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Review Article

Mitigating Hotspot Issues in Heterogeneous Wireless Sensor Networks

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Wireless Sensor Networks (WSNs) consist of a spatially distributed set of autonomous connected sensor nodes. The deployed sensor nodes are extensively used for sensing and monitoring for environmental surveillance, military operations, transportation monitoring, and healthcare monitoring. The sensor nodes in these networks have limited resources in terms of battery, storage, and processing. In some scenarios, the sensor nodes are deployed closer to the base station and responsible to forward their own and neighbor nodes' data towards the base station and depleted energy. This issue is called a hotspot in the network. Hotspot issues mainly appear in those locations where traffic load is more on the sensor nodes. The dynamic and unequal clustering techniques have been used and mitigate the hotspot issues. However, with few benefits, these solutions have suffered from coverage overhead, network connection issues, unbalanced energy utilization among the sink nodes, and network stability issues. In this paper, a comprehensive review of various equal clustering, unequal clustering, and hybrid clustering approaches with their clustering attributes is presented to mitigate hotspot issues in heterogeneous WSNs by using various parameters such as cluster head selection, number of clusters, zone formation, transmission, and routing parameters. This review provides a detailed platform for new researchers to explore the new and novel solutions to solve the hotspot issues in these networks.

1. Introduction

Wireless Sensor Networks (WSNs) are developed for sensing and monitoring vital signs of the environment and area by using distributed and connected sensor nodes. The sensor nodes are further classified into normal nodes, sink nodes (SNs), and Gateway Nodes (GN). The sensor nodes are tiny in size and have inadequate resources in terms of energy, processing, and storage space [1–3]. In most cases, the sensor nodes are deployed in a very intense and harsh environment [4, 5]. The main objective of this deployment is to sense the data remotely and forward it to the end-user or system for decision-making. For data forwarding, there is a need for more efficient mechanisms to manage the node's energy system and improve the network lifetime [6].

The sensor nodes are sensing and perceiving the information from the surrounding environment and process and transmit it to the closest node till the data reached the base station (BS) [7]. In WSN, due to the limited energy resources of sensor nodes, there is an essential requirement of well-efficient and balanced data aggregation mechanism and energy-efficient routing protocols [8]. The energy factor is always one of the considerable factors to design any solution for WSNs [9, 10]. Several types of routing protocols have been proposed to conserve the sensor nodes' energy [7, 11, 12]. The clustering technique is an efficient topological control mechanism that can effectively improve the scalability period and lifespan of WSNs [10]. The WSN applications have gained popularity including target tracking [13, 14], environmental monitoring [8], security [15–19], disaster response [5], and health monitoring [20, 21].

In a clustering environment, the data is engaged from one node to another node and causes hotspots or energy hole problems. A hotspot is caused by the node deployed closest to the BS and quickly drains its energy due to traffic coming from other nodes and forwarded from it. These sensor nodes do not only send their data but also transmit the data from other sources due to which early death of nodes causes hotspot issues. In this paper, Heterogeneous Wireless Sensor Networks (HWSN) are discussed in terms of network lifetime primarily based on hotspot issues [22]. Figure 1 shows the architecture of WSN.

The other objectives of this paper are as follows.

Clustering is the most popular energy-efficient technique and has proven benefits, but it also suffered from hotspot issues.

(i) The absence of current and detailed survey articles on hotspot approaches motivated us to accomplish this research. To the best of our knowledge, this is the only review performed on hotspot issues

(ii) First, we introduce a detailed classification of HWSN considering all the foremost characteristics of clustering algorithms, which includes types of clustering protocol, clustering design process, and data transmission for general understanding of clustering algorithms

(iii) Secondly, an assessment of the clustering protocols is executed and highlights the hotspot issues based on equal, unequal, and hybrid cluster size, considering all the design and data transmission aspects of the protocols, i.e., cluster size, CH selection, data transmission, data aggregation, type of clustering, and zones

The rest of the paper is organized as follows: Section 2 presents the introduction to clustering. Section 3 presents the clustering attribute classification. Section 4 addresses the hotspot issue and classification of protocols based on equal, unequal, and hybrid clustering protocols. The last section concludes the paper with a future direction.

2. Clustering in WSN

In WSNs, clustering refers to the division of nodes into groups based on some characteristics. Clusters could be formed based on residual energy [23], location [7], and network topology. Normally, a node that takes more responsibilities is called the CH. The CH formation techniques are distributed [8] or centralized [23] in WSNs. In the former techniques, every node broadcasts information (residual energy) to the one-hop neighbor, and eventually, the node with greater value becomes CH. In the latter techniques, every node is responsible for sharing information back to BS which does computation and selects CHs in the network. BS then informs all the nodes about their respective CHs.

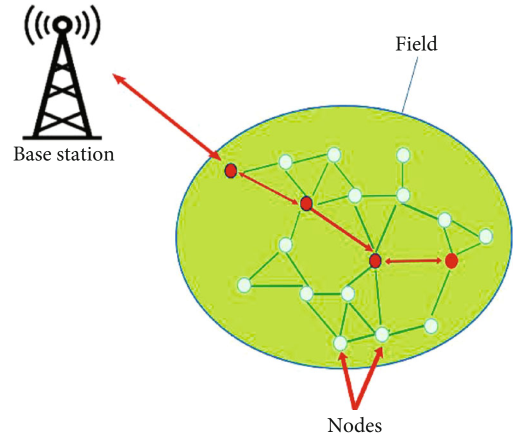

Figure 1: Wireless Sensor Network architecture [7].

WSN is comprised of nested clusters in a supercluster. CHs in small clusters gather data from sensor nodes and forward to super CH in a hierarchy. By using this way, the network works in a multihop fashion, and the role of the node as CH is rotated in a cluster, depending on the hierarchy.

