# CLUSTER HEAD SELECTION ALGORITHMS FOR ENHANCED ENERGY EFFICIENCY IN WIRELESS SENSOR NETWORKS: A SYSTEMATIC LITERATURE REVIEW

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***ABSTRACT***

*The extension of the sensor node's life span is an essential requirement in a Wireless Sensor Network. Cluster head selection algorithms undertake the task of cluster head election and rotation among nodes, and this has significant effects on the network's energy consumption. The objective of this paper is to analyze existing cluster head selection algorithms and the parameters they implement to enhance energy efficiency. To achieve this objective, systematic literature review methodology was used. Relevant papers were extracted from major academic databases Elsevier, Springer, Wiley, IEEE, ACM Digital Library, Citeseer Library, and preprints posted on arXiv. The results show that there are many existing Cluster Head Selection Algorithms and they are categorized as deterministic, adaptive and hybrid. These algorithms use different parameters to elect Cluster Heads. In future the researchers should derive more parameters that can be used to elect cluster heads to improve on energy consumption.*

***KEYWORDS*:**

*Cluster head, Cluster Head Selection Algorithms, energy efficiency, LEACH, Sensor node, Parameters, wireless sensor networks.*

## 1. INTRODUCTION

A Wireless Sensor Network (WSN) is a wireless network made up of a large number of small, low-cost, low-power, and intelligent sensor nodes that monitor physical or environmental parameters in many locations, such as humidity, temperature, pressure, motion, and water levels. The sensors are placed at random around a sensing field to collect data about their surroundings. [1]. WSN's intelligent nodes include an integrated CPU, which is one of their most distinguishing features. Furthermore, rather than sending the data to the sensor nodes in charge of combining it, they employ their processing capabilities to do simple processing and relay essential and partially processed data. WSN has the potential to improve humans' ability to monitor and interact with the physical world remotely because of these characteristics. [1]

Routing protocols and algorithms for Wireless Sensor Networks should be constructed to provide fault tolerance in the event of individual node failure due to battery operation while consuming less energy. Furthermore, because all sensor nodes must share the network's limited channel capacity, these sensor network routing protocols must be inventive in order to implement local cooperation and save bandwidth and energy. In a WSN (Wireless Sensor Network), all nodes are considered homogeneous and energy limited [2].

DOI: 10.5121/ijcses.2022.13303 

Sensor Nodes (SN) in WSN are battery-powered and have a minimal computing capability, they remain stationary once they've been installed in the appliance contexts. Furthermore, the expense of replacing the nodes' batteries is prohibitively expensive. As a result, network lifespan improvement is a difficult challenge and a popular research topic. Communication also consumes a lot of energy when compared to processing. As a result, communication between nodes should be kept to a minimum to extend the network's lifespan [3]. As a result of the nodes' energy constraints, the key difficulties in WSN efficiency are lifetime and coverage.

Idle listening, collision, eavesdropping, overhead, overhearing, unprepared nodes, and a variety of other activities all consume a significant amount of energy in wireless sensor nodes. Improvements in energy economy are a critical issue in WSN, and building a power-efficient protocol is vital to prolong the lifetime of WSN [4]

Clustering the network is a one of the best approach to design routing protocols in WSN. HEED [5], TEEN [6], DD [7] and LEACH [8] are some of the WSN protocols that have been developed based on clustering. The use of clustering approach can significantly reduce energy consumption [9]. Energy usage is reduced by choosing the most suitable sensor node as cluster head (CH) depending on standards defined inside the clustered sensors [9]. Cluster Head Selection Algorithms are in charge of selecting Cluster Heads. However, the developed routing protocols have yet to attain the much-needed greater levels of energy efficiency. As a result, the goal of this research is to examine existing cluster head selection algorithms and the parameters that they employ in order to increase energy efficiency.

The following is how the rest of the paper is organized: Section two covers related works, while section three looks at methodology, section four tackles discussion and finally section five is the conclusion of the study.

## 2. RELATED WORKS

Wireless sensor networks are used in a variety of applications, including health care monitoring, environmental detection, industrial monitoring, and data logging. Researchers must, however, resolve critical obstacles that are blocking widespread use of these infrastructures in order to realize their full potential. Wireless sensor network power consumption is a significant consideration while constructing sensor networks. The designers employ hierarchical routing protocols based on clustering to achieve balanced energy usage and scalability [10]. The following are some of the hierarchical routing protocols based on clustering:

Younis and Fahmy [11] devised a "Hybrid Energy-Efficient Distributed Clustering (HEED) technique of extending network lifetime while maintaining dynamic scalability. For homogeneous WSNs, this technique uses two factors to find cluster heads: remaining energy and node density. In this protocol, the Cluster Head (CH) is elected on a regular basis based on a mix of residual energy and node degree. In intra-cluster communication, however, the cluster structure fails to achieve the lowest energy utilization. Furthermore, the HEED-generated clusters are imbalanced.

Adaptive Threshold sensitive Energy Efficient sensor Network (APTEEN) proposed by Manjeshwar and Agrawal [12] . APTEEN is a TEEN enhancement that aims to capture frequent data harvests and respond to time-sensitive events. The cluster head will employ broadcasting to provide all of the properties (transmission schedule and threshold value) to all of the nodes in the network as soon as the clusters are established by the base station. Finally, to save energy, the cluster heads will perform data aggregation. The primary benefit of APTEEN over TEEN is that nodes use less energy. APTEEN's key drawback is the longer wait periods induced by the system's complexity.

Cheng and Yang et al [13] developed the Novel Hierarchical Routing Algorithm (NHRPA), which is another routing protocol for WSN. The NHRPA algorithm determines the best routing approach for the nodes based on their residual energy usage, density, and distance from the BS (Base Station). Because a node in a WSN typically performs the following three operations: loop operations, judgment operations, and assignment operations, the suggested routing technique lowers the calculation cost for these three activities. Furthermore, when a sensor network is established, each node's initialization process is performed just once during the network's lifetime. As a result, if the appropriate threshold value is selected, various concerns such as energy and security can be balanced across a variety of conditions.

