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A Review of Stable Election Protocol Variants of Wireless Sensor Network

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Abstract- **Lifetime enhancement is the key trial in the design of energy restricted WSN. This leads the researchers to explore energy preservation for wireless sensor networks. Due to the energy-constrained nature of WSN, hierarchical energy-efficient routing protocols have gained significant attention. In the recent era, Heterogeneous Wireless Sensor Network Clustering Protocols have drawn tremendous attention due to their energy efficiency. Numerous states of the art heterogeneous clustering protocols have been proposed by the researchers to enhance the lifetime of the network but still, some of the parameters need to be addressed. In this article, a complete overview of the overall clustering mechanism is presented and emphases on the routing theories for various HWSNs scenarios and covers the state of the art in the area.**

Index Terms-- **WSN, Heterogeneous, lifetime, clustering, cluster head, energy.**

I. INTRODUCTION

The term Wireless Sensor Network (WSN) can be defined as, "Integrating sensing, processing, communication and storage potential into pint-sized, modest devices and joining them into so-called WSN" [1, 2]. Boost in wireless networking technology, micro-manufacturing, integration, and embedded systems have spread modern generations of sensor networks desirable for a wide array of commercial and military applications. WSN promises to inspire our way of living, interaction with the physical environment and work [3, 4].

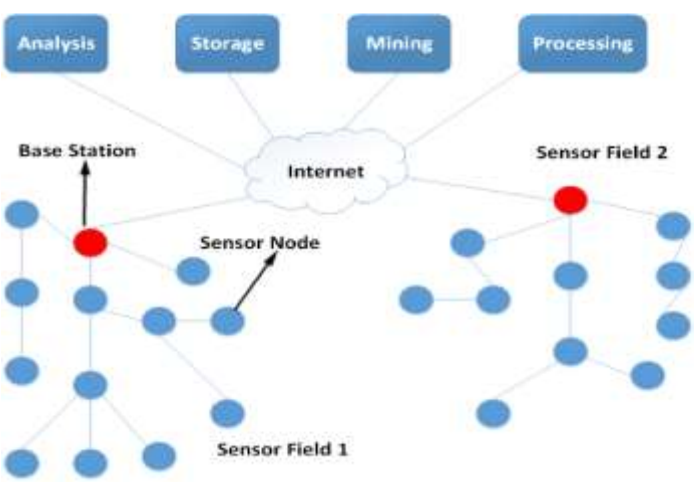

FIGURE 1: SENSOR NETWORK [1]

The WSN comprises an enormous number of sensor nodes ranging amongst few hundreds to thousands dispersed randomly through a geographic region or organized nearby to the phenomena. But network nodes have severe limitations in terms of limited energy, memory and transmission and computation power [5]. Subsequently, the network nodes have restricted energy, it will result in energy depletion faster, correspondingly, and the overall network period will be reduced. To optimize the network life and management strategies certain goals like prolonged network lifetime, scalability, coverage, and network simplicity are desirable, consequently, it is essential to pursue an energetic and flexible network layer protocol. To address the above-stated problems clustering protocol has been proposed by numerous investigators [6, 7].

Clustering protocols offer the solution to exploit the nodes and network energy consistently to enhance the network lifespan time, maximize the packet delivery ratio and throughput as well clustering of nodes avoids long-distance communication of nodes to BS. Heintzelman et al. [8] presented LEACH, a pioneering benchmark on hierarchical clustering.

Many researchers have already proposed the energy optimization issues in HWSNs but still, there are various open issues that still require attention e.g., CH selection and the optimal number of CHs per rounds. Due to the above-mentioned issues, in this article, we will investigate the performance of different protocols based on the following parameters.

- To explore various protocols in terms of energy heterogeneity
- CH selection process
- Evaluate different protocols based on the optimal number of cluster head per rounds

This article aims to analyze the performance of existing protocols, their stable and unstable region, throughput and especially CHs per round. Since the CH selection plays a critical role in network performance and a number of CH per round directly affects the overall network time. Many researchers have successfully enhanced the network lifetime but still, Optimal Cluster Head Selection, Node Deployment, Cluster overhead, Node deployment is an open issue. As the nodes tend to die out the network becomes unstable, due to this instability the number of CH elected per round.

II. CLUSTERING MECHANISM

In the clustering technique, the devices are partitioned into clutches known as clusters. In general, one cluster head is elected from the clusters and remaining cluster members (CM) connects with the cluster head based on the lowest distance from the cluster head. The cluster members communicate only with the cluster head and forward the sensed data to the cluster head. The cluster head then executes data aggregation and eliminates the correlated data and data fusion on the data obtained by the cluster members and transmits the fused data to the base station for further end-user processing.

III. CLUSTERING BENEFITS

In literature, the clustering protocols differ in their objectives. Usually, the clustering objectives are application-specific e.g., delay-sensitive, intra and inter-cluster connectivity, the distance between the cluster head and base station for cluster heads selection, cluster size, and members. The following are the famous objectives proposed by various researchers [9].

A. LOAD BALANCING

Partition the network into equal size of the cluster can greatly improve the time period. Due to the unbalance size of the cluster the network performance can be degraded. Since the cluster head performs multiple tasks and data aggregation due to which the energy of the cluster head is depleted rapidly as compared to other sensor nodes. It is very essential to balance the load between them to achieve the desired performance objectives. Load balancing is a critical factor in clustering [10], where a cluster head is randomly selected from the network nodes [11]. Besides load balancing the rotation of cluster heads also helps in fault tolerance [8].