After deployment of the sensor nodes in the network, there are normally two ways to transmit sensed data to the BS. First is direct communication or single-hop [8] between the sensor nodes and the BS. This consumes more energy of the sensor node and shortens the network lifetime. The second one is multihop communication [23], in which the sensor node forwards the data to another nearby node that is comparatively nearer to the BS. The nodes near the BS always serve as intermediate nodes, creating energy holes, which is a problem in WSN when a node cannot find the next forwarder node for multihop communication. Figure 2 shows the clustering process in WSNs.

2.1. Why Clustering Is Needed? The clustering mechanism provides a hierarchal grouping of the sensor nodes and provides scalability, efficiency, and collaboration in the network. It is a promising approach which not only decreases the total number of transmissions required towards BS but also saves energy in the clusters [10], because CHs aggregate data from its cluster members and forward it to BS. Furthermore, maintenance costs are incurred by dynamic topology after using the clustering technique. Reconfiguration is normally done on the CH level where the remaining cluster nodes are not affected. In short, clustering achieves the following objectives:

(i) Better utilization of resources

(ii) Scalability improvements

The network life can be enhanced to a greater extent if utilizing the network energy uniformly.

3. Clustering Attribute Classification

The categorization of cluster protocols is based on various clustering mechanisms, clustering types, and cluster design processes.

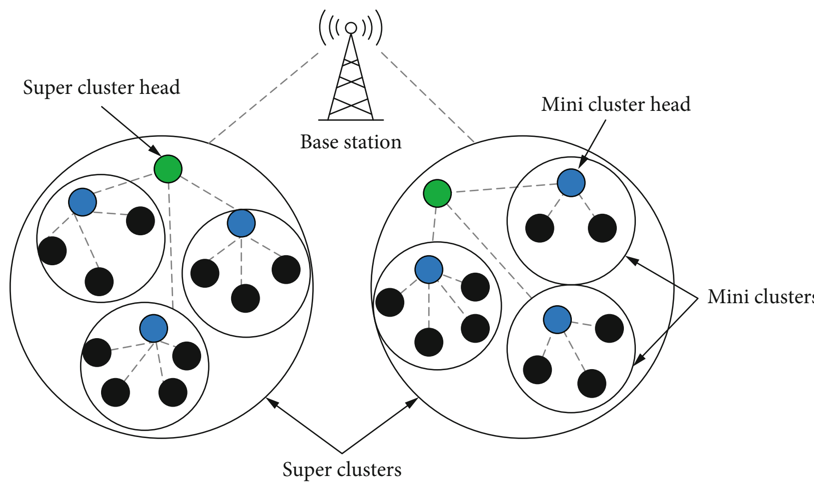

Figure 2: Clustering in WSNs [24].

3.1. Clustering Mechanism. Topology control is one of the most significant issues in ad hoc networks due to the massive number of sensor nodes and the inconsistency of the network infrastructure. In ad hoc networks, topology management strategies, choosing appropriate neighbors to establish links, and selecting the optimal neighbors for hop-by-hop data delivery are vital to enhancing scalability, resource utilization, and stability [25]. The clustering mechanism [10] is one of the most vital solutions which has been developed and proposed by a lot of researchers in WSNs. To enhance the network lifespan and network stability, the clustering technique is improving resource utilization. The clustering mechanism can manage and organized the network system into a set of clusters for topological control. Figure 3 shows the clustering protocol classification.

3.2. Clustering Types. The clustering protocols are divided into two types including homogenous [26] and heterogeneous [27]. In the former, all network nodes have the same initial energy while in the latter, network nodes are equipped with different initial energy levels. In the homogenous type of clustering, the network nodes have the same initial energy, processing capabilities, and sensing range. The homogenous networks require high hardware costs. To overcome the limitation of homogenous networks, heterogeneous networks are proposed in which two types of sensor nodes are introduced. Generally, the heterogeneous network has two types of nodes having different energy levels termed as high energy or advanced nodes and low energy or normal nodes. The advanced nodes have maximum energy than the normal nodes. Depending on node heterogeneity, the heterogeneous network can be classified into two-tier or multi-tier heterogeneous networks.

3.3. Clustering Design Process. The clustering process in WSN maximizes the network lifetime, and it is mainly due to the whole network being partitioned into different clusters and each set of a cluster-defined set of nodes. The cluster formation process and the number of clusters are very important factors in clustering protocols. The clusters should be well balanced, and the number of messages exchanged during cluster formation should be minimized. The complexity of the algorithm should increase linearly when the network grows. CH selection is another important challenge that directly affects network performance. The best possible node should be selected so that the network stability period and overall network lifetime should be maximized [27]. The clustering process is divided into three steps, i.e., CH selection, cluster formation, and data transmission [27].

3.3.1. Cluster Head Selection. As CH is primarily used for aggregating and distributing the information to the SN, CH selection plays a very crucial part in optimizing energy consumption. However, the appropriate CH selection enhances the network lifetime. In a cluster-based network, CH near the BS quickly exhausts its energy, which leads to hotspot problems. Unequal clustering algorithms are utilized [28] to overcome this problem. The CH selection is based on various parameters such as probability [29], distance [30], residual energy [23], RSSI [31], cluster density [32], node degree [33], initial energy [34], threshold [35], and hybrid method [36]. The energy utilization of the CH is more extensive as compared to the normal sensor nodes. After the CH selection, nodes joined their CH based on the minimum distance forming a cluster. Figure 4 shows the clustering design process.