The primary idea behind the Base-Station Controlled Dynamic Clustering Protocol (BCDCP) is to elect clusters in such a way that they are balanced as proposed by Muruganathan and Ma et al [14]. Before deciding on a routing path, the BS gathers information about the current energy state from all nodes in the network. Based on the responses received from all nodes, the base station calculates the average energy level of all nodes by multiplying the energy levels of all nodes by the number of nodes in the network. The base station then chooses a few nodes with higher energy levels than the rest. Aside from that, each cluster is divided into equal numbers of nodes in each cluster head so that: none of the cluster heads become overloaded; all cluster heads are uniformly positioned throughout the network; and cluster head-to-cluster head (CH-to-CH) communication is used so that data can be easily transferred to the BS without consuming additional energy.

Another hierarchical routing protocol based on clustering in WSN is Extending Cluster Head Lifetime (ELCH) developed by et al [15]. In the ELCH protocol for cluster head selection, all nodes in the network voted for their neighbors. This protocol employs a hybrid technique, as a result of which it consumes little energy, hence extending the network's life. This approach blends cluster architecture with multi-hop routing.

Heinzelman et al [16] proposed Low Energy Adoptive Clustering Hierarchy (LEACH). According to [16]LEACH is a self-organizing, adaptive clustering system that distributes energy equitably throughout the network's sensors via randomness. LEACH nodes form local clusters, with one node serving as the cluster-head or local base station. If the cluster heads were chosen a priori and fixed throughout the system lifetime, as in traditional clustering systems, it's easy to see how the unlucky sensors chosen to be cluster heads would perish quickly, thereby ending the usable lives of all nodes belonging to such clusters. As a result, LEACH includes a randomized rotation of the high-energy cluster-head location, which rotates across multiple sensors rather than draining the battery of a single sensor. LEACH also uses local data fusion to reduce the amount of data sent from the clusters to the base station, thereby saving energy and extending the system's life. Many more hierarchical routing protocols for WSNs have been developed in addition to the ones mentioned in other article [17], [18] and [19] etc.

There are various reviews that have been done over the years on cluster head selection algorithms in WSN. Some of the reviews includes:

One of the review is carried out by Tyagi and Sudhanshu [20] they described a number of cluster-driven hierarchical routing protocols based on the standard LEACH protocol, as well as their advantages and disadvantages in comparison. Several factors, such as CH selection, load balancing, routing, security, and so on, are chosen for comparison of the LEACH-based protocols. The parameters are selected based on the applications and environment in which the

WSN is used. The absence of any statistical information on the discussed protocols, as well as the lack of a statistic chart for the risk analysis, are the study's key weaknesses. The paper also lacks research methodology.

Another review was carried out by Tamilselvi and Rizwana [21]. This paper discussed various cluster head selection algorithms that seek to minimize energy consumption by taking into account the residual energy of sensor nodes. The main issues in this paper is that it only focuses on cluster head selection algorithms that used remaining energy parameter to minimize energy consumption. Another weakness is that it is a traditional literature review meaning it does not have methodology and the author can be bias.

Khalid, Raza and Shah [22] conducted a systematic review of the literature on Energy-Efficient Routing Protocols for WSN. The paper describes existing energy-efficient protocols for wireless sensor networks, analyzes and compares them, and cites their advantages and disadvantages. The paper's main flaw is that it lacks eligibility criteria.

## 3. RESEARCH METHOD

This research was carried out as a systematic literature review based on Barbara Kitchenham's original guidelines (2007) to systematically review existing cluster head selection algorithms used by routing protocols, parameter they use to improve the lifespan of sensor network and their limitations. A scientific literature review, in other words, can be used to locate, assess, and interpret all relevant research for a certain research question, topic area, or phenomenon of interest. This study is classified as a tertiary literature review because the purpose of the review is to examine systematic literature reviews (which are referred to as secondary studies). The approach is divided into three steps. This stage consists of three parts: planning, conducting, and reporting on the review as shown in figure 1 below.

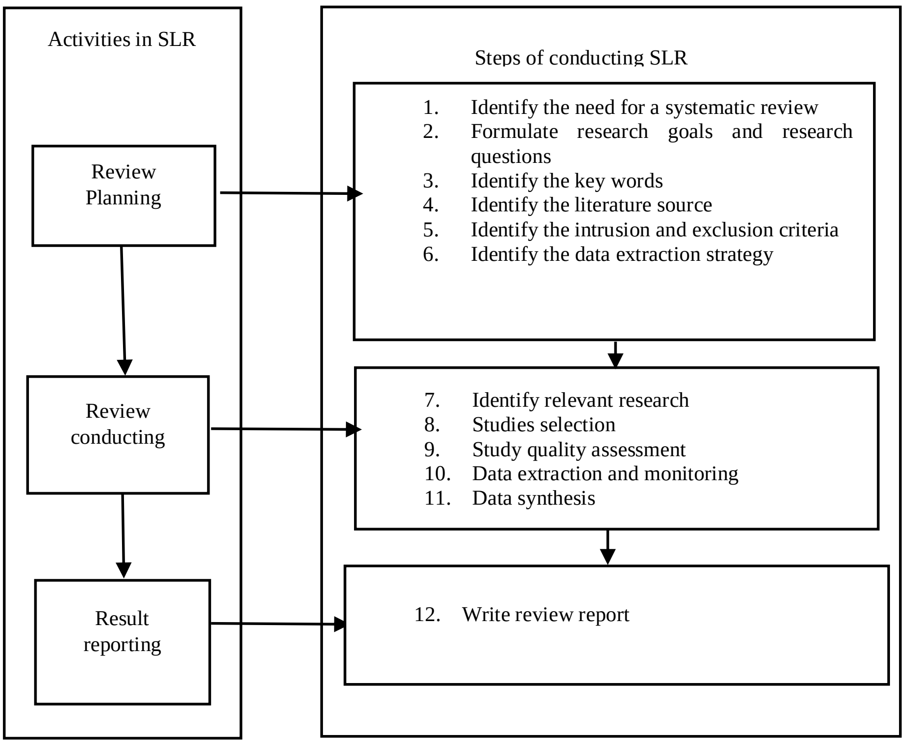


Figure 1. Steps used to conduct systematic literature review

## 3.1. Planning the Review

The planning process includes determining the need for a review, defining research topics, and establishing a review technique.

### 3.1.1. Aim of the Systematic Literature Review

The goal of this literature study is to compile existing research on cluster head selection algorithms and review the parameters and variables they utilize to increase energy efficiency. To further the conversation, the study employs a variety of research questions.