B. FAULT TOLERANCE

In certain applications, nodes are organized in a harsh environment due to which the nodes are exposed to malfunction or physical damage. To avoid the data loss, fault tolerance property of cluster head is desired in some applications. The most common method is to re-cluster the network but due to excessive resource utilization, this method is not very encouraging. Another approach to overcome the cluster failure is by adding a backup or secondary cluster head and the function of the secondary or back cluster heads varies. By round rotation of cluster heads between the network nodes provide additional benefit through fault tolerance [8].

C. GUARANTEED CONNECTIVITY

This objective of marginal cluster count is primarily mutual when some cluster heads are equipped with more resources, processing, and computational power as compared to normal cluster heads [12]. Due to their size, cost and vulnerable nature, network designer tends to deploy the minimal number of these nodes.

D. ENHANCING THE NETWORK LIFETIME

When cluster heads are highly equipped as compared to other network nodes, it is very vital to decrease the intra-cluster communication energy [13] and the distance amid the cluster head and member nodes should be kept minimum [14].

E. NUMBER OF CH

The number of cluster heads in the network should be optimal. When the node is selected as a cluster head, it depletes additional energy as compared to its member nodes. If the number of cluster heads in a network is not optimal. It will diminish the network lifetime as the rate of energy consumptions at cluster heads is higher.

Besides data aggregation, the cluster heads are also responsible for communicating with the base station and nodes transmit to their respective cluster heads. In this way, a substantial amount of energy of non-cluster heads nodes is saved and the energy utilization is further reduced by inter-cluster and intra-clustering communications as it minimizes the number of sensor nodes that are taking part in distant transmission. The data aggregation also helps to reduce energy utilization as data aggregation is executed by the cluster heads.

F. ENERGY EFFICIENCY

Besides data aggregation the cluster heads are also responsible for communicating with the BS and nodes transmits to their respective cluster heads. In this way, a significant amount of energy of non-CHs nodes is saved and moreover, the energy utilization is further reduced by inter-cluster and intra-clustering communications as it minimizes the number of network nodes that are taking part in distant transmission. The data aggregation also helps to reduce energy utilization as data aggregation is accomplished by the CHs.

G. SCALABILITY

Clustering protocols restrict the number of transmissions among nodes, thus allowing a maximum number of devices that can be installed in the network. Compared to traditional routing protocols, clustering protocols are simple to manage and are more robust to react to the events in the environment.

H. MAINTENANCE

The clustering methods also benefit the network maintenance in terms of, node mobility, topology control, node failures, reacting to network changes triggered by network dynamics and local changes. Since these tasks are performed by the concern cluster head and the whole network does not take part in making the maintenance process simpler and easier.

IV. TAXONOMY OF CLUSTERING ATTRIBUTES

A. CLUSTERING APPROACH

To consume the network energy effectively and limit the correlated data, data aggregation and sensor fusion many novel techniques have been suggested by the researchers [8]. To consume the network energy uniformly and enhance the lifetime of the network clustering has gained much attention in WSN due to their cluster head selection and data aggregation. In the clustering method, the nodes are partitioned into groups known as clusters. In general, one CH is selected from the clusters and other CMs connect with the cluster head. The CMs communicate only with the CH and forward the sensed data to CH. The cluster head then executes data aggregation and data fusion on the data obtained by the CMS and transmits the fused data to the base station for further end-user processing.

Clustering-based techniques play a key role in improving energy efficiency and guaranteed to prolong network lifespan, for reusing the bandwidth and data gathering [15] and target tracking [16], single-hop or multi-hop communications, routing [8,17-20], etc. Clustering is predominantly suitable for a large type of network comprising of a hundred or thousand nodes that requires scalability. Scalability in those network environments which involves load balancing, well-organized resource exploitation, and data aggregation [21].

B. CLUSTERING ELEMENTS

Commonly the cluster is comprised of three main elements. Cluster Heads, Member Nodes, and BS [22].

a) CLUSTER HEAD:

The cluster head plays a crucial role in HWSN since it performs multiple roles. The CH is selected from the network devices and the selection criteria of CH selection differs from protocol to protocol. After the selection of CH, it exchanges messages with the network nodes for cluster formation

The CH is involved in intra and inter-cluster communication and moreover, it also performs data aggregation and data fusion and it also acts as a gateway among the nodes and the BS due to which the energy of CH is drained at a rapid rate as compared to other network devices. To balance the energy depletion, the CH is chosen in every round [9].

b) CLUSTER MEMBER NODES:

The cluster member nodes or network nodes are those are not elected as CH during the clustering selection phase. After the cluster selection phase, the nodes join the nearest CH forming a cluster. The cluster member senses or monitor the area within their sensing range and transmits it to the CH.

In some applications, the nodes are equipped with more processing and computation power as compared to other CHs. Generally, HWSN consists of two-tier nodes i.e., normal, and advanced nodes. The advanced is equipped with more capacity and strength as compared to normal nodes. In some articles, the HWSN is extended to three-tier nodes, i.e., normal, intermediate, and advanced nodes. The energy of the intermediate node is kept among the normal and advance nodes. In most of the networks, it is anticipated that the network nodes are fixed but sometimes it is essential to provide the mobility of nodes in scenarios like target detection. It becomes very challenging to sustain the connectivity of the network nodes with the CH.