3.3.2. Cluster Formation. The cluster formation can be classified into two categories, centralization by the BS or distributive by the nodes themselves [37]. The clustering algorithm uses the network's global knowledge in centralized approaches, while in distributed approaches, local knowledge is used to create clusters. In the distributive approach, the CHs declare their selection to the network nodes by broadcasting advertisement messages where each network node responds by sending a join message to the CH. Each type of cluster comprises a cluster member (CM), and each cluster has a leader whose task is to transmit the data to the other neighbor nodes or BS. The cluster size can be equal, unequal, or hybrid. After the cluster formation, the

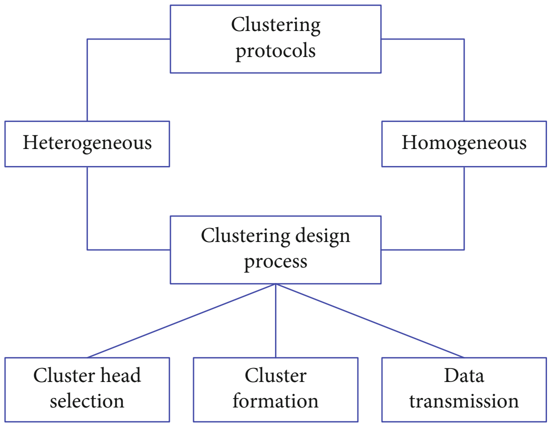

FIGURE 3: Clustering protocol classification [26, 27].

CH receives the data from the CM, and after, the data aggregation/fusion process forwards the data to the BS via single or multihop transmission for the end-user processing.

3.3.3. Data Transmission. In the clustering technique, both communication models such as single [8] and multihop [23] communication, chain-based [38], or tree-based [39] have unavoidable energy dissipation among the cluster members. This situation arises when some sensor nodes die permanently and hence reduces the lifespan of the network. In clustering protocols, the energy depletion of the sensor nodes which are deployed near to the BS is higher as compared to other nodes, which leads to a hotspot problem [40] or energy hole problem. Due to this hotspot problem, a set of data is forwarded to the BS and collapse the complete network system. Experiment results in [26] indicated the vital information that over ninety percent (90%) of the energy of the whole network remains unutilized if the lifetime of the network is dropped out due to the hotspot issues.

4. Hotspot Issue

The hotspot problem [40] degrades the network transmission. Transmission is interrupted because the number of nodes drains out their energy due to the excess of transmission from that nodes. To alleviate the hotspot issue, many authors have discussed the energy imbalance issue by implementing the unequal type of clustering techniques. Most of the dynamic unequal cluster techniques improve the hotspot issues, but they have also a lot of other issues like overhead along with coverage, connectivity, and network stability issues. So, static or equal clustering [41] technique is used, and this technique can consume a minimal amount of energy and less overhead. But static clustering techniques also have issues while mitigating hotspot and balancing the energy utilization among the SNs. The number of clusters in a zone is the main issue in the static clustering technique while mitigating the hotspot problem increases the lifetime and the network. Increasing the cluster size makes the node closest to the BS deplete their energy fast and causes hotspot issues. A decrease in cluster size increases the intracluster communication cost where nodes die due to excess communication and the cause of hotspot issues. Figure 5 shows the classification of protocols.

In this paper, we present some parameters of architectures and investigate the hotspot issues. Conducting research based on eliminating hotspot or energy hole issues, we classified protocols according to different clustering techniques including equal [41], unequal [28], and hybrid [36]. In equal clustering, the size of the clusters is consistent throughout the network. Conversely, in unequal clustering, the size of clusters differs throughout the network based on the distance to the BS.

4.1. Equal/Static Clustering Protocols. In this section, equal clustering protocols are discussed whereas Table 1 summarizes static protocols and their performance parameters and comparison.

4.1.1. HUCL. The HUCL [42] protocol comprises both dynamic and unequal clustering static and equal clustering. In this protocol, CHs are nominated based on the principle of residual energy, distance from the BS, and the number of engaged SMS. To avoid the overhead in the network, the set of data transmission stages consists of major slots, and slots are partitioned into several minor slots, and each set of minor slots has sets of CMs, which forward the data to the CH. This CH sends the aggregated data to the BS, and each major slot consists of a new CH, and also, the current CH informs the new CH about its sensor nodes and all information in the transmission phase.

4.1.2. EADUC. An efficient clustering protocol for elevating hotspot or energy hole issues is discussed in [43], in which the authors proposed the protocol called Energy-Aware Distributed Unequal Clustering (EADUC). This protocol elects the CH on the principle of average residual energy of the surrounding sensor nodes and the residual energy of the SN itself. It developed a cluster of uneven sizes to mitigate the hotspot issues. The CH which is closest to the BS has a smaller number of clusters which are used to efficiently balance the energy consumption and make the network energy preserved for intercluster communication.

4.1.3. IEADUC. In [44], the authors proposed an Improved Energy-Aware Distributed Unequal Clustering protocol (IEADUC) as an improved version of [43]. In IEADUC, one step is included when electing CH, and that is considering the neighbor nodes. In this protocol, the selection of the next hop for data forwarding the Relay Node (RN) is used. The RN can formulate the set of tables that consists of energy utilization of nodes instead of location and distance information used in the EADUC protocol.

4.1.4. ZECR. In [45], the authors proposed a protocol called Zone divided and Energy Balanced Clustering Routing protocol (ZECR). This algorithm partitions the area into several types of zones and uses unequal clustering techniques to alleviate the hotspot issues. These types of hotspot issues are produced by the nodes which are closer to the BS and send the data passing through it. Due to this factor, nodes