### 3.1.2. Research Questions

To achieve the objective of the research various research questions were used

a) What are the existing cluster head selection algorithms?
b) What are the parameters used by cluster head selection algorithms?
c) What are the limitations of existing cluster head selection algorithms?

## 3.2. Conducting Research

The following are the processes taken throughout the review: eligibility criteria, the search process, study selection, data collection process, inclusion and exclusion criteria and synthesis methods.

### 3.2.1. Eligibility Criteria

This specifies intrusion and exclusion criteria for the literature review and how studies were grouped for synthesis. This sets the boundaries of the review. This guarantees that only the most relevant studies are included in the data analysis. Articles for the Systematic Literature Review were chosen in three stages: first selection based on title, second selection based on reading the abstract and final selection based on reading the whole paper. For inclusion and exclusion, the following criteria were used in this research:

a) Articles on existing wireless sensor network routing protocol and cluster head selection algorithms should be included.
b) In WSN, include comparative studies of cluster head selection strategies.
c) Use the most recent version of the articles (if any).
d) Consider articles that were published between 2010 and June 2021.
e) There articles must be peer reviewed journal publications or published conference proceedings.
f) Exclude articles that that are not reviewing cluster head selection algorithms but are related to enhancement of energy efficiency in WSN.
g) Articles, papers and journal that are not peer-reviewed journal or conference papers are excluded.

### 3.2.2. Search Process

This section explains how to come up with search phrases, how to search, which databases to search, and how to document your search. An extensive literature review was conducted by examining relevant papers from seven major academic databases: Elsevier, Springer, Wiley, IEEE, ACM Digital Library, Citeseer Library, and preprints posted on arXiv.

The papers were chosen using a keyword-based search. It entails looking for index keywords based on common variation of the terms in the literature “cluster head selection”, “cluster head selection algorithms”, “cluster head selection strategies” and other key words like “ energy efficient routing protocols ”, “LEACH”e.t.c.

The research was limited to articles published between 2011 and June 2021 because we are primarily interested in recent achievements in this area of study. The papers were then examined to find relevant publications for additional research based on titles, abstracts, and keywords. After then, a backward and forward snowballing method was used to locate further publications, which consisted of leveraging the reference lists of the selected studies and the citations to these papers to identify additional papers.

### 3.2.3. Data Extraction and Synthesis

For the years 2011–2021, a table was built with each row academic databases papers reviewed were selected from and the number of journal papers that were examined in each database. Table 1 below shows various papers that have been selected from each academic database.

Table 1. List of journals paper selected form major academic databases.

| Academic Databases | No of Journal Papers Reviewed |
|---|---|
| IEEE | 20 |
| Elsevier | 2 |
| SPRINGER | 22 |
| ACM Digital library | 17 |
| Citeseer Library | 4 |
| arXiv. | 1 |
| Wiley | 1 |
| Total | 67 |

A sample of the data extraction tool is attached as Appendix I. Relevant bibliographic information (e.g., title, author, database, and page numbers) was captured for each article, as well as a hyperlink to the piece for reading. The article abstract was gathered as a major part of the first phase of this analysis for each article.

To answer questions the researcher considered abstract, introduction, and literature review and result sections in all the papers that were selected. The decision to include an article in the final review was made in two stages. Reading each abstract and classifying the paper as relevant or not to the review was the first part. The relevance of the abstract was assessed by comparing it to the above-mentioned search phrases. The review took into account the authors, publication date, article type (e.g., journal, conference proceeding), technique-based taxonomy, and datasets. In order to address the research questions, these information must be found. Figure 2 below show a flow chart for the selection of articles and papers.