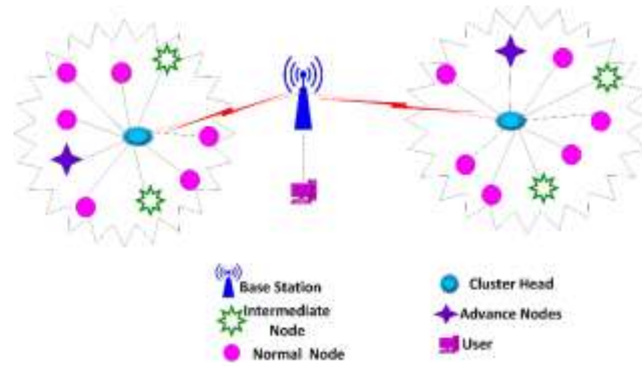

FIGURE 2: CLUSTERING ELEMENTS

c) BASE STATION:

The BS performs further desired computation on the data forwarded by the CHs for end-user requirements. Usually, the base station is static but in some desired application it can be mobile too [7]. The static base station is deployed far away from the nodes while in the case of the mobile base station it follows a fixed trajectory. In most recent research, the BS is deployed at the middle of the network.

V. CLUSTERING PROPERTIES

Generally, clustering methods attempt to attain some features for the generation of clusters. These features can be linked to the internal configuration of the cluster or in what way it transmits to other nodes. The following are the applicable clustering properties [23].

a) CLUSTER COUNT

In various published works, the number of CHs is fixed and consequently the number of clusters fixed. In other research, the CHs are randomly generated and the number of CH varies. Since the energy consumption is maximum in CHs the number of clusters should be kept balanced or minimum to preserve the network energy.

b) DYNAMIC AND STATIC CLUSTERING

In Dynamic or adaptive clustering, the number of clusters and node membership changes in every round while in static clustering. In dynamic clustering, the energy of the network is consistently distributed between the network nodes, but it inserts additional overhead in reelecting the CH in every round by exchanging discovery messages. Node membership remains static i.e., the association of nodes with their respective cluster head remains unchanged. Likewise, in dynamic clustering, the energy wasted in the selection of CH is preserved but to static membership, the energy of the CH is depleted at a faster

VI. CLUSTER HEAD CAPABILITIES

As argued above the network design affects the clustering method; mainly the node abilities and the choice of the in-network handling. Attributes of the CH nodes are discussed as [23].

A. STATIC OR MOBILE

In most of the research the CH is static while in some applications the CHs are mobile and due to their mobility, the membership of the clusters changes dynamically which results in continuous cluster management. In the case of static clustering, cluster formation is steady. In some scenarios' the CH can be relocated to a new location to maximize the coverage.

B. DATA AGGREGATION/FUSION

Due to the random placement of the nodes, sometimes the nodes are deployed very close to each other and their sensing region overlaps with each other. As a result, nodes might produce lots of correlated data, identical packets can be collected from several nodes. The CH implements data aggregation on the packets received from the network nodes and eliminates the identical copies of the packets. After the data aggregation process, the CH performs data fusion and transmits the data to the BS for end-user processing. This method has ensued in energy effectiveness and network traffic optimization in clustering algorithms and the network life is also enhanced. To guarantee that CH is not overburdened the number of cluster members should be balanced in every cluster.

C. ROUTING

In most literature, heterogeneous networks are classified as two-tier energy protocol, where the nodes are divided into high energy nodes and low energy nodes but in few types of research, they are termed as multi-tier protocol. The routing in clustering protocols is accomplished in dual phases, first is intra-cluster routing and the second is inter-cluster routing [41].

D. ROLE

A CH performs the task like a network router. The CH performs multiple tasks. Firstly, it communicates with its CMs for collecting data and forwards the collected data to the BS for end-user processing. Secondly, the CH accomplishes data aggregation and data fusion on the data received from its CMs.

VII. THE CLUSTERING PROCESS

Designing of the clustered network is on the most crucial step for effectively utilizing the network energy. During the designing issue, certain aspects should be considered, like optimal cluster head size, CHs selection criteria, etc. The clustering establishment process can be divided into three main phases' i.e. (i) CH selection, (ii) cluster creation and (iii) data transmission phase [22].

A. CLUSTER HEAD SELECTION

CH selection can be classified into three categories, centralization by the BS, decentralization by the nodes or hybrid selection and some by the nodes themselves.CH selection is a foremost task to prolong the network lifetime and make the network energy efficient. The cluster head is chosen amongst the existing sensor nodes. The selection measures of CH varies in the suggested research but the key intention these studies is to decline the energy consumption and prolong the network life span. To minimize the routing complexity and make the network more energy efficient it is necessary to decide the optimum number of CH, which will minimize the overhead while maintaining the network connectivity in case of topology changes occur. Researchers have proposed different mechanisms to select the cluster head but still its open research problem.