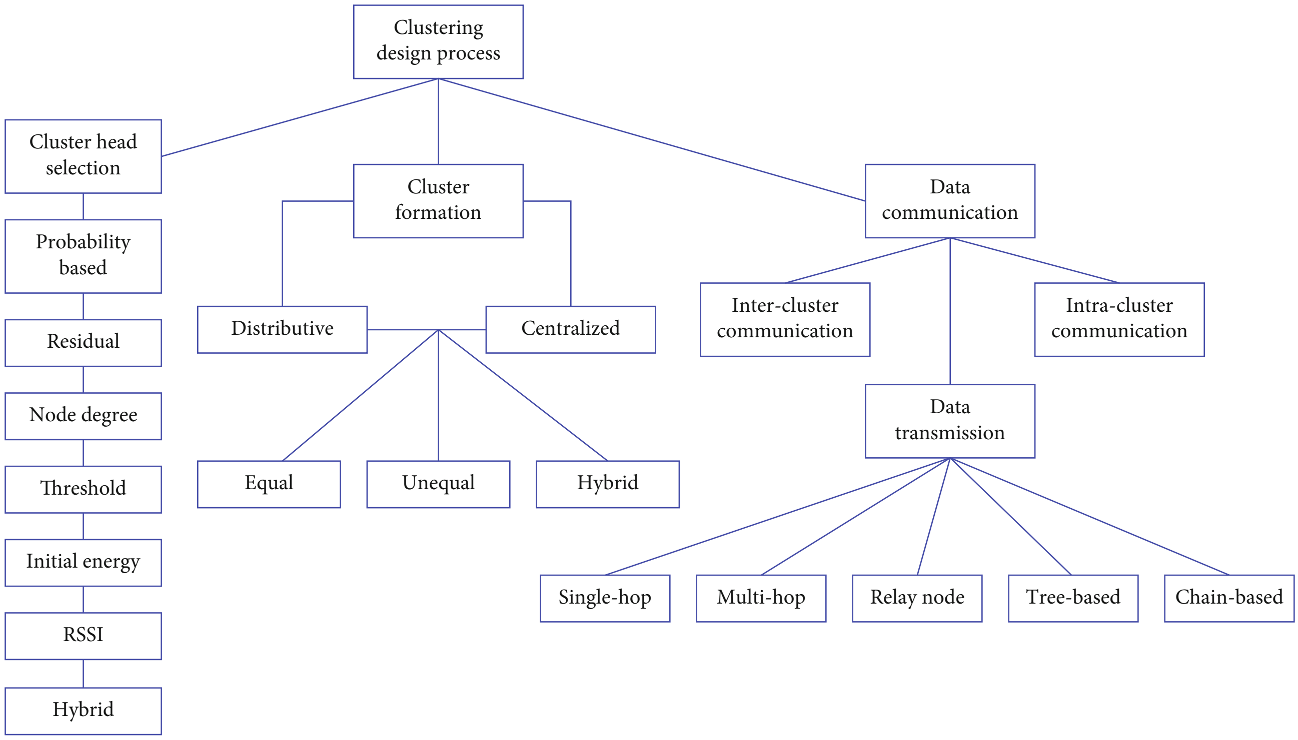

FIGURE 4: Clustering design process [23, 29–36].

deplete their energy faster and created hotspot issues. The technique of CH selection is based on the principle where the nodes can only be selected as a CH that has an energy that is defined in the protocol. The energy should be equal to the respective standard defined in the protocol. RN for intercluster communication is selected based on high residual energy, and data is transferred to the BS efficiently.

4.1.5. IEEUC. In [46], the authors proposed Improved Energy-Efficient Unequal Clustering (IEEUC). The IEEUC protocol is the improved and extended version of the EEUC protocol [33], which does not only depend upon the physical orientation of the SNs but also depend upon the distance of the SNs to the BS. The number of clusters closest to the BS has a small size and preserves more energy in contrast to the cluster far away from the BS.

4.1.6. LUCA. In [47], the authors proposed a Location-based Unequal Clustering Algorithm (LUCA). In this protocol, there is an unequal cluster mechanism that is established based on the location factor. Due to this location factor, the clusters are changed, respectively. The cluster size in the protocol changes concerning the distance of the SNs from the BS. This protocol forms the smaller clusters close to the BS to preserve the energy and balances the energy among the sensor nodes whereas the larger clusters are distant from the BS and the whole process is done to alleviate the hotspot issues.

4.1.7. EBCAG. An efficient clustering protocol called Energy Balancing Unequal Clustering Approach for Gradient-based routing (EBCAG) using gradient-based routing for eliminating the hotspot issue is discussed in [48]. The protocol divided the nodes into an unequal set of clusters where each set of SNs can preserve a gradient value. The gradient value in the protocol is set to be formulated as the minimum number of hops to BS. The size of the cluster in this protocol is depending on the set of gradient values of the CH of respective clusters. The selection of the CH is based on the principle that first a tentative CH is selected with a random probability of the nodes and becoming a CH. If a CH that is tentatively selected has maximum remaining energy, it is set to be updated as a final CH. The CH in an unequal clustering collects the data from the SNs of its respective clusters and sends the data to the BS on the descendent gradient of the CH.

4.1.8. EBUCP. In [49], the authors suggested an algorithm called the Energy Balanced Unequal Clustering Protocol (EBUCP). This algorithm confirms the nonexistence of isolated nodes for the formation of unequal clusters. This protocol consists of two steps, where in the first step the radius of the cluster is formulated. In the second step, the CH selection process is contained and provides the detail that there are no isolated nodes in the network system. The protocol is partitioned into a multilayer mechanism in which the circular area is divided into a set of multilayers. In these types of multilayers in circular rings, each layer has a balanced energy consumption mechanism.

4.1.9. Dynamic Unequal Clustering Protocol. In [50], the researchers proposed an energy-aware protocol called the dynamic unequal clustering protocol. The main purpose of this protocol is to avoid hotspot issues and prolong the