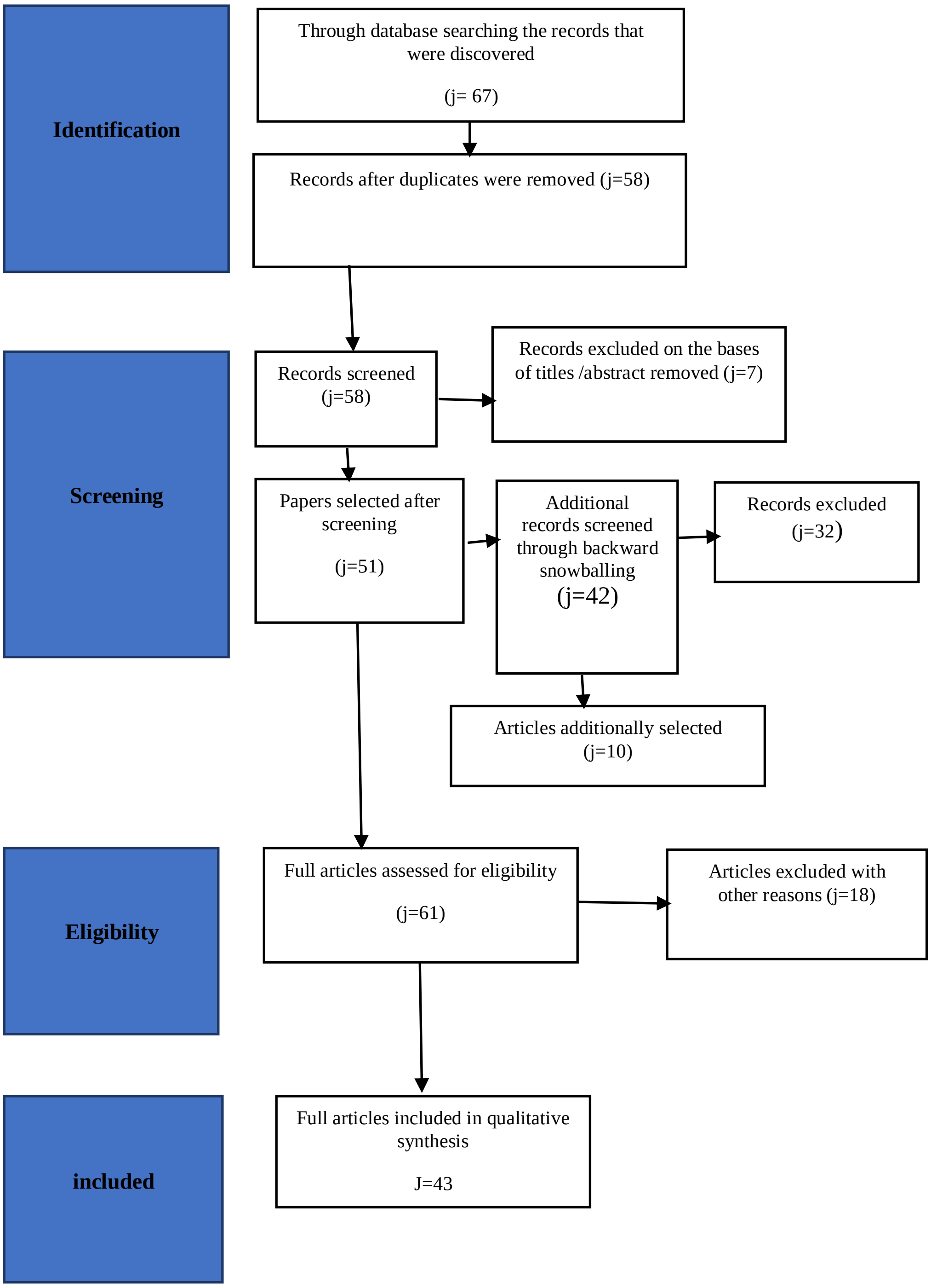


Figure 2. Flow chart for the selection of the articles

## 3.3. Reporting and Review

The responses to our research questions from the papers considered are discussed in this part. The paper looks at the cluster head selection algorithms that should be used in LEACH a WSN routing protocol, their properties, parameters and variables and their limitations. The following is how the research findings are structured in relation to the research questions:

**RQ1**. What are the existing cluster head selection algorithms?

WSNs are projected to change the way data is collected, processed, and disseminated in a range of contexts and applications. The most important design consideration in WSN is energy consumption. To overcome the challenge and extend the network's lifetime, each node's energy resources must be effectively managed. The structure of the most well-known energy efficiency strategies is hierarchical. Hierarchical routing strategies based on clustering can effectively reduce energy consumption. Many clustering concepts for extending network lifetime have been proposed, including various tactics for cluster-head election and role rotation among sensor nodes, all based on distinct characteristics, in order to perfect LEACH's restrictions [23]. The study sought to identify existing cluster head election algorithms that have been used to improve energy usage in LEACH protocols in WSN as a fundamental question in this body of literature. Out of the 43 papers examined to have addressed this research issue 34 were found to have done so. The key characterization of these cluster head election techniques on a shared platform presents the following problems [23].

- Who will be the first to choose a cluster head?
- Which parameters define a sensor node duty?
- Which sensor nodes will serve as the cluster's leader?
- Will the cluster formulation procedure have to be restarted?
- Are the election cluster heads distributed evenly?
- Will it guarantee the formulation of a well-balanced clusters?
- Which strategy, single-hop or multi-hop, is the best for a vast network?

The Figure 3depicts existing classification of cluster head election algorithms.

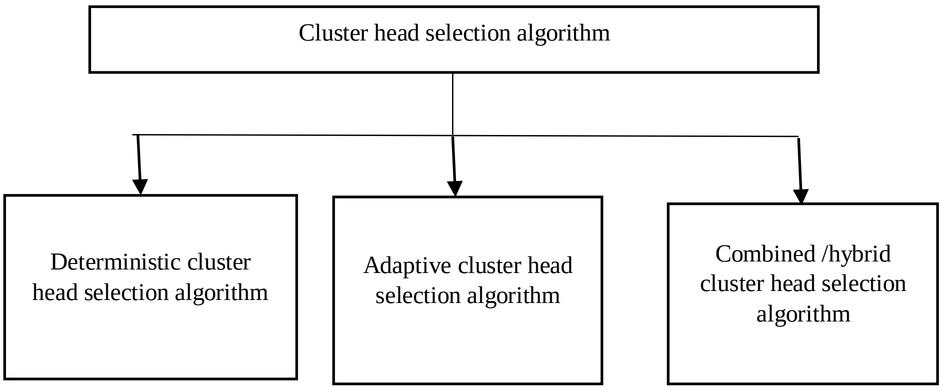


Figure 3. Cluster head selection algorithms

According to [23] they classified cluster head selection algorithms into three categories namely deterministic, adaptive and combined /hybrid cluster head selection algorithm.

The following section discusses each classification of cluster head selection algorithms and their examples.

### 3.3.1. Deterministic cluster head selection algorithm

Sensor nodes in a communication range that meet the `node degree criterion in the beginning will choose themselves as cluster heads. According to [23] "to establish the CH duty, throughout every round, all sensor nodes will send messages to their neighbors, and the nodes that receive the most transmission shall declare themselves cluster leaders and relay a cluster configuration. The presence of precisely one cluster leader in a communication range is validated by prohibiting nodes that received the setup broadcast from broadcasting again. The sensor nodes that received the setup broadcast send joining requests to the cluster head, who confirms it, generates the time schedule, and distributes it to the cluster members".

The deterministic approach chooses the best cluster heads based on sensor node characteristics such as identification number (Node ID), number of neighbors (Node degree), and main reference point (MRP)[23].

Algorithm for Cluster Establishment (ACE)

An example of this scheme is an Algorithm for Cluster Establishment (ACE) proposed by Haowen et al [24] which developed a cluster formulation algorithm. There are two parts to this algorithm. The first section specifies how nodes can spawn (by allowing each node to choose its own leader), while the second section controls how clusters will move dynamically without colliding. The ACE approach addresses cluster establishment, but not sensor node energy variations throughout the working phase. For f min, they used the spawning threshold function, which is an exponentially decreasing function based on the amount of time after the protocol was begun for that node. That is, as the algorithm continues, f min should decrease. As a result, fewer clusters emerge at the start of the process. With fewer clusters at the start, clusters will have greater room to separate themselves from one another, laying the groundwork for effective clustering. As time passes, the algorithm will gradually fill in the gaps between the clusters by spawning new clusters more aggressively. The formula proposed by Haowen et al [24] to calculate the spawning threshold function is:

$$f\min = ({}_{e}{}^{-}\mathrm{k1}\ t/\mathrm{ci} - \mathrm{k2})\mathrm{d}$$

According to [24] "the time since the protocol's beginnings is denoted by t, and the period during which each node performs the protocol is denoted by cI, where c is the average number of iterations expected per node and I is the expected period of the iteration timeframe. d is a network node's expected average degree (number of neighbors), which is calculated ahead of time. The parameters k1 and k2 determine the exponential graph's shape".