HSWSN are generally two-level protocols equipped with normal nodes having basic energy of "E0" and m advanced number of nodes having extra energy "α" as related to typical nodes. The total energy of the network is increased to "(1+m.α)" times. So, the whole initial energy of the network develops to:

$$E_{TOT} = nE_o(1 + m\alpha) \qquad (1)$$

The probability of normal nodes (P_{NS}) and advance nodes (P_{AS}) to be elected as CHs becomes [11]:

$$P_{NS} = \frac{P_{opt}}{(1 + \alpha * m)} \qquad (2)$$

$$P_{AS} = \frac{P_{opt}}{(1 + \alpha * m)}(1 * \alpha) \qquad (3)$$

$$T_{(S_{NS})} = \begin{cases} \dfrac{P_{NS}}{1 - P_{NS} * (r * \mathrm{mod}(\frac{1}{P_{NS}})} & \text{if } S_{NS} \in X' \\ 0 & \text{otherwise} \end{cases} \qquad (4)$$

$$T_{(S_{AS})} = \begin{cases} \dfrac{P_{AS}}{1 - P_{AS*} * (r * \mathrm{mod}(\frac{1}{P_{AS}})} & \text{if } S_{AS} \in X'' \\ 0 & \text{Otherwise} \end{cases} \qquad (5)$$

Where, r is the present round, X' and X" are nodes that are not selected as CH within the last round.

B. CLUSTER CREATION

In the cluster creation or set-up phase, the cluster formation takes place. The cluster heads declare their selection to network nodes by broadcasting advertisement messages and each network node responds by posting a accompany message to the cluster head. For N number of network nodes, an assured sum of clusters is formed during each round.

The energy consumed by the cluster head in a certain period is computed by the following equation [11].

$$E_{CH} = P.E_{Ckt}\left(\frac{n}{C} - 1\right) + P.E_{AD}\frac{n}{C} + P.E_{Ckt} + P.\epsilon_{fs}d^2_{TX} \qquad (6)$$

Where C is the sum of clusters, EAD aggregated data and dTX is the distance amongst the cluster head and BS. The energy utilized by a non-cluster head is as follows.

$$E_{NCH} = \begin{cases} P.E_{Ckt} + P.\varepsilon_{fs}.d^2_{CH} & \text{if } d_{CH} < d_{BS} \\ P.E_{Ckt} + P.\varepsilon_{mp}.d^2_{BS} & \text{if } d_{CH} > d_{BS} \end{cases} \qquad (7)$$

Here dCH is the distance amongst the associated nodes and the cluster head and the average can be gauged by "dCH=M/(√2π)". dsk is the distance amongst the adjacent node and the BS.

C. DATA TRANSMISSION

In data transportation or steady-state phase, the CMs forwards sense data to their corresponding cluster heads, and the cluster head performs data aggregation and forwards it to the BS. The entire energy consumed in the network becomes equal to,

$$E_{TOT} = P.\left(2nE_{Ckt} + nE_{AD} + \epsilon_{fs}\left(C.d^2_{TX} + n\frac{M^2}{2\pi C}\right)\right) \qquad (8)$$

VIII. TYPES OF CLUSTERING

Commonly the clustering can be group into two types' homogeneous clustering or heterogeneous clustering and static or dynamic clusters. In formal type is the clusters are established on the function of the nodes within the cluster while the earlier deals with cluster formation [23].

A. HOMOGENOUS CLUSTERING

In the homogenous type of clustering, the network nodes have identical initial energy, processing potential, and sensing range.

A homogeneous sensor network comprises of BS and network nodes are equipped with similar potential and energy level, for example, their computation and processing capability is the same. The homogenous networks require high hardware cost. To overcome the limitation of homogenous networks heterogeneous networks were proposed in which two types of sensor nodes were introduced [8].

B. HETEROGENEOUS CLUSTERING

Generally, the heterogeneous network has two types of nodes having different energy levels termed as high energy or advance node and low energy or normal nodes. The advanced nodes contain maximum energy potential as compared to low energy nodes. Depending on node heterogeneity the heterogeneous network can be classified as two-tier or multi-tier heterogeneous networks [6].

C. STATIC CLUSTERING

In static clustering, the clusters are created nears the high energy nodes at the time of placement. The properties of cluster elements remain static such as cluster volume, number of CHs, number of nodes. The static clustering can be deployed in limited a predefined Scenario.

D. DYNAMIC CLUSTERING

In the dynamic clustering, the membership of the network's nodes may vary to different clusters in the network. The arrangement of clusters may be periodic or dependent on the occurrences of certain events [23].

IX. HWSN LIFETIME STAGES

In clustering protocols, the network operations are measured in rounds. When the network becomes operational, the whole network will progress into three phases: stable period, usable period and weak sensing period.

a) STABLE REGION

It is a region where all network nodes perform smoothly or in other words the network is stable.

b) UNSTABLE REGION

Unstable regions begin when the first network nodes drain their energy till the half of alive network nodes. The instability period affects the cluster head criteria adversely and the number of CHs per round is not optimal which degrades the network performance.

c) WEAK SENSING REGION

The weak sensing covers the unstable region from the remaining half of the network nodes until the last network node. In the weak sensing phase, the sensing capability of the nodes declines rapidly [24].