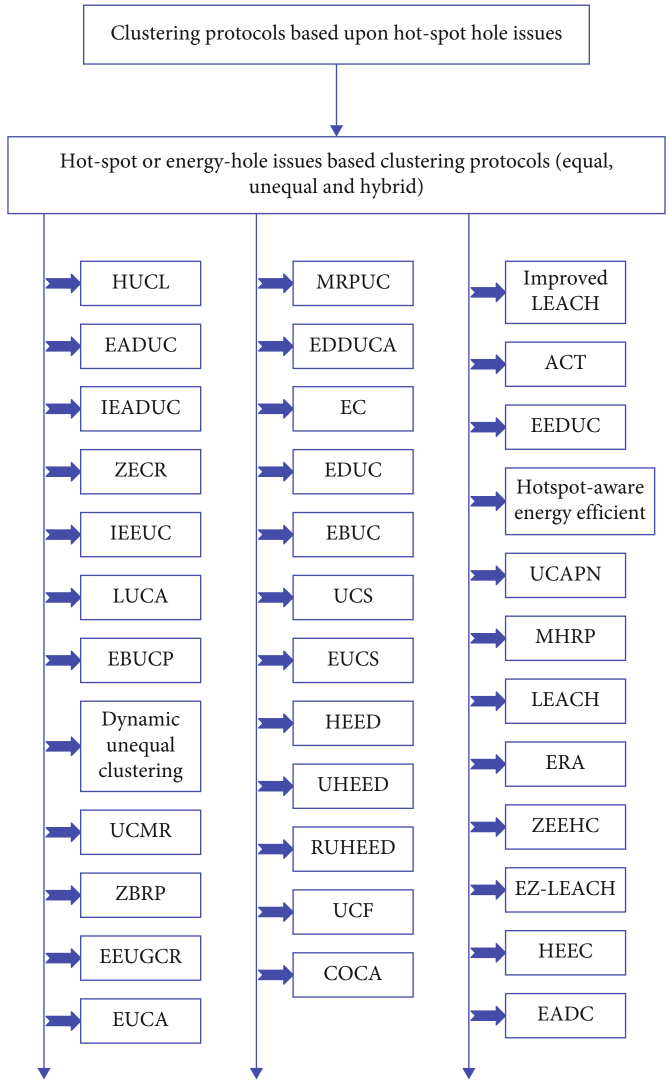

Figure 5: Classification of protocols.

network lifetime and network stability. In this protocol, the cluster size is variable. It means that unequal clustering is used for preserving the energy of the sensor nodes. In this protocol, the CH selection mechanism is based on the node's residual energy and the distance of the nodes to the BS. The CH nomination mechanism is established on the remaining energy and the distance of the nodes to the BS.

4.1.10. UCMR. In [51], the authors proposed a protocol called the Unequal Clustering Multihop Routing protocol (UCMR). In this protocol, each set of the cluster has different cluster sizes; this cluster size is grounded on its distance from the BS. This protocol reduces the hotspot or energy hole issues with the help of an unequal clustering process. In this protocol, the unequal clustering process manages the network with cluster sizes. The cluster near the BS has a small size to preserve energy as likened to the cluster which is distant away from the BS. Table 1 shows the comparison of the static protocol.

4.1.11. ZBRP. In [52], the authors proposed a protocol called the Zone-Based Routing Protocol (ZBRP). It consists of clustering technique and network space aspect to eliminate the hotspot issues. In this protocol, the CH selection is depending on the random back of time in each round. The set of nodes closer to the BS having higher residual energy and previously sending less data is selected as the RN. The protocol formulates uneven-sized clusters, and these types of clusters have very small overhead while considering the location information.

4.1.12. EEUGCR. In [53], the authors proposed a protocol called the Energy-Efficient Uneven Grid-based Clustering Routing protocol (EEUGCR). This protocol uses a centralized technique in which the BS is responsible for all types of tasks such as CH nomination, cluster establishment, and RN selection criteria. The BS in this protocol partitioned the entire network into a set of unequal-sized clusters. The cluster size is based on its distance from the BS. Greater

Table 1: Static protocols.

Sr. no.	Protocol	Data transmission	Node type	Clustering type	CH selection
1	HUCL	Multihop	Homogeneous	Hybrid clustering	Distance to the BS and adjacent nodes, energy
2	EADUC	Multihop	Heterogeneous	Unequal clustering	Deterministic
3	IEADUC	Multihop	Heterogeneous	Unequal clustering	Residual energy, surrounding nodes
4	ZECR	Multihop	Heterogeneous	Unequal clustering	Residual energy
5	IEEUC	Multihop	Homogeneous	Unequal clustering	Hybrid
6	LUCA	Multihop	Homogeneous	Unequal clustering	Random
7	EBCAG	Multihop	Homogeneous	Unequal clustering	Deterministic
8	EBUCP	Multihop	Heterogeneous	Unequal clustering	Remaining energy, average energy
9	Dynamic unequal clustering protocol	Multihop	Homogeneous	Unequal clustering	Remaining energy
10	UCMR	Multihop	Homogeneous	Unequal clustering	Deterministic
11	ZBRP	Multihop	Homogeneous	Hybrid clustering	Remaining energy
12	EEUGCR	Multihop	Homogeneous	Unequal clustering	Centrality factor
13	EUCA	Multihop	Homogeneous	Unequal clustering	Residual energy
14	MRPUC	Multihop	Homogeneous	Unequal clustering	Deterministic

distance from the BS increases the size of clusters, and closer to the BS decreases the size of the cluster for preserving more energy. Due to a lot of energy dissipation of the cluster near the BS, the grid clustering method is introduced where the hotspot issues are alleviated. In the end, data is sent to the most upper-level layer, and from this layer, data is sent to the BS through data mules.

4.1.13. EUCA. In [54], the authors suggested a protocol called the Enhanced Unequal Clustering Algorithm (EUCA) based on the UCA protocol. In this protocol, the authors have enhanced the UCA protocol to overcome the hotspot issue. The basic idea behind this solution is placing the BS closer to the clusters and BS nodes which are tiny in size placed far away from the clusters. This strategy enhances the network lifetime by consuming less energy in the network.

4.1.14. MRPUC. In [55], the authors proposed the protocol called Multihop Routing Protocol with Unequal Clustering (MRPUC). The main purpose of this protocol is to develop an unequal clustering technique to enhance the network lifetime and network stability. Nodes nearer the BS have a tiny cluster size to evade hotspot issues. The selection of CH is based on the node which has higher residual energy in the system. The number of clusters that are closest to the BS is kept small where they preserved the energy in intracluster communication and forward the packets for intercluster communication.