One of the cluster heads identified by the ACE system dies prematurely as a result of increasing energy demand, which is one of the algorithm's major flaws. Since they are the better cluster leaders in those clusters, appointing other nodes as cluster heads will result in higher communication costs. Another issue is that if we lose or destroyed a cluster head, the cluster members will reconstruct a new group, which means we will lose a portion of the network's scope, until the time new cluster is established.

The following is an explanation of how ACE functions. An ACE node can be in one of three states: un-clustered, clustered, or cluster-head. When the algorithm starts, all nodes are un-clustered. Each node delays the next iteration before deciding what action to take. This is done by waiting for a random iteration interval.

When iteration arrives, the alternatives open to a node are determined by its current state. This ACE technique, which is primarily concerned with cluster formation time, ignores the sensor node residual energy levels. Unless sensor nodes suffer significant changes, ACE's cluster heads will remain unchanged. Cluster leaders require a lot of energy than cluster members because they are in charge of integrating and relaying data to the base station [25]. The limitations of ACE are as follows:

One of ACE's shortcomings is that the cluster heads chosen by the algorithm expire early due to their increased energy demand. Because they are the finest cluster leaders in the clusters region, appointing other nodes as cluster chiefs can reduce communication costs. The second disadvantage is that if we lose a cluster leader, cluster members will have to must form a new cluster, which means that we can lose a portion of the network's coverage, until the new cluster is formed. Finally, the ACE model's optimal cluster head selection is too basic to account for cluster communication costs [25].

Algorithm for Cluster Establishment by Counting (ACE-C)

An Algorithms for Cluster Establishment by Counting proposed by [26] is another example of deterministic selection algorithm that employs node ID to identify cluster heads. Assume there are N number of sensor nodes in a mobile sensor network, each of which is numbered from 0 to N - 1. From above assumption the author suggested that [26] “the assigned number can be used as a unique identity (ID) for each sensor node in the network. In each cycle, we assume there are C clusters”. The ACE-C algorithm will select sensor nodes as cluster heads by the uses of round-robin fashion using the node IDs. In other words, the cluster-heads in the first round are sensor nodes with IDs ranging from 0 to C–1. According to [26] “the second stage the cluster-heads are the nodes with IDs ranging from C to 2C-1. The algorithm will continue to run for a few more rounds. After N C rounds, each sensor node has served as the cluster head once, and the process begins again with the sensor node with ID = 0 as the starting point”.

This method enables each node to autonomously determine whether they are cluster-leader in the current round. Each sensor node keeps trail of the total number of all cluster-heads formed in each round and make that decision based on its unique ID. If the time comes, it will claim to be a cluster-chief in the current cycle or else, it will become a non-cluster-head node. This improves the results of ACE-C algorithm [26]. In a vid variable, each sensor node v will save its ID. Algorithm ACE-C has the advantage of continuing to work even if certain sensor nodes die (consume up all of the energy) in the course of election process. Because the ACE-C algorithm only considers the ID of sensor nodes rather than their locations when deciding cluster-leaders. As a result, the sizes of cluster in all formed clusters may vary. Cluster-heads that have large number of sensor nodes in their clusters will have a high energy consumption, resulting in a short system lifetime.

Algorithm for Cluster Establishment by Location (ACE-L)

The ACE-L method is a reference point-based algorithm proposed by [26] that is particularly very useful in mobile sensor nodes. According to [26] “the basic concept is to use node mobility to temporarily convert each sensor node into a CH. The CHs chosen will be the sensor nodes in the area of the mobile sensor network that are closest to the predetermined reference sites. To do so, we look at using the delay time metric of the distance between a sensor node and a reference point, which is employed when a sensor node competes with another sensor node on a channel. As a result, the choice is influenced by sensor node channel contention”.

Assume that each round has C clusters. The ACE-L approach begins with the creation of C fixed reference points. The priority of a node contending for a radio channel, as well as the positions of the elected cluster-heads, will be influenced by these C reference points. Consider the following illustration: a sensor node at random v. The main point of reference is the one that is closest to v (MRP). The distance between v's present location and its MRP is used to compute the wait time for v, which is very significance for contending channel. All sensor nodes with the similar MRP will compete for a channel, and the one with the smallest wait time will win. The channel is apparently collected by the sensor node near to MRP. As a result, we can choose the CH that is most closely associated with MRP. When a sensor node is chosen as the CH, it will use the channel allocated to it, to transmission a CH beacon to the other nodes. Sensor node v, on the other hand, stops the competition and it will not become a cluster head in this round. If it receives a beacon of becoming a cluster leader from another sensor node u during the wait period or channel contention, and node u has the same MRP as v. The fact that ACE-L consumes less energy than ACE-C is one of its advantages [26].

### 3.3.2. Adaptive cluster head selection algorithm

Variables such as residual energy, energy squandered during the previous cycle, and the beginning energy of the nodes are employed in adaptive systems to determine the next cluster head in the network [23]. An adaptive strategy can be grouped as base station aided or self-organized (Probabilistic) subject on who initiates the cluster head election. Depending on the factors used to determine the duty of a sensor node, this scheme can be classified as base station aided adaptive schemes, fixed parameter adaptive schemes, or resource adaptive schemes [23]. Below section will review existing adaptive cluster head selection algorithms.

The base station aided adaptive scheme groups the network and enlightens these nodes based on pre-existing or collected node deployment information from the sensor nodes. The base station or the sensing nodes select the cluster heads [23]. The effectiveness of base station-assisted approaches is evaluated in light of the various requirements for cluster head selection. It's worth noting that under these methods, the base station is in charge of re-clustering, whereas the sensor nodes aren't responsible for computing the cluster heads.

Least Mean Squared Subtractive Clustering (LMSSC), suggested by P. Tillapart et al [27] is an example of this technique. A suitable number of CHs is calculated by assessing the node metric (CH), which is a definite ratio of a sensor node's outstanding energy, to the sum of the squared distances from the involved node to all sensor nodes in the cluster, as well as its squared distance to the base station.

After the nodes have been divided into clusters, the base station chooses and elects a suitable cluster leaders for each group. When determining the nodes' metric (CH) of active nodes in a group in order to elect a CH, the base station takes two critical parameters into account. The sum of squared distances from an afflicted node, other cluster nodes, and a squared distance from the affected node to the base station is the first variable. The second variable represents the injured node's extra energy (Eri). P. Tillapart et al formula's is used to determine CH for each node [27].

$$CH(i) = Er_i * \left[ 1/\left( \sum_{j=1}^{n} d_j^2 + d_{BS}^2 \right) \right]$$

According to [27] "for node i CH(i) denotes the node's measure. The distance between node I and the base station is expressed by dBS. dj represents the distance between nodes i and j in the same cluster. The letter n represents the number of other nodes in the cluster. The node with the most CH will be chosen as the cluster head. The proposed method causes the selected nodes to form cluster heads until they die. A new cluster–head will be chosen after that".