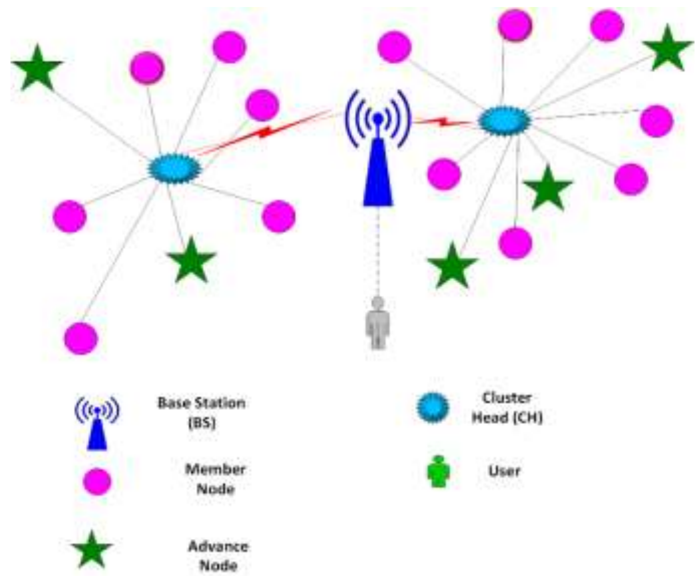

FIGURE 2: HETEROGENEOUS CLUSTERING

In weak sensing regions, the cluster head selection criteria become highly unstable and even in most of the rounds no cluster head is elected which mean no communications have been taken place in those rounds.

X. HWSN NODE DEPLOYMENT

The node deployment of in WSNs is application-specific and affects and plays a significant role. The node organization can be either deterministic or random. In former method nodes deployed manually. Conversely, in random sensor node deployments, nodes are distributed arbitrarily in an area. In this organization, the site of BS is also critical in terms of network performance and energy efficiency. If the node distribution is not uniform it could lead to serious energy issues and degraded network performance. Additionally, the transmission range and the comparative CH vicinity to the BS are critical concerns that need to be addressed. Transmission range is generally restricted, and a CH may not be able to reach the BS even if the sensor node transmits straight to the BS.

Random node deployment is the most frequently considered node deployment method in the HWSN [18]. Though, it is inefficient from an energy efficiency perception due to Node's different energy levels. The unfeasibility usually arises in two sorts of conditions, one where the number of nodes is vast, and the other when the network is comprised of heterogeneous nodes i.e., nodes having various energy levels. In these scenarios, the requirement of a well-designed node deployment algorithm is becoming viable to maximize the network lifetime. But all this prior research work ignores the placement of advance nodes which have a higher priority to be elected as CH.

XI. HWSN ENERGY PREDICTION MODEL

According to node energy heterogeneity, the HWSN network can be designed by introducing different energy levels, i.e., two, three or multi-energy levels.

A. TWO LEVEL HWSN

The two-level HWSN model contains two kinds of node normal nodes N and advances nodes m, equipped with unlike energy levels. Where normal nodes are energized with energy E0 and advance nodes are equipped with higher energy as related to normal nodes i.e., E0 (1 + α). Since the N is the total number of network nodes, then Nm is the sum of advance nodes while N (1-m) is the number of normal nodes. Therefore, the network's total initial energy is equivalent to the sum of energies of both types of nodes.

$$T_{IE=}N(1-m)E_0+Nm(1+\alpha)E_0 \quad (9)$$

$$T_{IE=}NE_0(1-m+m+\alpha m) \quad (10)$$

$$T_{IE=}NE_0(1+\alpha m) \quad (11)$$

B. THREE LEVEL HWSN

This type of network contains three types of nodes. These three types contain different energy levels i.e. normal, intermediate and advanced level nodes. The energies of both normal and advance nodes are the same as the two-level HSWN whereas the energy "µ" of the intermediate node is set among normal and advance nodes E0(1+b). Since "N" is the sum of network nodes, then the sum of intermediate nodes becomes "Nbm" and "Nm (1-b)" advance nodes. Therefore, in three-level HWSN, the over-all initial network energy becomes,

$$T_{IE=}NE_0(1-m-b)+mNE_0(1+\alpha)+NbE_0(1+\mu) \quad (12)$$

$$T_{IE=}NE_0(1+m\alpha+b\mu) \quad (13)$$

Where "b" represents the number of intermediate nodes equipped with energy "µ" and "µ=α/2". The three-level heterogeneous WSNs hold "(α + µb)" times additional energy as with respect to homogeneous WSNs. SEP-E and T-SEP is the example of three-level HWSN.

C. MULTI-LEVEL HWSN

In multi-level HWSN, the basic energy of the network nodes is arbitrarily dispersed over the close-set "[E0, E0 (1 + αmax)]", where "E0" represents the initial energy and αmax represent maximum energy. Initially, the node the nodes are energized with "E0. (1 + αi)", which is "αi" time's additional energy. So overall initial energy of the networks becomes

$$E_{\text{Total}=}\sum_{i=1}^{N}E_0\,(1+\alpha_i)=E_0\,(N+\sum_{i=1}^{N}\alpha_i) \quad (14)$$

XII. SUMMARY OF HETEROGENEOUS CLUSTERING PROTOCOLS

In this section, a summary of renowned Heterogeneous Clustering protocols is presented in Table 1 at the end of the article.

A. SEP

In [9] the author has introduced energy heterogeneity to perpetuate stability cycle beforehand the expiry of the initial network node, which plays a critical role for certain applications in which the response from the network must be consistent. In SEP the CH selection is centred on the contingency of individual nodes related to remaining energy. Since the advance nodes have additional energy which ensures that, this increment will work perfectly and the increased energy will have used efficiently, the advance nodes will elect cluster head more often than the normal nodes. The election of CH is made in the start of each round by choosing a random number [0, 1], if the value of the random number generated is less than the set threshold, the node will become cluster head in the current round. The threshold for both advance T_{AN} and normal nodes T_{NN} is given as,

$$T_{NN}=\begin{cases}\dfrac{P_{NN}}{1-P_{NN}*(r*\mathrm{mod}(\frac{1}{P_{NN}})} & \text{if } S_{NN}\in X' \\ 0 & \text{Otherwise}\end{cases} \quad (15)$$

