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Survey of Energy-Aware Cluster Head Selection Techniques in Wireless Sensor Network

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***Abstract-* Recently, wireless sensor networks (WSNs) are becoming very famous as they are inexpensive and easy to maintain and manage. The network contains a group of sensor nodes, which are capable of sensing, computing, and transmitting. Energy efficiency is one of the most important challenging problems in WSN. Sensor nodes have inadequate energy and installed in remote areas. Hence, it is difficult to restore the batteries in WSN. Therefore, to maximize the network lifetime, appropriate clustering techniques and cluster head (CH) selection methods should be implemented. The main idea behind the cluster- ing technique is that it clusters the sensor nodes and reduces the composed data simultaneously and then, it broadcasts the data. In this process, CH selection is an essential part. Therefore, this survey paper provides an overview of the clustering techniques for reducing energy consumption by reviewing several CH selection techniques in WSN that provide high energy efficiency. Several techniques have been employed for CH selection based on partitional clustering, optimization, low-energy adaptive clustering hierarchy, hierarchical, distributed, and other classification methods. Finally, an analysis is done based on the implementation tools, metrics employed, accuracy, and achievements of the considered CH selection techniques.**

***Keywords-* Wireless sensor networks · Clustering · Cluster head selection · Low-energy adaptive clustering hierarchy · Sensor nodes · Network lifetime · Energy.**

I. INTRODUCTION

WSN is an emerging industrialized platform with real time applications in various fields, such as cultivation, mili- tary, residence networks, health and structural monitoring, healthcare system, entertainment, etc. [1]. The purpose of WSNs in security surveillances, domestic, and industri- alized fields, etc., are growing in the real-world environ- ment. For instance, Fig. 1 demonstrates network employed for observing the geological field and linking that area to the internet using the BS node [2]. The latest researches in WSNs have escorted to several recent protocols that are particularly intended for sensor networks, where electronic devices, called sensor nodes. The sensor nodes are proficient to identify the physical trends, which are inhibited in processing power, bandwidth communication, and for supplying the energy [1]. Typically, a sensor node consists of a variety of modules like processing, communication, and sensing module. The sensing module is employed for measuring the parameters, such as action, force, temperature, etc. Then, the estimated value is broadcasted to a mid area, called base station (BS) or sink, which utilizes the communication module. There is a requirement in the initial processing area to transmit the estimated value before broadcasting [4, 5].

In WSNs, the most vital challenges for the researchers are extending the network lifetime and maximizing energy efficiency. Therefore, providing an energy-efficient method to overcome the challenges associated with cluster head (CH) selection, clustering, and routing protocols is a neces- sity [2, 6]. There is a major limitation in WSNs that usually work with battery power in sensor nodes, i.e. each node is associated with the embedded processor, less power radio, and inadequate memory. The battery power sensor nodes are usually installed in an unattended aggressive environment.

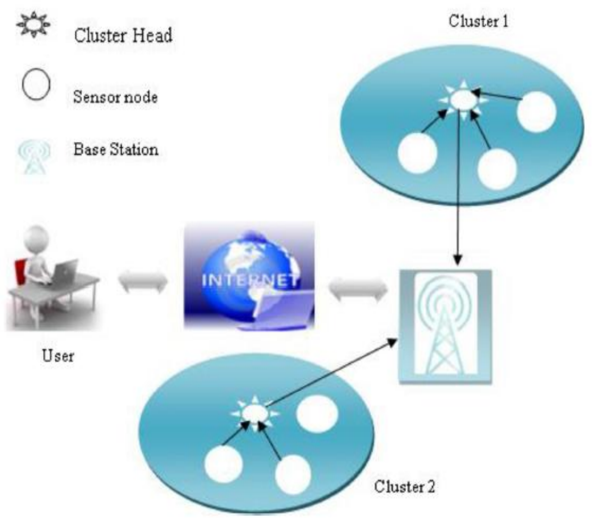

Fig. 1 Outline of WSN.

Hence, the choice of their battery power is approximately impracticable, as it limits the energy efficiency of the sensor nodes [7]. Simultaneously, the lifetime of the network, cost, and consumption of power are considered as an enhance- ment of WSN transmission. Many of the researchers devel- oped various energy saving modes, but none of them achieve energy efficiency or improve the network life span in an effi- cient way [8]. Therefore, clustering is an efficient method employed to minimize the energy loss of the sensor nodes in WSNs [7, 9]. Clustering is the method that isolates the geological field into tiny sectors and elects one of the nodes as a head, named CH, in the cluster [10]. The CH selection plays a significant role in transmitting the energy data effec- tively in the realistic environment [1].

CHs are more important for intra-cluster and inter-cluster transmissions in the WSN. Typically, these transmissions exhaust more energy when compared to the non-CH sensor nodes. So, several protocols have been presented to balance the energy loss in WSN [4]. The cluster-based protocols divide a network without extending the clusters. Thus, each network consists of CH, which acts as a gateway to other sensor node and BS. In general, clustering contains two levels: setup state and steady-state. CHs are elected, and the clusters are formed in the setup level. Each sensor node communicates with its data packet to the consequent CH, and then, the CH forwards the collected data to the sink in the steady-state phase [1]. Hence, the process of cluster- ing prolongs the network lifespan, distributing the unbiased energy through the mobile sink and BS or static sink. When identical size clusters are employed for the transmission, energy loss is maximized [8]. The benefits of clustering nodes in WSNs are, minimizing the intra-cluster transmis- sions; providing load balancing in the network using CHs, minimizing the updating process when restraining most of these messages to intra- cluster transmission, and maxi- mizing the scalability [11]. Hence, the energy-aware CH selection techniques in WSNs employed for minimizing the energy consumption are reviewed in this paper. Fifty research papers based on energy-aware CH selection process are reviewed by providing a classification based on various factors, and features. The main purpose of this survey is to develop and plan the algorithms for performing the energy- aware CH selection in WSN, which can be used to search the good routing path to prolong the network lifetime of sensor nodes so that the energy loss in the network environment can be minimized. From the analysis, it is perceived that many of the research papers reviewed have utilized MATLAB as the implementation tool.