Another base station aided adaptive cluster head selection scheme is Base Station Controlled Dynamic Clustering Protocol (BCDCP) proposed by [28]. According to [28] "BCDCP assigns the required nodes with the highest energy status responsibility for the current round and gets to pick sensor nodes with an energy level above the average as possible cluster leaders. Two cluster heads with the biggest separation distance between them divide the network into two clusters, and the sensor nodes are separated to balance the clusters. Until the network has been divided into the requisite number of balanced clusters, this method of cluster division is used. The cluster setup method is repeated when the cluster head energy has been decreased below a predetermined threshold".

In fixed parameter probabilistic scheme, cluster heads are picked for the initial and following information gathering cycles by measuring an expression based on defined variables, utilizing fixed variables such as the cluster heads number and the number of round.

An approach in this classification is the Energy Residue Aware (ERA) algorithm proposed by Chen et al. [29] , which is a LEACH-based clustering technique. According to [29] "it employs the same cluster head appointment technique as LEACH, but there are differences in the clustering association procedures for cluster heads and non-cluster members, for which each CH is required to submit data". The Energy Residue Aware (ERA) algorithm, which is a LEACH-based grouping scheme, is the Aware of Energy Residue approach in this classification. It uses the same cluster head appointment technique as LEACH, but there are differences in the grouping connection procedures between CH and non-cluster members, for which each CH must submit data. The Energy Residue Aware (ERA) clustering method is used in extend the life of a network in order to balance its energy consumption.

When cluster leaders are appointed in a particular round of ERA, every other non-cluster head node joins one of the existing CHs and provide a return channel to the sink. The node with the highest energy residues will be chosen instead of the one with the least amount of energy use. By harmonizing energy use on the network, this clustering approach effectively extends the lifetime of a sensor network.The following paragraphs describe the process in this subordinate phase. After the cluster head selection operation is completed, each CH calculates its remaining energy (E CH-res)i and broadcasts this data together with its CH duty to the nearby nodes. The expression (E CH-res)i can be written as follows [29]:

(E CH-res)i=(E CH-rem)i-(E toBS)i , iϵ SC

According to [29] "the set of CHs is denoted by SC. The unused energy of CH i in the current round is specified by (E CH-res)i, and the transfer of energy from CH i to the sink is specified by (E toBS)i. The value of (E CH-res)i is then included in each CH's announcement message, which is then sent to other nodes in the network. In the course of cluster head selection phase, each non-cluster head node collects all announcement communications and extracts all of the CHs' remaining energy information from the announcement messages".

In addition, for each CH, each non-cluster head node computes energy remains (E nonCH-res) j [29].

$$(E_{nonCH-res})_j = (E_{nonCH-rem})_j - (E_{toCH})_{ji}, j \in S_N, \forall i \in S_C ,$$

SN indicates a collection of non-cluster head nodes. (E nonCH-rem)j describes the unused energy of nodes in the current round that are not cluster head nodes j, whereas (E toCH)ji specifies the energy of the declaration from non-cluster head node j to cluster head node i. Finally, based on the amount of energy it has left behind, so every non-cluster head makes the decision to join a cluster head:

$$\max\{(E_{CH-res})_i + (E_{nonCH-res})_j \mid \forall i \in S_C\}, j \in S_N$$

The resource adaptive cluster head selection technique uses data about available node resources to pick cluster heads for later rounds. [30] Proposes an Energy Adaptive Cluster Head Selection Scheme that adjusts the threshold based on variables including remaining energy, energy spent in the current round, and average node energy as a third variable.

### 3.3.3. Hybrid cluster head selection algorithm

Some hybrid techniques that integrate clustering with one or more other architectures as well as better energy efficiency are recommended [23].

The Adaptive Clustering Algorithm Based on Energy Restriction (ACAER) presented by Xuehai Hu et.el [31] is an example of this algorithm, which selects cluster nodes based on criteria such as coverage rate and unused energy. WSN operates in ACAER in a logical manner, with each period consisting of an initialization phase and a stability stage. According to [31] "to save energy, the stability period is significantly longer than the start-up phase during the beginning step of the ACAER protocol, a sensor nodes will be informally selected as a cluster based on a specified proportion". The cluster algorithm is as follows:

Make r=0; Ai=0, where Ai is the current angle and r is the current turn number.

$$A_i = \begin{cases} 1; node\ i\ is\ cluster\ head \\ 0; node\ i\ is\ non-cluster\ head \end{cases}$$

Let $R_{ir} = rand(1) * \left(\frac{W_{iR}}{W_0}\right)^2$

Where rand (1): the value range (0,1) of the random function; Wo: the total energy of all nodes at the start; Wir: the 'i' node's remaining energy in the 'r' turn.

$$T = P * min\left(\frac{C_0}{C_{r-1}}, q\right) * min\left(\left(\frac{\sum_{i=1}^{n} W_{iR}^2}{nW_0^2}\right), u\right)$$

The fraction of nodes that form clusters is denoted by P. C r-1 signifies the coverage of the 'r-1' turn; r denotes the current turn; The coverage compensation limit is denoted by the letter q. The energy compensation limit is denoted by u. The node becomes a cluster when Rir>T.

Lee et al [32] proposed the Gradual Cluster Head Election Algorithm (GCA), a hybrid cluster head selection technique that chooses cluster heads based on their closeness to neighbor nodes and extra energy level (Er) at each grouping phase. This method selects cluster heads based on a number of features. The number of sensor nodes present at each cluster tree level is used to pick cluster leaders first. Second, the number of cluster leaders is determined by the number of join requests received from non-joined sensor nodes, which allows for network density-aware cluster head selection. Finally, all clusters keep the number of cluster heads that must be elected (NCH)), and when NCH is less than one, at least one cluster head can be ensured in the next level.