4.2. Unequal Clustering Protocol. In this section, unequal clustering protocols are discussed.

4.2.1. EDDUCA. In [56], the authors suggested a protocol called Energy Degree Distance-based Unequal Clustering (EDDUCA). CH election is centered on outstanding energy, the degree of the node, and the distance of the CH from the BS. This solution consists of an unequal clustering technique for preserving the energy of the nodes closer to the BS. Due to the unequal clustering mechanism, the size of the cluster closer to the BS is kept smaller as compared to the clusters which are far away from the BS.

4.2.2. EC. In [57], the authors presented a disseminated protocol called Energy-efficient Clustering (EC). This solution maintains the sizes of the clusters founded on the distance of the clusters from the BS. In this protocol, uncertain CHs are selected arbitrarily, and the concluding CH is selected based on the highest leftover energy. The intercluster routing protocol developed the balanced energy scenario and produces less amount of overhead due to the route discovery mechanism.

4.2.3. EDUC. In [58], the authors presented an Energy-Driven Unequal-based Clustering protocol (EDUC). The protocol consists of the unequal clustering method and CH rotation mechanism. In this solution, an unequal set of clustering methods is responsible for the balance of energy consumption among the nodes. The CH rotation mechanism is used for the dissipation of energy among the cluster nodes. The number of clusters that are contiguous to the BS has a smaller size and thus preserves the energy. While in another case, the clusters which are distant from the BS have a larger size.

4.2.4. EBUC. In [59], the authors proposed and evaluated an algorithm called the Energy Balance Unequal Clustering (EBUC). This algorithm consists of an unequal clustering technique that is most often used for periodic data collection. This protocol provides the mechanism in which the CH preserves more energy and avoided hotspot issues. This protocol adopts both inter- and intracluster routing. For intercluster routing, the CH can relay the data with the help of RN. This RN gathers the accumulated data from the CHs and relays this data to the BS.

4.2.5. UCS. In [60], the authors proposed a protocol called Unequal Clustering Size (UCS). The protocol provides the mechanism that CH nodes can completely adjust their location and the cluster size and the load balancing among different CHs should be managed properly.

4.2.6. EUCS. In [61], the authors presented an Enhanced Unequal Clustering (EUCS). In [61], the clusters which are closer to the BS have tiny cluster sizes as related to the clusters which are distant from the BS. The CH selection mechanism consists of the nodes which have the highest residual energy and also the distance of it from the BS, to balance the energy utilization between the SNs and the CH reelection mechanism. So, in this scheme, the CH reelection mechanism is initiated when the CH energy becomes less than the set threshold. Table 2 shows the static protocols, their performance parameters, and their comparison.

4.2.7. HEED. In [62], the authors proposed a Hybrid Energy-Efficient Distributed clustering (HEED). The HEED protocol uses a hybrid scheme for CH selection and comprises outstanding power of the nodes and the degree of the respected nodes in an equal clustering manner.

4.2.8. UHEED. In [63], the authors presented an algorithm called Unequal Clustering Hybrid Energy-Efficient Distributed (UHEED) based on [62]. This protocol can mitigate the hotspot issues and improve the energy utilization among the nodes and prolong the network lifespan and stability. In [63], the CH selection is based on the unequal size cluster mechanism. These types of clusters are formed with a set of parameters such as distance among CH and BS. In this scheme, the size of the clusters is kept smaller near the BS as compared to the size of the clusters which are far away from the BS. Due to this type of cluster formation, the intracluster communication cost closer to the BS reduces. The clusters are smaller near the BS, and there is less burden on the CHs as compared to the CHs which are far away from the BS.

4.2.9. RUHEED. In [64], the authors proposed a Rotated Unequal clustering protocol (RUHEED). This protocol is the extended form of [63], with a more rotating CH node for the CH election mechanism. The CH is rotated in a specific manner among the nodes of the identical cluster. This CH rotation is depending upon the node which has the highest outstanding energy in the cluster.

4.2.10. Fuzzy-Based Clustering. In [65], the authors proposed a protocol called fuzzy-based clustering mechanism for mitigating hotspot issues in WSNs. This protocol can develop a systematic unequal clustering technique using the fuzzy logic mechanism. In this protocol, the selection of CH is not only dependent upon the residual energy of the nodes but also dependent upon other systematic information of the set of nodes. In this protocol, the cluster size adjacent to the BS is lesser in contrast to the clusters which are distant from the BS. These adjacent clusters preserved their energy in intracluster routing and use this energy for intercluster communication and balance the load among the nodes.

4.2.11. COCA. In [66], the authors proposed a Construction of Optimal Clustering Architecture (COCA) for WSNs. This protocol developed a mechanism for optimal cluster formation in which the energy utilization mechanism in all clusters is even. Due to this even energy utilization, the hotspot issues are alleviated systematically. In the second part of the protocol, a CH rotation mechanism is developed in such a way that the energy which is consumed during intracluster communication lessens, and hence, it overcomes the hotspot issues.

4.2.12. Improved LEACH. In [67], the authors proposed a protocol called the Improved Low Energy Adaptive Clustering Hierarchy (Improved LEACH) protocol for WSNs. The CH sends the data directly to the BS without any assistance from any other nodes. The CH selection is centered on the round-robin principle, and the selection of time slots is predefined. In the data transmission phase, the SNs of the respective cluster use the TDMA time slot scheme to send the data to the CHs and the CHs use the CSMA technique to send the collected data to the BS.

4.2.13. ACT. In [68], the authors proposed a protocol called Arranging Cluster size and Transmission range (ACT) for WSNs. This protocol provides an extension mechanism for arranging the set of clusters and their transmission. This scheme describes that size of clusters is depending upon the distance of the clusters from the BS. Clusters that are closer to the BS have a tiny cluster size in contrast to the clusters which are distant from the BS which reduces the extra burden on the nodes near the BS.

Table 2: Unequal clustering protocols.