The rest of this paper is organized as follows: Sect. 2 pre- sents related work based on energy-aware cluster head selec- tion techniques in WSN. In Sect. 3, the research gaps identi- fied in the existing works are provided. Section 4 contains the analysis part that is based on, evaluation metrics, pub- lished years, network lifetime, energy consumption, param- eters considered in combination with energy and implemen- tation tools. Finally, the study is concluded in Sect. 5.

II. REVIEW OF LITERATURE

This section depicts a review of the literature on various existing energy-aware cluster head selection techniques in WSN. The traditional energy-aware cluster head selection techniques in WSN considered for the survey contains the techniques based on partitional clustering, optimization, LEACH, hierarchical, distributed, and so on, as shown in Fig. 2.

1. Partitional clustering-based CH selection techniques

The partitional clustering techniques considered for the review are discussed as follows,

Arghavani et al. [4] have developed optimal clustering in circular networks (OCCN) method based on optimal param- eters, which were employed for reducing the energy loss and thereby, maximized the network lifespan. The parameters considered the optimal clusters number, optimum number of cluster size, and optimum one-hop communication, for a circular network, while the BS was situated in the mid of the network. The benefit of the OCCN method is that the network life span significantly maximized. The main impact of this method is that the method cannot be stable in the trends of energy loss because the behavior of net- work energy loss is easily predictable. Kalantari et al. [2] have suggested a K-means clustering protocol, which was employed for selecting the CH in WSNs. This method mini- mized the energy loss even if there was a delay due to less energy sensor nodes, especially the death of nodes in the entire network. The advantage of this method is that the method created the unbiased clusters, whereas the CHs are not elected arbitrarily, and also this method maximized the network lifetime with the maximal number of density avail- able in the network environment. However, the energy in the sensor nodes reduces in each round of the network.

Ni et al. [12] have designed a CH selection strategy based on particle swarm optimization (PSO) and fuzzy cluster- ing. The fuzzy clustering was employed for the preliminary clustering, whereas the extended PSO was employed for the selection the CH. This method considerably minimized the casualty rate of sensor nodes to increase the lifetime of the network. The main drawback of this method is that the method is not suitable for preliminary clustering to mini- mize the computation time. Su et al. [13] have suggested an energy-efficient Fuzzy C means clustering technique for WSN, which was employed to segregate the nodes into a specific number of clusters. This method considered the overall energy loss in the entire networks and predicted the optimal solution of CHs, which was based on the density node to prolong the network lifetime. The benefits of this method are that the algorithm effectively attained consist- ent spatial CHs distribution and unbiased the energy loss in the entire network. Even though this method effectively balanced the energy loss, the clustering algorithm is not suit- able for the original application of WSNs.

Torghabeh et al. [14] have designed an efficient routing algorithm, namely hierarchical routing, based on the clus- tering algorithm that increased the lifetime of the network. The two-level fuzzy logic elected the most eligible CHs. The eligible nodes were selected based on their neighbor- ing nodes and energy on the local level. Then, at the global

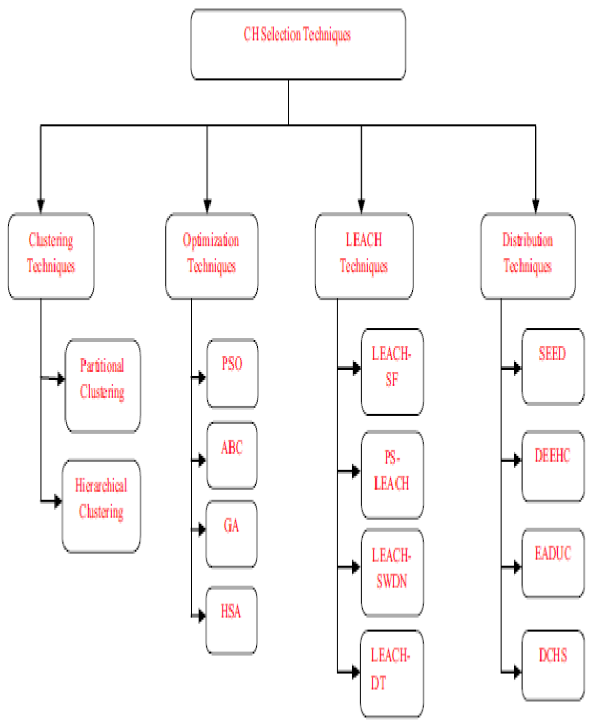

Fig. 2 Hierarchy of cluster head selection techniques.

level, the overall nodes were considered in terms of their proximity, centrality to BS and distance among CHs in the entire network. The advantage of this method is that the sensor nodes reduce energy consumption, extending their lifetime. However, this method has a low variant energy loss. Mirzaie et al. [11] have developed an adaptive multi cluster- ing technique based on fuzzy logic (adaptive MCFL), which was utilized to reduce the energy loss in WSN nodes. This method was used for minimizing the optimum number of CH selections, and also, to minimize the repetitive distribu- tion of CH communications to obtain high energy efficiency within the sensor network. The adaptive MCFL showed that the method has low energy loss and high energy efficiency. Yu et al. [15] have suggested a cluster-based routing pro- tocol for WSNs that consists of an energy-aware clustering technique and a cluster-based routing technique, without the identical distribution. This routing algorithm was employed to mitigate the energy loss between CHs by regulating inter and intra-cluster energy loss. As a result, the network could attain the stability of energy between the sensor nodes, increasing the network lifespan. However, the lesser energy sensor nodes limited the lifetime of the networks, and so, the energy of higher energy sensor nodes was exhausted in the heterogeneous scenarios.