Where r is the existing round, "X'" is the number of normal nodes which were not selected as CHs within the previous $\frac{1}{P_{NN}}$ rounds of the epoch, and to ensure that every normal node will be selected as CH precisely once in every round.

$$T_{(AN)}=\begin{cases}\dfrac{P_{AD}}{1-P_{AN*}*(r*\mathrm{mod}(\frac{1}{P_{adv}})} & \text{if } S_{AD}\in X'' \\ 0 & \text{Otherwise}\end{cases} \quad (16)$$

Similarly, "X''" is the number of advanced nodes which were not designated as CH within the last $\frac{1}{P_{AN}}$ rounds of the epoch SEP are based on election probability which focuses on the basic energy of every network node to be selected as CH by allocating a weight equivalent to the basic energy of individual nodes divided through preliminary energy of the normal nodes. The weighted probabilities for normal and advanced nodes in SEP were selected to reveal the additional energy presented in the network. The weighted probability for normal nodes P_{NN} and advance nodes P_{AN} is given by,

$$P_{AN}=\frac{P_{opt}}{(1+\alpha*m)}*(1+\alpha) \quad (17)$$

$$P_{AN}=\frac{P_{opt}}{(1+\alpha*m)}*(1+\alpha) \quad (18)$$

SEP protocol claims to maximize the stable region which as a result minimizes the unstable region and the protocol claims to improve the response of Clustered WSN in the occurrence of heterogeneous nodes. The downside of SEP is advanced nodes. Advanced nodes have extra energy and their probability to be selected as CH is higher with respect to the normal node which results in higher energy depletion and at a convinced stage, the potential of them becomes equivalent to the normal nodes but still, the probability of advance nodes to be elected as CH is maximum.

B. ON LIFETIME MAXIMIZATION OF HWSN WITH MULTI-LAYER REALIZATION

In [25] the author has proposed a horizontal intra-layer and vertical inter-layer optimization technique to find the global minima, which involves a minimized number of repetitions as compared to traditional single-layer realization of an HWSN. Additionally, cooperation amongst nodes is studied to transmit data to the fusion Centre receiver to increase data transmission accurately in adaptable transmission channel conditions.

A dynamic CH selection method is presented in this article which minimizes the overhead within the intra-cluster communication and reduces the non-uniform energy utilization. Subsequently, the proposed article delivers an energy effective solution for HWSNs to boost the growth of the network.

C. HT2HL

In [26] the author depicts a hybrid two-level heterogenous protocol. The protocol adopts the best features of [8] and TEEN [27] Protocols. The author has introduced energy heterogeneity in the network nodes and the cluster head selection is both probability-based [9] and threshold-based. Based on the cutoff value the nodes having the highest energy are selected as a cluster head for the existing period.

D. HACSH/MH

In [28], the author has adopted the hierarchical agglomerative clustering (HAV) protocol for CH selection. It is a dual step process the cluster is created by applying HAC on the network nodes and Euclidean distance amongst nodes. The election of the CHs is established on the closeness with a virtual network node depicting the optimum head site with respect to potential ingesting. The protocol is re-accomplished after each period to balance the potential utilization of the network nodes.

E. NEECP

In [29] the author depicts a new energy-efficient protocol for boosting the network lifetime in HWSN. This method actively chooses the CH by utilizing a variable sensing range and executes data aggregation by means of the chaining method. It also evades the broadcast of correlated data by implementing a redundancy check method for maximizing the lifespan of the network. It is applied by recognizing the data aggregation and without aggregation.

TABLE 1

S. No.	Protocol Name	Energy Efficiency	CH Selection Parameter	Data Transmission	Location Of BS
1	On Lifetime Maximization of HWSN With Multi-Layer Realization	High	Dynamic /Minimum Reduce Energy Consumption	Single Hop	Center
2	HT2HL	Good	Probability-Based	Single Hop	Center
3	HACSH/MH	Good	Euclidean Distance	Both	Center
4	NEECP	Good	Threshold / Residual Energy Based	Multi-hop	Center
5	EADUC	Poor	Ratio Among the Average Remaining Energy of the Peer Nodes and the Remaining Energy of the Node	Multi-hop	Center
6	Improved EADUC	Fair	Distance, Residual Energy, Number of Neighbors	Single Hop	Center
7	Heterogeneous DEEC	Excellent	Weighted Probability	Single Hop	Center
8	MLHEED	Good	Residual Energy, Node Density	Single Hope	Center
9	PSABR	Good	Battery Power and Residual Energy	Single Hop	Center
10	DCHSM		Redundant Nodes/Remaining Energy and Average Energy	Multi-hop	Center
11	EECCCP	Excellent	Probability/ Euclidean Distance	Single Hop	Center
12	BEECP	Good	Biogeography-Based Optimization	Single Hop	Center
13	SEECP	Poor	Residual Energy	Single Hop	Center
14	P-SEP	Good	Average Sensor node Energy Of Present Session, Advanced Nodes Preliminary Energy	Single Hop	Center
15	DSEP-FL	Poor	Fuzzy Logic/Maximum Energy	Single Hop	Center
16	FECR and FEAR	Good	Node initial Energy and Current Energy	Single Hop	Center
17	DEECIC [55]	Good	Neighbor	Multi-Hop	Center
18	WBCHN		Residual Power, Number of Live Peers and Proximity to BS	Single hop	Center
19	EHE-LEACH	Average	Probabilistic	Multi-Hop	Center
20	Fuzzy	Good			Center
21	AZ-SEP	Excellent	Remaining Energy of Nodes	Multi-hop	Center
22	EUCA	Good	Nodes Remainging Energy	Multi-Hop	Center
23	EECPK-means	Good	Energy centroid and nodes cutoff energy	Single	Center

