and a VH node switches over as the CH when the remaining energy of a cluster head hits a particular threshold. Orphan nodes in O-LEACH are able to attend clusters. they transmit their sensed information to the sink node. The number of time intervals in all time-division multiple access tables of CHs is fixed in LEACH-T. The algorithm calculates residual energy when forming clusters in addition to envisioning the network's ideal number of CHs. In TB-LEACH, CHs are chosen randomly. Every round has a set number of CHs.In Improved-LEACH, two criteria are taken into account: distance and residual energy When choosing CHs. A Bayesian sample is employed to identify CHs in BN-LEACH. EADCR Strengthen network lifetime via making use of the FCM algorithm. It creates clusters and selects CHs based on a fitness equation considering Euclidean distance and the nodes' leftover power. W-LEACH has two sorts of nodes: working and resting nodes, which the base station distinguishes. As a result, CHs are identified with weight value Wi, determined using leftover energy and node density. Without centralization in the BS, WD-LEACH works by partitioning into working and resting nodes dependent on the amount of nodes in the same neighbourhood in the entire network. L-LEACH selects CHs relying on their distance. Depending on the length of the sink, the multi-hop approach is employed instead of the single-hop. The CH selection is limited to nodes with sufficient residual energy in BRE-LEACH. The ratio of residual energy to beginning energy in this algorithm is added to the threshold formula. To aggregate data from CHs, it chooses the root CH with the most energy and the shortest path to the sink node and transmits it to the sink. Rather than sending packets straight to the sink node, MH-LEACH employs the many-hop strategy among cluster heads to reach the sink node by creating a routing schedule for all CHs. MHT-LEACH employs many hops Between CHs., To get to the sink node. The distance from the sink node separates CHs into two distinct sections. CHs are segmented into multiple levels by IMHT-LEACH for all levels having a length of $d0/2$. CHs employ a multi-hop strategy to transmit data to the sink node in agreement with their routing schedule. In DynMHT-LEACH, the CHs are spread in various levels, every one of which is d02 in length. A cost function is used to generate each CH's routing table. As a result, the price function changes, and CHs modify their data path multiple times in the same round.EDMHT-LEACH modifies the threshold function to select CHs based on the remaining node energy. It establishes the highest number of sensor nodes included in a cluster. The CHs and INs (Independent nodes) routing table is constructed using a cost function. In routing, the route is dynamically structured based on the cost function.

8. Conclusion

This study concentrated on two primary areas: (1) reviewing the most well-known hierarchical procedures, LEACH and their ongoing development. (2) demonstrating and debating several major routing algorithms based on LEACH, defining their fundamental characteristics, challenges, and advantages. LEACH is considered the first energy-efficient clustered routing algorithm. The network's longevity was recommended to be extended while minimizing its energy losses. LEACH, on the other hand, has several flaws in energy savings, Cluster head selection, and data transfer within the network that all restrict the network's longevity. Researchers developed a set of routing algorithms to supplement the traditional LEACH algorithm to address these issues. These LEACH-based algorithms were built using cluster head choosing and data transfer strategies. Furthermore, various criteria that would be addressed, such as leftover power, energy effectiveness, one-hop transmission, more than one-hop routing, and so forth, significantly impact WSN. These factors are used to structure the algorithms stated because of their impact on the WSN's stability and endurance. These procedures were divided in the survey into five categories for enhancing the LEACH algorithm by (1) upgrading the cluster head selection, (2) improving data transmission processes, (3) developing cluster Head selection and data communication methods, (4) employing fuzzy logic approach, and (5) utilizing external energy sources to maximize network energy.

The survey aims to deliver technical advice to researchers regarding how to enhance routing algorithms. It gives a comprehensive overview of the LEACH concept as well as a collection of prior investigations. What distinguishes the study is the focus on two essential issues in the monitor network area. The first issue concerns network set-up steps (CHs picking and cluster construction). The second issue is the consideration of the data packet transmission step. This work thoroughly categorizes 36 distinct algorithms with a qualitative comparison between them depending on their operations and effectiveness. Also, Considering the survey, we've found (1) among the most energy-efficient solutions is the clustering approach. Some clustering algorithms ' features include data aggregation, load balancing, lower energy use, and scalability. (2) We found that Multi-Hop LEACH outperforms single-hop LEACH due to conserving energy by reducing the distance travelled from cluster heads. (3) the fuzzy logic approach based on clustering is more powerful than other clustering algorithms because it is inconsistent with human reasoning and can translate more from one input to one output. (4) In the future, machine learning combined with a wireless sensor network could be researched to reduce energy use and integrate data before transmitting it to the sink node.

9. Future studies and work concerns

many strategies for improving the basic LEACH protocol have been developed. These strategies have factored in several variables. Other outstanding research topics, on the other hand, must be resolved in the future. (1) The primary objectives of developing the LEACH algorithm are to promote Wireless sensor network performance, energy consumption, energy allocation between nodes, scalability, finding the optimal sensor node to be the Cluster Head for each cluster, WSN security, network delay reduction, and network stability. However, this field has not been fully applied in new LEACH versions. (2) more proposals for moveable sink and cluster head nodes in WSNs are needed. (3) The majority of the centralized LEACH implementations depend on expensive and power-consuming GPS to provide position data. The best and lower-cost position methods must be proposed and implemented. (4) Solar LEACH, Founded on LEACH strategies, is a method of gathering solar energy as an external power supply to nodes in the network. It is just so expensive due to additional hardware. It is necessary to suggest and put into practice the best, least expensive methods using LEACH founded on solar energy (5). Harvesting energy methods are still not fully employed in WSN or modifications of LEACH. Solar, wind, heat, and kinetic energy can be employed as energy harvesting. Also, salinity tendency levels can be utilized for energy harvesting. (6) To further reduce power consumption and aggregate sensed data before sending it to sinks and control nodes, machine learning integrated with the WSN could be investigated. (7) It is frequently easier for different kinds of cyberattacks to occur in WSN when transferring data packets; the randomly moving sensors also provide hackers many chances to perform denial-of-service assaults, lowering the WSN's security. It requires investigating authenticated encryption techniques in WSNs that support privacy and network security.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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