Amgoth et al. [16] have designed energy-aware routing algorithm (ERA) for the cluster-based WSN. In this algorithm, the entire nodes were classified into different groups. Each sensor node had initiated the selec- tion of CH by starting a time delay based on its remaining energy. It prolongs the lifespan of the network, but it has not examined the features of fault tolerance and active scenario of the WSN.

Maryam et al. [17] have developed an energy-efficient hierarchical cluster-based routing technique for WSNs in a distributed way. The purpose of this method was to minimize energy loss caused by control message communications. This technique afforded more energy efficiency and then, prolongs the lifetime, but the sensor node distribution has not improved the entire lifetime of the network.

Jain et al. [18] have developed a heuristic method, Eigenvector central- ity for cluster size control (Ev-CSC). In contrast to various cluster size control approaches, the Ev-CSC approach was relevant for most of the energy exploitation, sink location and spatial dealing of the sensor network. The limitation of this method is that the approach still needed to be executed on the testbed. However, a similar issue has been tackled by examining the simulation parameters with the possible condition, which is offered for actual testbed verification in real time applications.

Mahajan et al. [3] have suggested a CH weight selec- tion approach, namely cluster chain weight metrics method (CCWM), which had taken the service parameters for maximizing the performance level of the network. This approach was employed to minimize the energy loss and balancing the load by electing the CH sensor nodes, and then, it analyzed the well-organized distributed groups in the node. Thus, the approach minimized the transparency of the sensor network and also decreased the transmission cost in real time environment.

Chiang et al. [19] have devel- oped a method, regional energy-aware clustering with iso- lated nodes for WSN (REAC-IN), to prolong the lifespan of WSN. In this method, the CHs were chosen by the estimated density values, which were based on the remaining energy of every sensor node and the regional standard energy of the whole sensor's networks in each cluster. Therefore, REAC- IN had maximized the performance of CHs selection and resolved the problem of the isolated sensor node. Moreover, it expanded the lifetime of network and increased the net- work stability effectively.

Saadi et al. [20] have designed an energy-aware clus- ter head selection technique, for heterogeneous WSNs to increase the performance of the network stability and resid- ual energy. To manage the energy loss of sensor nodes via an adaptive method, an oriented energy-aware scheme (OEAS) employed the standard energy of the sensor network. Con- sequently, the OEAS was unaware of large-scale energy at each selection round. This method illustrated that the life- time of network performance and robustness are maximized in terms of heterogeneity energy.

1.1 Advantages of partitional clustering techniques

- Partitional clustering preserves inadequate energy resources and maximizes the energy efficiency level.
- These techniques afford the robustness and scalability of the sensor network.
- They permit the reprocess of bandwidth, good resource distribution, and maximizes the control of power.

2. Optimization based CH selection techniques

The optimization-based clustering techniques considered for the review are explained in this section. Ouchitachen et al. [21] have designed improved multiobjective weighted clustering algorithm (IMOWCA) based on the improved version of genetic algorithms (GA) [22] to solve the issues of energy in the significant WSNs, where each node attempted to reduce the transmission cost and average density nodes in a distributed method regarding the optimal solution. The IMOWCA method had reduced the vast amount of energy loss, which was a huge challenge in the early stage.

This method cannot consider the intention of latest protocols regarding the mobility of node and also, it cannot handle the routing protocols, which integrated the clustering model. Shankar et al. [23] have suggested an algorithm obtained by the hybrid of PSO and harmony search algorithm (HSA) utilized for selecting the CH as energy efficient. This hybrid algorithm had revealed the efficiency of HSA with the highest search, and the PSO permitted the stirring from one area to another area with the optimal num- ber to maximize the lifetime of network nodes.

The standard variation of the remaining energy for different BS positions and a large number of sensor nodes indicated that the dif- ference is low in hybrid HSA-PSO. These are considered as the major challenges in this hybrid algorithm.

Srinivasa Rao et al. [7] have designed an energy-efficient CH Selection technique based on PSO (PSO-ECHS), which was extended with an efficient method, such as particle fit- ness and encoding function. Several parameters, such as residual energy, intra-cluster distance, and sink distance of sensor nodes, have been considered for energy efficiency. This technique was verified widely on the basis of CHs, several scenarios of WSNs, and with the modification of sensor nodes. However, this technique cannot consider problems, like fault tolerance and energy balancing using a suitable meta-heuristic method of WSNs. Sirdeshpande et al. [24] have developed a hybrid optimization technique namely, FLION, which combined the fractional calculus (FC) and lion algorithm [25]. Herein, the lion algorithm was employed to select the CH with high energy efficiency based on the FC model. Thus, the FC was employed to enhance the integration of lion algorithm by producing the latest neigh- bor node. Therefore, the FLION clustering algorithm could prolong the lifetime of the nodes.