Sr. no.	Protocol	Data transmission	Node type	Clustering type	CH election
1	EDDUCA	Multihop	Homogeneous	Unequal clustering	Compound
2	EC	Multihop	Homogeneous	Unequal clustering	Hybrid
3	EDUC	Multihop	Heterogeneous	Unequal clustering	Random
4	EBUC	Multihop	Homogeneous	Unequal clustering	Heuristic
5	UCS	Multihop	Homogeneous and heterogeneous	Unequal clustering	Preset
6	EUCS	Multihop	Homogeneous	Unequal clustering	High residual energy
7	HEED	Multihop	Homogeneous	Static and equal clustering	Hybrid
8	UHEED	Multihop	Homogeneous	Unequal clustering	Hybrid
9	RUHEED	Multihop	Homogeneous	Unequal clustering	Hybrid
10	UCF	Multihop	Homogeneous	Unequal clustering	Fuzzy
11	COCA	Multihop	Homogeneous	Unequal clustering	Hybrid
12	Improved LEACH	Single-hop	Homogeneous	Unequal clustering	Hybrid
13	ACT	Multihop	Homogeneous	Unequal clustering	Deterministic
14	EEDUC	Multihop	Homogeneous	Unequal clustering	Hybrid

4.2.14. EEDUC. In [69], the author suggested a protocol called Energy-Efficient Distributed Unequal Clustering (EEDUC) for WSN. The protocol systematically collects the periodical data to balance the energy utilization among the SNs. In this protocol, CH is selected based upon some type of efficient intracluster parameters. Each type of SN in a cluster established a waiting time. This waiting time consists of the residual energy of the SNs and also the number of adjacent nodes in a cluster. With the help of this waiting time selection, the CH is selected. While removing the hotspot, there is an unequal clustering mechanism that clusters adjacent to the BS have reduced cluster size as matched to the clusters which are distant from the BS, and hence, load on CHs near the BS is lessened. But there is a defect in this technique which is a lot of energy utilization while relaying the data from CH to RN and RN to BS.

4.3. Hybrid Protocols. In this section, hybrid clustering protocols are discussed.

4.3.1. Hotspot Aware Energy. In [70], the authors proposed a hotspot aware energy resourceful clustering approach for WSN. In this protocol, an unequal clustering mechanism is formulated where unequal clustering depends upon the distance from the BS. In this protocol, there is a two-tier mechanism in which CH is put under the higher tier and the SNs put under the lower tier. Each set of SNs can send the data to the higher tier which is CH, and the CH can send the gathered data to the BS. Initially, the CH is selected centered on the remaining energy of the node. If a node fell in more than the individual cluster range, then sensor nodes can select the CH which has low intracluster communication.

4.3.2. UCAPN. In [71], the authors proposed an energy responsive imbalanced clustering algorithm for prolonging the network lifetime (UCAPN). This protocol partitioned the network into unequal cluster sizes. This protocol selects the CHs built on the set of outstanding energy of the adjacent nodes and developed an unequal clustering mechanism. In this protocol, the set of clusters that are close to the BS has smaller cluster sizes as compared to the clusters which are distant from the BS and minimized the energy consumption.

4.3.3. MHRP. In [72], the author proposed energy effective Multi-Hop Routing Protocol (MHRP) for WSNs. In [72], the CH election process is based on SNs with the highest outstanding energy and a systematic set of routing paths that are selected for the outstanding energy and the distance among the nodes. This protocol divides the network area into a different set of regions or zones where CH is selected based on the remaining energy of the SNs and for the data forwarding process. This protocol has a mechanism for multihop communication.

4.3.4. ERA. In [73], the authors proposed an Energy-conscious Routing Algorithm (ERA) for WSNs. The CH selection is established on the remaining energy. For the selection of CHs, initially, each node uses a time slot based on the set of residual energy of the nodes. For the cluster formation process, this protocol uses the set of SNs which are sending a message to the adjacent CH created on the remaining energy and its distance from the BS. Data forwarding from CH to BS is based on a series of CHs where the data is forwarded and reached the BS.

4.3.5. ZEEHC. In [74], the authors presented a Zone-based Energy Proficient Hierarchical Clustering convention (ZEEHC) protocol for WSNs. In this type of protocol, the network system is divided efficiently into the desirable size of zones to raise the stability and network lifetime of the network system. In this protocol, there is a concept of multihop propagation of information from CH or ZH to RN and then to BS. Table 3 shows the hybrid protocol comparison and performance metrics.

4.3.6. EZ-LEACH. In [75], the authors proposed an improvement on LEACH called Energy-Zone-LEACH (EZ-LEACH)

Table 3: Hybrid protocols.

Sr. no.	Protocol	Data transmission	Node type	Clustering type	CH election
1	[52]	Multihop	Homogeneous	Unequal clustering	Residual energy
2	UCAPN	Multihop	Homogeneous	Unequal clustering	Residual energy
3	MHRP	Multihop	Homogeneous	Optimal and equal clustering	Residual energy
4	LEACH	Single-hop	Homogeneous	Dynamic clustering	Random
5	ERA	Multihop	Homogeneous	Optimal clustering	Hybrid
6	ZEEHC	Multihop	Homogeneous	Static and equal clustering	Residual energy
7	EZ-LEACH	Multihop	Homogeneous	Static and equal clustering	Hybrid
8	HEEC	Multihop	Homogeneous	Optimal clustering	Hybrid
9	EADC	Multihop	Heterogeneous	Dynamic clustering	Hybrid
10	DHCS	Multihop	Homogeneous	Dynamic clustering	Hybrid
11	ESDCH	Multihop	Homogeneous	Optimal clustering	Hybrid
12	DHCM	Multihop	Homogeneous	Optimal clustering	Hybrid
13	DCH-NPSO	Multihop	Homogeneous	Optimal clustering	Hybrid
14	PSO-DH	Multihop	Homogeneous	Optimal clustering	Hybrid

protocol for WSNs. The first step of the protocol is network formation in which the network is divided into a set of four logical zones. CH is selected in this protocol where the node which has a centrality factor can send its location to the BS. Then, BS selects the CH node which is closed to the central node. The residual and average energy is also considered for the selection of CH.