24	CREEP	Excellent	Threshold & Probability Based	Single hop/dual hop	Center

F. EADUC

In [30] author proposed energy-aware distributed unequal clustering protocol EADUC on which the author has improved the life span of Wireless sensor network. The proposed clusters were assumed with unequal size and unbalance competitive radius through the use of numerous issues, viz. the distance to BS, the residual energy and the number of neighbours. The cluster closer to the base station were small in size as compared to the cluster which was at a far distance from the base station. The energy utilization amongst the CHs nodes is more effectively balanced.

G. IMPROVED EADUC

In [31] author aims to extend EADUC's lifespan and prevent hot spot problems in heterogeneous multi-hop HWSN. It is broadly utilized in persistent information-collecting applications. It varies from [30] in the concern of node degree while computing competition radii in addition to remaining node energy and transmission distance to the base station. Node degree is involved in inappropriate uniform energy distribution in the network.

In [31], the nominated cluster heads are centred on the ratio of the average energy of peer nodes and remaining energy of the node itself. The competitive radius is computed based on three factors: remaining energy, transmission distance to BS and node degree. [31] uses node energy as a relay metric for choosing relay nodes whilst [30] makes use of distance to BS as a relay parameter. The same cluster configuration is used for multiple rounds, reducing re-clustering overhead and minimizing energy utilization.

H. HETEROGENEOUS DEEC

In [32], the author has proposed a three-tier HWSN model categorized by a sole model metric and described it as, level-1, 2, and 3 energy heterogeneity in the network. Which is liable upon the cost of the vector framework, it can be label as level, 1, 2, and 3 heterogeneities. In this article, the HWSN model additionally helps to choose CHs and their corresponding cluster contributors by means of weighted election chance and a threshold value.

I. MHLEED

In this paper [33], the author proposes a heterogeneous multi-level network model with dual sorts of the framework, primary and secondary parameters Cluster formation is dependent on node energy levels. Two parameters such as a node's outstanding energy and node density are taken into account simultaneously during cluster creation.

J. PSABR

In [40] the author proposed PSABR, which together with battery-powered nodes reflects driven nodes. It is a distributed system based on a tree, with a backbone routing assembly consisting primarily of infinite driven nodes. The battery-operated nodes are allocated to the resource-intensive jobs to reduce the battery-powered nodes ' energy ingestion. In [27] demonstrates substantial improvement over the shortest path routing algorithm during network lifespan. Though the implementation is instinctive, as the battery-operated nodes are not battery-restricted, and the method may be troublesome to implement with limited functionality of driven nodes in daily circumstances.

K. DCHSM

In [35] the researcher suggested a Dynamic Cluster Head Selection Method that analyses network power consumption balancing depending on the heterogeneity of energy and redundant nodes. Using the Voronoi diagram, the zone to be tracked is partitioned into clusters, and the redundant nodes are nominated as first sort CH nodes. The existence of unwanted nodes doesn't disturb the coverage of network and moreover, their sensing role can be turned off to minimize the power utilization during the network operations. The CH selection method is used after the death of the redundant node's dependent on the ratio of the residual power and the average energy of the existing network nodes. The suggested procedure shows enhancement in network lifetime and stable region, however, the collection of two unlike types of techniques for CH selection might boost the operational cost.

L. EECCCP

In [36] the author suggested Energy Efficient Concentric Circular Clustering Protocol for 3-level potential in HWSN. The considered path is split into concentrated areas in which ordinary nodes and super nodes are positioned simultaneously in the near and furthest areas of the BS. The advance sensor nodes are organized in the area among the binary regions. The normal sensor nodes and the super nodes transmit their packets straight to the BS and the advance sensor nodes adopt the clustering created method. The CH selection is dependent on the node's remaining power and the average power of the network. In [36] demonstrates enhancement, in terms of throughput and network life span. Nonetheless, direct communication may not be a better choice for super nodes, which are distant from the BS, the chance of deterministic placement of nodes may not be available.

M. SEECP

In [37] the researcher developed SEECP, a reactive routing protocol with threshold value based on data transfer nodes identical to [26]. Based on the node's remaining power a fixed set of CHs is deterministically picked. It considers dual-hop transmission between CH and BS to decrease the transfer power of faraway CHs not lying within an appropriate. [37] Displays increased efficiency, in terms of stable region and variance in strength.

N. BEECP

In this article [38], a new approach for CH selection in HWSNs founded on biogeography-based optimization has been anticipated. BBO is a famous evolutionary algorithm used to resolve numerous composite real-world issues. BBO defined three key operators namely "elitism, migration, and mutation". In the approach investigated, the "fitness function" for BBO was modified on the root of the cluster size and the distribution of CHs in the network area. The density must be diminished to create compact clusters such that each node can transmit data to its respective CH with minimum distance while the distribution of CHs should be greater to effectively cover overall network zones.