Sarkar et al. [26] have suggested Firefly with cyclic ran- domization (FCR) algorithm, for choosing the optimum CH solution in the WSN environment. Firefly algorithm was expanded for prolonging the network energy efficiency and sensor node's lifespan. Therefore, the FCR protocol con- served the network energy efficiency, but the distance among the sensor nodes had become very low, and a possible num- ber of alive nodes were aborted. However, the performance of the FCR network was prolonged in the real environment. Oladimeji et al. [27] have presented an algorithm, algorithm for clustering hierarchy protocol (HACH), for balancing and maximizing the energy by choosing the distributed sensor nodes with huge energy efficiency as CHs to increase the lifetime of the network. This method not only yields bet- ter performance in the network under various levels of het- erogeneity of WSN settings but also prolongs the network lifespan.

Mann et al. [28] have designed improved Artificial Bee Colony (iABC) meta-heuristic algorithm with an enhanced solution that was utilized to maximize the exploitation of search equation in the network. The protocol employed an energy-efficient method that elected the optimum CHs based on the well-organized fitness function and an enhanced search equation. Therefore, the Bee cluster had reduced low energy issue and increased the lifespan of the network when distributing the packet's end to end delay in different WSN environment. However, this algorithm is not suitable to exe- cute the actual testbed of sensor nodes with the application of specific domain in the network environment.

Zahedi et al. [29] have developed Swarm intelligence based fuzzy routing protocol (SIF) to examine the remaining energy, the distance from the group nodes to choose CHs, and the distance from the nodes to the sinks. These analyses were carried out to overcome the ambiguity of fuzzy rule in the WSN environment. The fuzzy rule-based table optimization was used to enhance their relevant performance, maximizing the network lifespan. Therefore, the protocol was more energy-efficient regarding the cluster load balance, reducing the distances of intra clusters and maximizing the network lifespan.

Potthuri et al. [30] have suggested a hybrid differential evolution and simulated annealing (DESA), which was employed to prolong the lifetime of the network by maxi- mizing the termination of the CHs. Since CHs were loaded with the highest number of nodes, it led to the rapid termina- tion of sensor nodes because of the unnecessary selection of CHs. The DESA method had incorporated a fitness function, which makes an allowance for the remaining energy and distance among the CH with the sensor nodes. Therefore, this method prolonged network life.

Kumar et al. [31] have presented an energy-efficient clustering method based on FC and Artificial Bee Colony (FABC) technique, which was used to prolong the network energy efficiency and sen- sor node's life by electing the optimal CH. The deviation of FC [32] was employed by ABC to produce the latest neighbor node by maximizing the union of ABC algorithm. The FABC method was adapted to select the CH in WSN. Accordingly, this FABC method afforded the high energy efficiency in the sensor network and also prolonged the life span of sensor nodes for a long time of operation.

Dabirmoghaddam et al. [33] have designed a randomized clustering protocol that was based on clustering algorithm for forming the cluster-based data collection and refined it to generate the suitable clustering of the sensor network regard- ing the consumption of energy. This protocol not only based on inconsistent clustering approach, which maximized the energy of the sensor network but also based on the basic consistent clustering approach, which was extremely efficient in the network with energy starvation.

Investigating the lifetime of network and analyzing the possible solutions are not suitable for allocating the data gathered load balanc ing function during the sensor network. Li et al. [34] have developed a constructing optimal clustering architecture (COCA) approach to reduce the entire energy loss of the sensor nodes. This approach attained constant energy loss between the sensor nodes, which was based on efficiently distributed protocols for energy-aware CH routing and rota- tion. Moreover, this approach has not been precise enough and diverge a modest change from the real environment because of the uncomplicated radio propagation model.

Singh et al. [35] have suggested a PSO approach for selecting the location of optimal CHs on account of the fit- ness function. The PSO maximized the transmission distance by establishing the optimum position of the CH sensor nodes in the cluster. However, this approach has not integrated the execution of sensor node in maximal dimension region and allocated the application of PSO in heterogeneous WSNs. Singh et al. [36] have presented a particle swarm optimiza- tion semi distributed (PSO-SD) approach for minimizing the intra-cluster distance from the cluster group to the CH. Accordingly, the PSO minimized the cost of optimum loca tion for the header sensor nodes. Therefore, the retransmission calculation for crash data packets supported the entire energy loss in the sensor network. However, this method is not appropriate for implementing the sensor nodes in the highest dimensional region and also it could not concentrate on the application of PSO in the heterogeneous networks.

2.1 Advantages of optimization-based CH selection techniques

- The optimization-based techniques outperformed the best optimal solution within the given number of solutions.
- The techniques require a smaller verification to attain an optimum formulation.

3. Leach Based Ch Selection

Low-energy adaptive clustering hierarchy (LEACH) is one of the types of routing protocol in WSNs. In this protocol, the CHs are elected between the sufficient numbers of nodes on the basis of rotation, which was communicated with the BS. The techniques involved in this classification are explained as follows, Shokouhifar et al. [1] have developed an energy-effi- cient cluster-based routing protocol using LEACH - Sug- eno fuzzy inference system (LEACH SF), for forming the unbiased clusters by fuzzy c-means clustering algorithm to increase the lifetime of the network in WSNs for select- ing the appropriate CHs, which could transmit the data to the sink directly. This method prolongs the lifetime of the network, increasing the possible number of external data packets in the sinks, and decreasing the distances of intra- cluster. However, the method is not suitable for enlarging the number of CHs to maintain the sensor mobility nodes in the maximum topological fields.

Patil et al. [37] have suggested an energy-efficient clustering protocol, named as a PS-LEACH algorithm, for maximizing the effectiveness of energy in the sensor node. Therefore, this algorithm indicated better network lifetime and dynamic rate of sensor nodes. This algorithm cannot extend a cross-layer design approach, which examined the strength of radio signal for discovering the neighbor node to minimize the transparency of the sensor network.