4.3.7. HEEC. In [76], the authors proposed a Hierarchical Energy-Efficient Clustering algorithm (HEEC) for WSNs. The CH is selected grounded on the set of outstanding energy of the SNs and the distance to the BS. The CH selection process also consists of the node alive status where the node can transmit data to the BS. This protocol also introduces the reelecting of the CH. The BS check after the first round the energy status of the CH and compare it to the other node. If it has less energy like aliveness and residual energy, then the reelecting process is continued. This load balance makes the network system energy efficient.

4.3.8. EADC Scheme. In [77], the authors presented a protocol with nonuniform node distribution for WSNs. This scheme consists of two main parts: the first is the Energy-Aware Clustering algorithm (EADC) and the second is cluster-based routing phenomena. This EADC scheme has the ability to establish clusters that are even sized and use the process of competition ranges. There are balanced energy consumptions among the node systematically. In the second part of the protocol, to balance the energy consumption among the CHs, a cluster-based systematic routing protocol is developed. In this protocol, to systematically balance the energy consumption among the CH, there is a set of mechanisms that are established for intracluster and intercluster energy consumption adjustment. The CH selection mechanism consists of nodes with the highest residual energy, and also, the average remaining energy of the adjacent node is set to be considered for the selection of CH.

4.3.9. DHCS. In [78], the authors proposed the energy resourceful Dual-Head Clustering Scheme (DHCS) for WSNs. The dual CH mechanism is established in which two CHs are considered which has the ability of network route management, data relaying, data aggregation process, cluster maintenance process, and set of intracluster and intercluster communication mechanisms. The addition of these two CHs makes the network system efficient, and there is a load balance in the network system, and also, the CH reelection mechanism is removed. The dual CH selection mechanism consists of a set of criteria in which the first CH is selected based on the residual energy of the node. The node with maximum residual energy is selected as the first CH. The second CH which is called the aggregated head is selected by the first CH and is used for data aggregation, cluster formation, and another set of clustering operations.

4.3.10. ESDCH. In [79], the authors proposed an Energy-Saving Dual-Cluster Head protocol (ESDCH) for WSNs. In this protocol, each set of SNs can arrange itself into clusters and set the states of the SN into sleep state or active state established on the outstanding energy of the nodes. This protocol considers the dual CH mechanism, and the purpose of this dual CH is to balance the load in the whole network system systematically. Primary CH is chosen which has the maximum remaining energy in the cluster, and after that, secondary CH is chosen from the remaining nodes in the cluster which are nearer to the primary CH. Primary CH can collect all the data from the SNs and provide some aggregation mechanism and send this to the BS. Secondary CH is only active when the working of the primary CH is interrupted. This protocol can balance the energy intake among the nodes systematically.

4.3.11. DHCM. In [80], the authors proposed a protocol called the Dual-Head Clustering Mechanism (DHCM) for WSNs. This protocol can use the dual CH mechanism. This dual CH mechanism balances the load in the whole network system and makes the network system energy efficient. The set of communication between CHs and the BS uses the multihop mechanism, and due to this, CHs which are nearer to the BS get burden with heavy relay traffic where nodes die out, and the network system gets partitioned. To overcome these issues, the authors developed a dual CH mechanism, and this mechanism balanced the load and makes the network system energy efficient. Both CHs have different responsibilities in the network system. One CH is used for data collection from all the nodes; then, another CH has the responsibility of data relaying and also data aggregation mechanism.

4.3.12. DCH-NPSO. In [24], the authors presented Dual Cluster Heads using Niching Particle Swarm Optimization (DCH-NPSO). In this protocol dual CH, the mechanism is established and balances the energy utilization in the whole network system. Two CHs are selected in the individual cluster, and these CHs balanced the load in each cluster. Master CH and Slave CH are two CHs that are selected in each cluster. Master CH can collect all the data from the CMs and provide some type of aggregation mechanism and send this data to the Slave CH. Slave CH can send the data to the BS. Master CH cannot transfer data straight to the BS and hence balance the energy utilization in the network system.

4.3.13. PSO-DH. In [31], the authors proposed a protocol called the Double Cluster Heads clustering algorithm using Particle Swarm Optimization (PSO-DH). This protocol provides a mechanism for selecting two CHs using the PSO technique. This protocol does not only provide a systematic mechanism for CH selection but also provide a balanced energy consumption mechanism among the nodes. Two types of CHs are selected which are master CH and vice CH. Master CH collects the data from all the CMs and provides some aggregation mechanism and sends it to the vice CH. Vice CH receives this aggregated data and relays it to the BS. Master CH cannot directly communicate with the BS, and in this case, there is a balance of energy consumption in the clusters.

5. Conclusion

We may deduce from the aforesaid analyses that routing strategies may improve sensor network energy efficiency or extend network life. However, the hotspot issues are still under consideration. This research alleviated the hotspot problem in WSN. The hotspot problem refers to that where the sensor nodes are close to the BS and consume more energy and depleted faster than the other placed sensor nodes. Due to significant data traffic from CMs and other CHs towards the BS, the areas around BS are hotspots. In WSNs, hotspot issues are still an open challenge. Hotspot or energy hole issues make the network system halt, partition the network system, disappear the coverage area, reduce the efficiency of the system, and in addition decrease the network lifetime. Many existing clustering protocols like dynamic and unequal clustering techniques have tried to overcome hotspot issues. However, while tackling the hotspot issue, these protocols have suffered from other issues like overhead and connectivity. This research reveals that static and equal clustering techniques are more efficient for avoiding hotspots. There is a pressing need to design a more efficient and smart clustering protocol for WSN to tackle the hotspot issue. In the future, we will review some other issues in WSN and relate those with hotspot issues.

Conflicts of Interest

The authors declare no conflict of interest.

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