To make the GCA better Lee et al. [32] Presented the Gradual Cluster Head Election with One-Hop Neighbor Information (GCA-ON) algorithm, it gets to pick the cluster leader relying on Er and sensor node relative location data, such as the number of cluster heads in one-hop neighbors (NCH-ON). Based on the extra energy level (Er) of nodes and the number of cluster leaders in one-hop neighbor, the cluster leader that received join requests elects cluster heads for the next level (N CH-ON). Cluster chiefs are elected at the next level by cluster heads from non-joined nodes with the lowest N CH-ON and highest Er.

Local Negotiated Clustering Approach (LNCA), proposed by [33] , is another hybrid cluster head selection algorithm. The LNCA technique is the first to employ node reading similarity as the major factor for cluster formation. As a result, LNCA is very good at lowering in-network data-reporting traffic and, as a result, individual sensor node energy consumption.

#### 3.3.4. Other Cluster head selection algorithms

Lin et al [34] Fan shaped clustering (FSC) is an algorithm that divides a large network into dense rings before subdividing each ring into subrings. CH is in charge of network-based clustering and data transmission, which is utilized to partition the network into square grids. A network is built by selecting and categorizing all CHs. According to [34] “the gathered data is separated into a network of sync networks for a rectangle network in two stages”. Nine successive low-level clusters that are intentional in exchanging cluster data generate clusters for obtaining cluster data at the lowest level. The FSC approaches look at performance indicators like total live nodes, total remaining energy, and packet accumulation speed.

Lee et al [35] suggested a hybrid hierarchical clustering technique (HHCA) built on a distributed cluster and a hybrid core network. HHCA is based on a three-tier clustering algorithm which are superior to the two-tier method previously used. This approach defines grid heads and distributes cluster heads from a central location. According to [35] “the number of nodes in contact with the base position, as well as the three layer (TL) sequence, both contribute to increased energy gain. TL-HHCA is concerned with improving network performance based on network life expectancy and cluster numbers”.

In order to address the issue of excessive energy consumption. Akila et al [36] on a flimsy foundation, a fuzzy-based cluster was presented. The remaining energy, confidence, signal interference plus noise ratio, and load characteristics will all influence the CH value. Intra-cluster routing is generated by a blur-based cluster protocol that uses a network index-based probability route diagram to calculate the cooperative endpoint joining the cluster. Particle swarm optimization (PSO) technology is used to determine the most perfect path connecting data transmission CHs at each cooperative node.

The Fuzzy-Based Balanced Cost CH Selection technique (FBECS) was presented by Mehra et al. [37].The extra energy, distance, and density of node are all inputs to the Fuzzy Inference System. They chose the most eligible CH based on the Suitability index for each node. Load balancing was ensured by the protocol's selection of the best candidate for cluster coordination.

Deepa et al [38] to reduce power consumption, an improved QoS-based clustering with multipath routing protocol was presented (OQoS-CMRP). According to [38] “it solve the energy problem, the modified particle swarm optimization (PSO) technique is used to select and cluster CHs in the zinc cover zone. All target immersion methods are used to determine the best multidimensional hop communication mechanism from sync to sensors when selecting the next hop nodes”. The encircling robin path election technique is used to transport data over OQoS-CMRP to expand communication reliability, low latency, power enhancement, and network performance.

Another algorithm is proposed by Muthukumar et al [39] is OC-TAS-IM algorithm. This method is a modification to the optimal clustering (OC) algorithm that reduces network lifetime while increasing energy consumption. The cluster is built using the turbid ant swarm (TAS) technique, which uses node position and velocity, and the CHs are computed using decision trees using an improved myopic (IM) algorithm. Energy consumption, network longevity, route cost, network load, and distance are all factors to consider.

Regional Energy Aware Clustering with Isolated Nodes (REAC-IN) is a weight-based CH selection algorithm described by [40] that solves the problem of node isolation while simultaneously boosting the network's lifetime and stability.

The tables below displays some of  existing cluster head selection algorithms and the parameters the uses to improve on energy consumption as discussed in above section.

Table 2. Comparison of deterministic cluster head selection schemes

| Deterministic Schemes | Parameters |
|---|---|
| Algorithm for Cluster Establishment (ACE) [24] | Node degree |
| Algorithm for Cluster Establishment by counting (ACE-C) | Node ID, |
| Algorithm for Cluster Establishment with Location (ACE-L) | Reference Point (MRP) |
| Reconfiguration of Cluster Head for Load Balancing (RCLB) | Number of CHs range |

Table 2 displays compares existing deterministic cluster head selection algorithms and the parameters or variables they uses to select cluster head.

Table 3. Comparison of Adaptive Cluster Head Selection Algorithms.

| Schemes | CSA | Parameter |
|---|---|---|
| Least Mean Squared Subtractive Clustering (LMSSC) | Base station | Residual energy,<br>CH to SN and CH to BS distances |
| Base station Controlled Dynamic Clustering Protocol (BCDCP) | | Position information and energy level. |
| Energy Residue Aware (ERA) | Fixed parameter Probabilistic schemes | Number of cluster heads and round number |

Table 3 above compares existing adaptive cluster head selection algorithms and parameters they uses to select cluster head.

Table 4. Comparison of hybrid cluster head selection algorithm.

| Schemes | CSA | Parameter |
|---|---|---|
| Adaptive Clustering Algorithm Based on Energy Restriction (ACAER) | Sensor nodes (Self organized) | Remaining energy and coverage rate |
| Local Negotiated Clustering Algorithm (LNCA) | | |

| | | |
|---|---|---|
| Gradual Cluster head election Algorithm (GCA) | | The distance between nodes and the amount of residual energy (Er) |
| Gradual Cluster Head Election algorithm with One-Hop Neighbor Information (GCA-ON) | | Residual energy level (Er)and sensor node relative location information like the number of cluster heads in one-hop neighbor |

Table 3 above reviews existing hybrid cluster head selection algorithms and the parameters they uses to elect cluster head.

**RQ2**: What are the parameters used by cluster head selection algorithms?

From literature review the researcher identified there are so many parameters that are used to elect cluster head in WSN as discussed in above section. This section reviews some of the major parameters that are used to elect cluster heads and improve network life span. They include;

Residual Energy of Node

At the conclusion of each simulation experiment cycle, [41] it is the average remaining energy of the active sensor nodes is this value. It is one of the most critical considerations when routing a network to ensure its long-term viability. A linear function of voltage is commonly used to measure the residual energy in a battery.