Elshrkawey et al. [38] have developed an enhancement LEACH method to minimize energy loss and maximize network lifespan. It was achieved by enlarging the con- sideration of energy in clusters between the sensor nodes to reduce the dissipation of energy during network trans- missions. This method is not suitable for heterogeneous sensor networks, as this method was intended to solve or minimize the problem of energy loss. This method has not offered the data security and privacy to the WSN in real- world data. Wanga et al. [39] have designed an enhanced technique based on LEACH with sliding window and dynamic number of nodes (LEACH-SWDN) approach. The LEACH approach regulated the optimum number of CHs in the entire network, preventing the issues caused by various CHs that were selected itself from being CHs after few of the sensor nodes exited out of energy. Accordingly, this technique prolonged the lifespan of the network and guaranteed the consistency of energy loss in the sequence of the sensor network. Even though LEACH-SWDN maxi- mized the network load balancing, as the sensor nodes distribute the information of residual energy, it has a slight impact on the entire network.

Kang et al. [40] have presented a distributed CH selec- tion technique that considered the LEACH with distance- based thresholds (LEACH-DT) approach for WSNs based on the distance of sensor node to the sink, for balancing the energy loss between the sensor nodes. Thus, the nodes in the overall network structure formed the sensor groups resourcefully. Accordingly, this approach maximized the lifetime of the network.

Nguyen et al. [41] have devel- oped distance-based clustering routing protocols based on LEACH protocols, named as distance-based LEACH (DB-LEACH) and distance-based energy aware LEACH (DBEA-LEACH). To develop both the method, a CH sen- sor node was elected by examining the statistical distance among the candidate sensor nodes to the sink and also by considering the remaining energy of the sensor nodes in the WSN. However, the routing protocol attained high performance, even though it cannot examine several fea- tures utilizing various scenarios and constrictions, such as compression techniques, encoding, multi-levels communications, difficult clustering models, and QoS alert mechanisms. M.

Natarajan et al. [42] have suggested an Energy-aware Optimal CH selection approach using LEACH and PSO for WSNs. The election of a CH utilizing the PSO reduced the intra-cluster distance among cluster group and the CH, and also, reduced the inflation of energy-efficient management of the sensor network. Therefore, it seems that this approach prolonged the lifetime of the network by minimizing the overall energy loss in the network.

3.1 Advantages of LEACH based CH selection techniques

- The load balance is distributed among sensor nodes in these techniques.
- LEACH based techniques avert CHs from redundant conflicts and also, avoid much energy dissipation.

4. Hierarchical based CH selection techniques

Hierarchical clustering is a part of nested groups that were effectively structured as a tree. Accordingly, different tech- niques, such as hierarchical energy-balancing multipath (HEBM) routing protocol, energy-efficient hierarchical routing algorithm, and so on, are described as given below, Gherbi et al. [43] have presented HEBM for WSN. The purpose of this protocol was to attain the balanced cluster size effectively for extensive WSNs.

It accessed the clusters by reducing the topology of energy loss and increased the quality of service (QoS) features, such as error rate, throughput, and delay data rate, based on routing techniques for multi-hop WSNs. This technique has the advantage of reducing the routing control communications, and so, it was securely managed from an energy-efficient viewpoint. The main challenge of this method is that the HEBM method cannot concentrate on the variation of sensor exploita- tion environments with mobility node to accumulate the energy-efficient model.

Shankar et al. [44] have developed an energy-efficient hierarchical routing algorithm based on clustering techniques. The CHs were selected to transmit the data to the sink based on the indication of transmitted energy through a minimum distance. This method maximized both the lifespan of the network and the energy efficiently with the help of the nodes. This algorithm cannot evaluate the next phase hierarchy in the network, and also, it cannot con- sider the improvement of network lifespan.

Biswas et al. [45] have presented an energy-efficient hierarchical routing protocol to extend the network lifes- pan of the network. Herein, the CH was elected based on the remaining energy, distance of the sensor node from the sink, and then, analyzed how the node was elected as the CH, etc. Accordingly, the protocol was used to identify the malicious sensor nodes in the WSN and avoid them from the appropriate CHs. Therefore, this method offered better performance regarding the extension of the network's life time, identical collection of sensor node as a CH.

A unique node cannot constantly elect the CH, which caused the rapid energy exhausting, and so, it led the network to shut down the sensor node. Thus, the network was detached. Bozorgi et al. [46] have developed an efficient hierarchical routing protocol, namely novel energy efficient clustering (NEEC) method, based on energy harvesting and clustering from the network environment. The NEEC method showed the stability of virtual network and the enhancement of energy efficiency in the sensor nodes. The protocol balanced the energy loss in the sensor network and maximized the possi- ble number of restored data packets in the BS. Moreover, the NEEC has a lower amount of network failure, while trans- mitting the data packets in the sensor networks.

Gautam et al. [47] have presented distance aware intel- ligent clustering (DAIC) protocol based on the hierarchical routing protocol, for prolonging the energy-efficient routing in WSN. As a result, the DAIC technique has modified a routing protocol for improving the energy sensitivity in the applications of WSN. A substantial amount of energy was preserved by verifying the optimum solution of CHs enthusi- astically based on the sufficient number of alive nodes in the sensor network to avoid the redundant selection of a large number of CHs, but still, a huge number of sensor nodes were dead. Watfa et al. [48] have suggested battery aware reliable clustering (BARC) technique that integrated several characteristics, which was misplaced in various clustering techniques. It rotated the CHs by the battery recovery model, and also, it integrated a confidence factor for electing the CHs to maximize the reliability power. The BARC technique is not suitable for integrating the battery representation in a routing technique.

4.1. Advantages of hierarchical based CH selection techniques

- These methods are applicable for large area networks, and the energy loss is low.
- There is no postulation on the number of clusters because any possible number of clusters can be established to minimize energy consumption.
- The technique embeds the flexibleness in terms of the granularity level.

5. Distributed CH selection techniques

This section elaborates some of the distributed methods, such as sleep-awake energy-efficient distributed (SEED) clustering protocol, distributed energy-efficient heterogeneous clustering (DEEHC), energy-aware distributed unequal clustering protocol (EADUC), and distributed cluster head scheduling (DCHS), used for energy-aware CH selection as follows, Ahmed et al. [49] have developed the SEED protocol for heterogeneous WSNs. Each node had selected the CH independently based on its residual energy in the clustering technique. The sub clustering was initiated to tackle the issues of a frequent number of communications near the sink to accumulate the available power.

Therefore, the SEED protocol has limited control to select the optimal number of CHs along with the requirement. Moreover, the SEED protocol cannot consider the energy harvesting system to maximize network lifespan. Chanak et al. [50] have suggested DEEHC method based on the data routing method, which was more progressive for the failure of the network. The CHs had com- bined the entire data packets and transmitted the combined data packets to the sink through the displaced routes. The DEEHC method endured the possible number of network loss during the lifetime of network and maximized the QoS for the extended WSN. However, the data routing method has time complication.
Gupta et al. [51] have designed EADUC method, which was deployed to maximize the lifetime of WSN. The cluster formation was unequal in size with

unequal event radius. Thus, the energy loss between the CHs nodes was efficiently balanced. Additionally, the selection procedure was used for forwarding the data packets toward the sink regarding the energy consumption of the transmitter node. The method illustrated that the lifetime of the network was increased resourcefully and it resolved the problem of hot spot or energy hole in data congregation networks.

Kannan et al. [52] have presented the DCHS technique, for maximizing the network lifespan in WSN by isolating the network into primary and secondary tiers. The two tiers were based on the strength of the external signal of nodes from the sink. The DCHS techniques fulfilled the best distribution model of the CH between the nodes and distracted the repeated CH selection based on received signal strength indication (RSSI) and remaining energy level of the nodes. As a result, the DCHS techniques had attained better data delivery, less energy dissipation, and increased the lifetime of the network for the applications of energy sensitivity in WSN.

5.1 Advantages of distributed techniques

- The distributed CH selection techniques consistently distribute and balance the load data in the cluster.
- They offer higher energy scalability and efficiency.

6 Other techniques for CH selection

Other techniques for CH selection include energy-based CH unequal clustering algorithm using dual sink (ECH- DUAL), energy-efficient event driven hybrid routing proto- col (EDHRP), region-based energy-aware clustering (REC), energy balancing unequal clustering method for gradient- based routing (EBCAG), etc., as explained below.

Alagirisamy et al. [8] have developed a routing protocol, called ECH-DUAL, for transmitting the efficient data in the applications of a constant monitoring system. It minimized the hot spot problem and utilized the sensors node to maximize the lifetime of network and to minimize the energy loss in the network. The major challenges of this method were that the residual energy was different regarding net- work lifespan, energy level, and data transmission range for each sensor node. Faheem et al. [53] have suggested EDHRP to maintain the sensing, clustering, and routing problems, in the WSNs. The routing protocol achieved the performance concerning set up robustness, end-to-end inter- ruption, unnecessary data, energy efficiency, and congestion control. EDHRP is not suitable to improve the performance with difficult, and varied scenarios of WSN that includes the capabilities of various nodes to exhibit the strength of the method regarding several performance measurements.

Leu et al. [54] have designed the REAC-IN protocol for WSNs, which maximized the performance of CH selection and resolved the issues of node segregation. The method explored that the performance of the techniques employed in REAC-IN was to maximize the network lifespan and network stability. The high inconsistency designated that the overall energy of the sensor network has not correctly signified the importance of the overall network. Thakkar et al. [55] have presented Energy Delay Index for Trade- off (EDIT) routing technique, to optimize the delay and the energy objectives. EDIT was employed to elect the next hop and CHs by examining the requirements, like the delay or the energy of a specified application. This method cannot investigate the delay and the energy by executing it on an actual testbed.

Hasbullah et al. [56] have developed an energy-efficient forwarding protocol, namely REC, in WSN based on clus- tering technique. The REC was useful for maximizing the network lifespan, and QoS parameters. This method is not designed to expand the simulation parameters before con- sidering more contradicting scenarios, for instance, the mobile sink, fault tolerance, and impact of aggregation, etc. Liu et al. [57] have designed EBCAG method in WSNs, intended to attain the energy efficiency between CHs, minimizing the total energy loss of a sensor network, and maximizing the network lifetime. EBCAG was based on the WSN with consistent distribution. However, in few of the existent applications, the consistent sensor distribution method is not practically or precisely realistic.

III. RESEARCH GAPS IDENTIFIED

In this section, a few of the challenges in the existing CH selection techniques are described. While analyzing the traditional methods, there were several challenges that the researchers could not manage. In the existing review, sev- eral CH selection techniques based on partitional cluster- ing, optimization, LEACH, hierarchical, distributed and so on, have been elucidated. In general, these traditional approaches could not maintain the structure properly to reduce the energy loss and to maximize the lifetime of the network in the sensor nodes.