Distance between nodes and BS

A CH node receives data from member nodes, removes duplicates, conducts some basic processing, and then transfers it to the BS. Because data transmission consumes the most energy in a sensor node, especially when transmitted over long distances, the closer the CH candidate is to the BS, the less energy it requires to transmit data to the BS [42]. As a result, with each cycle of clustering, CH lifetime and steady-state phase duration increase (the interval between two set-up phases of CH selection expands), minimizing wasteful energy expenditure for reselecting CHs. As a result, the lifespan of the network has been extended. As a result, nodes near the BS are more likely to become CHs.

The Distance between Node and Its Neighboring Nodes

Because each member node communicates the data it has locally sensed to its CH, there is a direct relationship between distance and data transmission energy. As a result, the closer the member nodes are to the CH, the less energy they will expend communicating the data they have gathered [43] [44].

Node density

This is the connection between the number of nodes in the field and the surface of the field. Because the field's surface is constant, a higher node density means a shorter distance between nodes. That is, nodes in densely populated areas are more likely to be chosen as CHs [45]. The number of nodes per square meter is used to calculate network density. It varies depending on the node distribution from one deployment to the next and from one node to the next within the same deployment.

Number of Neighboring Nodes

It is critical to strike a good balance between cluster size and number. As a result, a threshold for the number of cluster members must be specified, with nodes with a large number of neighbors near the threshold having a better chance of being selected as CH [46].

Node position in the network

This is the agent node's network position. There are various types of node placements in the network. Normal, critical, and edge are a few of them. The node's usual position in the network is where it has a large number of neighbors. This type of node may collaborate with other network nodes to maximize the amount of vital data collected. The edge node is a network node that lies on the network's edge and has only one neighbor. It has a limited view of the network. Finally, when a node connects two network components, it is considered essential. That is, if the node runs out of energy, it may split the network, rendering many nodes behind it unavailable and, at best, necessitating a longer route for their data to reach the sink. Because of the increased number of hops, this longer journey requires more energy [47].

**RQ3**: What are the limitations of existing cluster head selection algorithms?

The study reviewed that there are many cluster head selection algorithms that have been developed over the years as discussed in RQ1 and can be categorized as deterministic, adaptive and hybrid cluster head election algorithms. This cluster-head selection algorithms have not fully solved the issue of energy consumption in WSN. This section reviews the limitations of some of this cluster head selection algorithms as shown in the table below.

Table 5. Limitations of cluster head selection algorithms.

| Cluster Head Selection Algorithms | Limitations |
|---|---|
| Algorithm for Cluster Establishment (ACE ) | Because of their higher energy requirement, the CH picked by the ACE algorithm die early [25].<br>Appointing other nodes as cluster heads will increase communication costs because they are the best cluster leaders in the clusters region [25].<br>If a cluster head is lost, cluster members must rebuild a new cluster, which means that a portion of the network's coverage will be lost until the new cluster is built [25].<br>Finally, the ACE model's optimal cluster head selection is too basic to account for cluster communication costs [25]. |
| Algorithm for Cluster Establishment by counting (ACE-C) | If a cluster head is lost, cluster members must rebuild a new cluster, which means that a portion of the network's coverage will be lost until the new cluster is built [26].<br>The cluster sizes of all created clusters may differ (the number of nodes in a group) [26].<br>Some sensor nodes (cluster-leaders with a large number of sensor nodes in their clusters) appear to be energy hogs, resulting in a short system lifetime [26]. |
| Adaptive Clustering Algorithm Based on Energy Restriction (ACAER) | Do not take other important parameter in account in CH selection like distance from nodes to BS and mobility of nodes |
| Regional Energy Aware Clustering with Isolated Nodes (REAC-IN) | When transferring data to prior CH nodes, isolated nodes use more energy [40]. |

| | |
|---|---|
| Gradual Cluster head election Algorithm (GCA) | Without the location information of sensor nodes, it would be impossible to create a well-organized network structure [32].<br>Increases the likelihood of a collision by increasing the amount of CHs [48]. |
| Fuzzy-Based Balanced Cost CH Selection method (FBECS) | Implementing an optimization concept could extend the network's lifespan. |

## 4. DISCUSSION

The research was aimed at reviewing available work on existing cluster head selection algorithms and the parameters they use to elect cluster head. Kitchenham and Charters' systematic literature technique and recommendations were followed in the research (2007). Data was gathered from primary studies published in journal articles, conference proceedings, and selected arXiv preprints between January 2011 and June 2021. After applying our selection criteria, we came up with a total of 43 suitable papers. Our discussions are summarized as follows:

RQ1. Our first research question was reviewing existing cluster head selection. Our study found out that there are existing cluster head selection algorithms to select cluster heads in wireless sensor networks. This algorithms have been classified into three categories they include deterministic, adaptive and hybrid or combined cluster head selection algorithms. The study reviewed that each CSA uses different parameters to elect cluster-heads as shown in table 2, 3 and 4 above.

RQ2. The second research question was reviewing the parameters used by cluster head selection algorithms. The research identified the major parameters and features that the uses to improve on energy efficiency in wireless sensor networks. These parameters or variables used to select cluster head include; node id, node density, reference point, remaining energy, coverage rate and distance between CH to BS and CH to SN.

RQ3. The third research question was to evaluate limitations of existing cluster head selection algorithms. The study reviewed that there are many cluster head selection algorithms that have been developed over the years as discussed in RQ1. The cluster head selection algorithms do not fully address the issue of energy efficiency in WSN. In this section various limitations of existing CSA were discussed as shown in Table 5 above.

## 5. CONCLUSION

Wireless sensor networks (WSNs) have received a lot of attention in recent years, and they can be used for a variety of applications. Clustering and cluster head selection are two of the most important research areas in the Wireless Sensor Network. A lot of effort has gone into designing effective and efficient cluster-Head Selection algorithms for WSNs over the last few years. Designing an effective, durable, and scalable Cluster-Head Selection Algorithm is a difficult task. Different cluster head selection methods were evaluated, categorized, and discussed in this work, with a particular focus on their cluster head election strategies and the parameters they employ to elect cluster heads. Based on our findings, we believe that a more scalable, energy-efficient, and cost-effective solution is required to elect cluster heads.

In the future, researchers should derive more parameters that can be utilized to elect cluster heads and create an effective, robust, and scalable Cluster–Head Selection Algorithm for Wireless Sensor Networks that improves energy efficiency.

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