The partitional clustering-based CH selection includes various algorithms as mentioned above, to reduce the energy loss and to prolong the life of the network. The partitional cluster-based algorithms can be dependent on the user to identify the possible number of clusters in advance and also, it has huge sensitivity for the starting phase, outliers, and noise. It fails to deal with inconsistent clusters for altering the density and size. Therefore, these algorithms are imprac- tical in the real-world sensor network. The main impact of the method in [1, 3, and 13] is that the method cannot be stable in the trends of energy loss because the behavior of the network energy loss is easily predictable. The method introduced in [12] is not suitable for preliminary clustering to minimize the computation time. The clustering algorithm in [13] is not suitable for the original application of WSNs. In [15], the lesser energy sensor nodes limited the lifetime of the networks, and so, the energy of higher energy sensor nodes was exhausted in the heterogeneous scenarios. The method presented in [16] has not examined the features of fault tolerance and active scenario of the WSN. The sensor node distribution in [17] has not improved the entire lifetime of the network [17].

The optimization-based CH selection is the second type, which was employed to select the efficient optimal solution within the given aspects, but when examining and apply- ing these methods in the research papers, various contra- dicting problems make those methods inappropriate in the real-world environment. The optimization problems are considered using various techniques to tackle the problems regarding an early-stage problem. They rely on energy con- sumption to maximize the lifespan of the network. However, these techniques are unsuitable in the sensor network. The method in [21] cannot handle the routing protocols, which integrated the clustering model. The major challenges in the hybrid algorithm are the standard variation of the remain- ing energy for different BS positions, and a large number of sensor nodes indicated that the difference is low in hybrid HSA-PSO [23].

The technique [7] cannot consider problems, like fault tolerance and energy balancing. The algorithm [28] is not suitable to execute the actual testbed of sensor nodes with the application of specific domain in the network environment. Because of the uncomplicated radio propagation model [34], it has not been precise enough and diverges a modest change from the real environment because of the uncomplicated radio propagation model. The method in [36] is not appropriate for implementing the sensor nodes in the highest dimensional region and also it could not concentrate on the application of PSO in the heterogeneous networks.

The LEACH based CH selection techniques provide vari- ous LEACH based methods, but it cannot be utilized in sen- sor networks, which transmit through long distances. Hence, these techniques cannot be effectively applied in large scale sensor networks. While applying the LEACH approaches in the sensor network, the consistent CH distribution can- not be guaranteed. The concept of dynamic clustering pro- longs their fixed cost as high. Even though the CH selection based on LEACH approach avoids energy dissipation, the energy loss is not unbiased. However, the performance of the CH selection using LEACH based approach is better than the optimization-based techniques.

The method introduced in [1] is not suitable for enlarging the number of CHs to maintain the sensor mobility nodes in the maximum top- ological fields. The method [38] has not offered the data security and privacy to the WSN in real-world data. Even though LEACH-SWDN [39] maximized the network load balancing, as the sensor nodes distribute the information of residual energy, it has a slight impact on the entire network. Meanwhile, the hierarchical based CH selection technique has recommended the solutions depending on their decision. The performance of the hierarchical based CH selection is better than that in the LEACH approach, but they have not integrated the battery model in the routing technique, and they cannot gain energy conservation with the fault tolerance capabilities for the sensor environment. It is very costly for massive and high dimensional datasets. The main challenge in [43] is that the HEBM method cannot concentrate on the variation of sensor exploitation environments with mobility node to accumulate the energy-efficient mode.

The algorithm in [44] cannot evaluate the next phase hierarchy in the network, and also, it cannot consider the improvement of network lifespan. In [45], a unique node cannot constantly elect the CH, which caused the rapid energy exhausting, and so, it led the network to shut down the sensor node. Thus, the network was detached. The NEEC [46] has a lower amount of network failure while transmitting the data packets in the sensor networks. The BARC technique [48] is not suit- able for integrating the battery representation in a routing technique. To overcome such problems, distributed based CH selec- tion techniques are designed.

The most important challenge of distributed based CH selection techniques is that the technique is less energy- efficient and has maximum control transmission over- heads. However, for realistic applications, this technique is less effective in minimizing energy loss and prolonging the life of the network. The distributed based CH selection techniques can provide correct results regarding the network lifetime, alive nodes, dead nodes, network through put, energy consumption, packet drop rate, and network stability period, but they have difficulties in analyzing and classifying an effective single-hop inter transmissions in the sensor network.

Therefore, it is examined that the techniques presented here are not effective and requires more effective protocols that are energy-efficient, sensi- ble, constant, and scalable, without much complications in the algorithms for CH selection in WSNs. Moreover, the SEED protocol [49] cannot consider the energy harvest- ing system to maximize the network lifespan. In DEEHC method [50], the data routing method has time complica- tion [50].

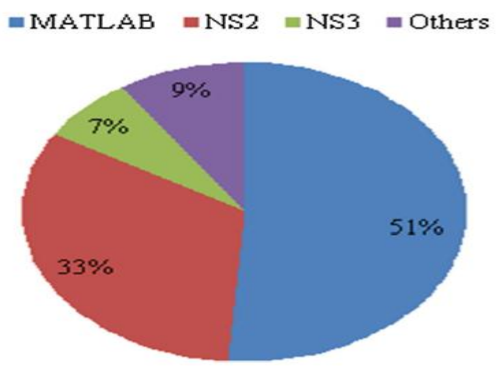

Fig. 3 Analysis based on the tools used for the implementation.

IV. ANALYSIS AND DISCUSSION

This section describes the analysis of the review papers based on the following phases, such as the tools employed for the implementation, evaluation metrics, and accuracy ranges.

1. Based on implementation tool

From the above review, it is examined that the existing works are executed on several platforms. The implementation section supports the researches how to design, and imple- ment the results effectively on the specific platform. From Fig. 3, it is examined that many of the research scholars have effectively executed their research on the platform of MAT- LAB. MATLAB is employed in 51% of the research papers, whereas NS2 simulator is utilized in 33% of the research papers. The remaining researches, i.e., 9%, are implemented in various kinds of platforms like dot net, JAVA, etc.

2. Based on evaluation metrics

Herein, several metrics employed for the performance evalu- ation are taken from the 50 research papers and are repre- sented using a pie chart in Fig. 4. The evaluation metrics examined for the analysis are energy consumption, residual energy, network lifetime, number of alive nodes, number of dead nodes, number of cluster heads, network throughput, number of packets send and received, and network stability period. Nearly 22% of the research papers employed energy consumption as the evaluation metric, while 21% of the research papers employed network lifetime as the perfor- mance metric. 14% of the research papers have employed the number of alive nodes as the metric for the performance evaluation. 10% of the research papers have considered the number of dead nodes, and the number of papers that employ other metrics ranges from 3 to 9%.

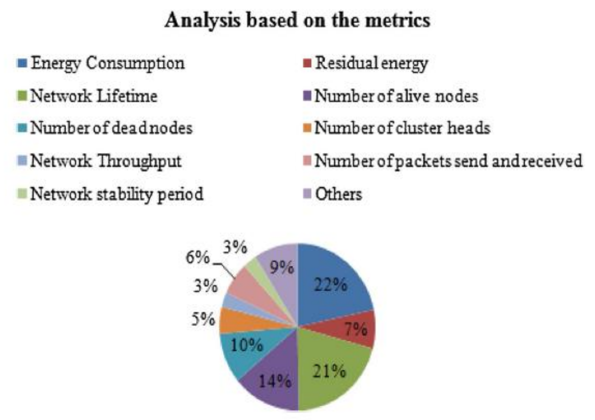

Fig. 4 Analysis based on the metrics.

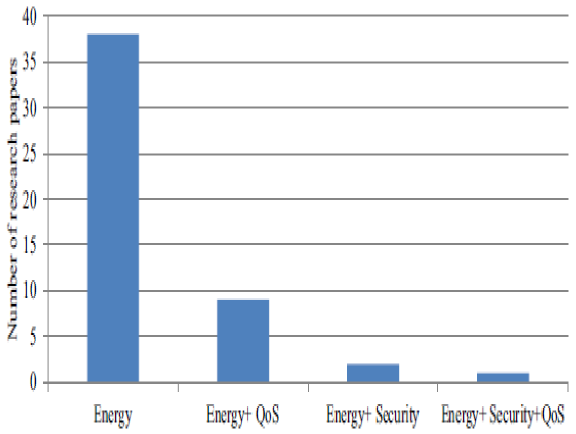

Fig. 5 Analysis based on energy, QoS, and security.

Table 1 Analysis based on network lifetime improvement

Network lifetime range	Research paper
10-30%	[3,13,16,19,40,51]
30-50%	[30,43,54]
50-90%	[14,15,28,31,37]

Table 2 Analysis based on energy consumption.

Energy Consmption range	Research paper
5-40%	[42,52,57]
30-50%	[4,21]
50-85%	[23,47]

3. Based on the combination of energy with other metrics

In this section, the number of research papers that employ different combinations of energy with other metrics, like QoS and Security, is discussed using Fig. 5. It is clear that most of the research papers, i.e. nearly 38 papers have imple- mented their work utilizing energy as the only parameter for CH selection. Nearly nine of the research papers have utilized energy together with QoS for the selection of CHs. Two research papers have considered both the energy as well as the security as the selection parameter to form the CH. Only one paper has utilized all the three considered metrics, such as energy, QoS, and security, for the CH selection.

4. Based on network lifetime and energy consumption

Network lifetime and Energy consumption play major roles in analyzing performance. Table 1 explains analysis based on various ranges of network lifetime improved in the papers reviewed. The improvement in the network lifetime attained by each paper is arranged in different ranges as 10–30%, 30–50%, 50–90%. Six research papers have improved the network lifetime in the range of 10–30%, and three papers made the network lifetime improvement in the range between 30 and 50%. Improvement in the network lifetime made in five research papers is in the range 50–90%. Table 2 shows the analysis based on reduction in the energy consumed by different techniques in each research papers surveyed. As shown in Table 2, nearly three research papers have reduced energy consumption in the range of 5–40%. Two of the research papers had achieved a reduction in energy consumption from 30 to 50%. The papers [23] and [47] had reduced the energy utility from 50 to 80%.

V. CONCLUSIONS

Inadequate energy of the sensor node is a widespread chal- lenge for designing the WSN. If suitable CH selection approaches are implemented, then there is significant growth in network lifespan. This paper explored several CH selec- tion methods. The main purpose of this study is to analyze several CH selection techniques based on energy awareness in WSN. Here, we have selected 50 research papers for the survey from various locations, such as IEEE, Science Direct, Springer, and Google scholar. Also, this survey provides a fundamental awareness of CH routing protocols. A hierarchy is provided for the classification of various CH selection techniques based on several features that permit the association of several systems employed to reduce the energy consumption in WSN, labeling the merits and demerits of each CH selection approach. In this survey, different CH selection protocols are described with their strategies of CH selection.

Then, the research gaps identified in each method, for optimizing the CH selection techniques, are presented so that it will be helpful for further research on the CH selection techniques. Moreover, an analysis is done based on the tools used for the implementation and performance evaluation according to their clustering method, energy efficiency, network lifetime, scalability, number of alive and dead nodes, energy consumption, residual energy, and so on.

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