O. P-SEP

In [39] the author proposed P-SEP, to extend the stability period of fog sustained HWSN. [P-SEP] considers normal nodes to be arbitrarily arranged and the advanced nodes to be placed at the predefined location. It allows an entirely distributed and appropriate selection of CHs depending on the sort -specific weighted probability of the node, considering the average power nodes int the current round, the initial energy of advance nodes, etc. [39] shows enhancements in terms of stability periods and data transfer rate. Though, the predefined assignment of the advanced node might not be feasible in some environments as it needs the approachability of the application placement zone.

P. DSEP-FL

This paper [40] suggests a novel protocol DSEP-FL that expands D-SEP by means of the Fuzzy Logic method. Fuzzy logic takes real-time verdicts with the incorrect info. The BS picks the node as CH having higher energy by means of four parameters that are nodes energy level, distance from BS, the concentration of network nodes, and criticality w.r.t. the whole CH. This article investigates the DSEP protocol using DSEP-FL cluster head by keeping 4 parameters such as energy, centrality, concentration, and distance to BS.

Q. FECR AND FEAR

In [41] the researcher suggested FECR and FEAR protocol for fog supported and two trier HWSN. The choice of CH is based on the role of likelihood taking into account the initial power and present power of the node. The CHs transmit their data to the adjacent fog node, which further processes and route the collaborative data before transmitting it to the cloud. The methods show enhanced energy and network lifetime.

R. DEECIC

The DEECIC [42] balances energy utilization and transmission delay for the connectivity and diminish latency from a node to its CH, DEECIC enables dual-hop communication from each device to its cluster head.

When two nodes are within the communication range of one another, they are assigned a neighbour and a sensor node degree represent the entire number of peers a sensor node displays a node density. It may be observed that there may still be some nodes that do not belong to any cluster after CH selection due to the random distribution of nodes. In [42] enables the creation of clusters from un-clustered nodes and arbitrarily picks 4-byte integers as their ID.

For a particular group of CHs, they can organize the remaining of the devices into distinct clusters in order to decrease energy ingesting and expand the lifespan of the network. Compared to other nodes, cluster heads use more energy the number of cluster heads should be minimized. Decreasing the sum of clusters while preserving the whole coverage area is precisely equal to increasing the average cluster size. Nevertheless, devices installed in dense zones can be picked as cluster head since the failure of a sensor node from such areas would not interfere with the entire network coverage due to the maximum coverage duplication of the coincided monitoring zones enclosed by the sensor node's peers. In certain scenarios, distributed sensor nodes in dense areas or at the boundary of the network cannot correspond directly with cluster heads because of the restraint of cluster transmission distance. In [42], transmission among a CH and a network node beyond the communication distance of CH is attained through intermediate sensor nodes.

S. WBCHN

The WBCHN [43] is a distributed algorithm in HWSN focused on three issues: remaining power, number of active peers and distance from BS.

This algorithm estimates outstanding power in the network by employing the approximation technique. In the subsequent round, each network node with a power greater than average power utilization and predefined cut-off energy, announces itself as a CH. Every node sends a group message to all its peers active in the subsequent period at the end of the period. Then each sensor node sends each weight in the current period to their neighbours forecasting energy consumption. In order to forecast power utilization, the number of active peers' nodes, it broadcast its announcements to its peers. Other network sensor nodes connect to a CH with the highest power utilization.

T. EHE-LEACH

EHE-LEACH [44] is an extension of [8] proposed in HWSN to maximize the node's lifetime. In [44] a predetermined threshold value is set for intra cluster and inter-cluster transmission. Nodes close to BS transmits to the base station directly, and network sensor nodes away from BS send their packets to the base station through clustered based communication. In this article, a static threshold is adopted to portion the network. Low threshold connected devices send their packets straight to the base station, and sensor nodes further back from the set threshold are clustered and their data is sent hierarchically to BS. This enhances the lifespan and stable region of the network. In nodes far away from the threshold, cluster heads are nominated randomly.

U. FUZZY

In [45] the researcher investigated the shortest path assessment using fuzzy logic which employs a fuzzy logic mechanism for data transfer in WSNs. It explores the idea of a pool manager node that is placed close to the source node and has infinite memory, computational power, and energy restrictions. Whenever data is to be communicated, the source node transmits a request to the PM to choose the shortest route to the designated receiver node. The PM transmits knock advertisement messages to all of the network nodes, and it determines the least delay path and notifies the source node about it based on the time delay of each reply received. The scheme lacks the nodes ' residual energy; this will affect the entire performance of the whole network.

V. ECCA

Energy centroid clustering algorithm [46] is an energy-efficient clustering algorithm. In thus protocol the energy threshold has been proposed for WSN. Here each cluster is arranged to own 25% of the sensor nodes by utilizing distance centroid algorithm. Cluster head selection is based on the energy centroid of each cluster and the energy threshold of the sensor nodes. For optimal dissipation of energy between the CH and the sink node distance of separation is used as a parameter.

W. AZ-SEP

For CH selection, the distance from the hubs to the base station, peers, and the number of peers is assumed in contrast to the remaining energy the researchers implemented an established advanced zonal stable election protocol (AZ-SEP) at [47]. It splits the network zone into three regions but the dimensioned of zones is not defined. The communication amongst nodes and the BS is hybrid either direct communication with the BS or multi-hop transmission amongst CHs towards the BS. They suggest that the network nodes of the nearest region transmit data directly to the BS. However, the nodes of the other regions assemble in clusters. The designated CHs then transmit data to BS.

X. UCA

In [48] the authors proposed a protocol called the enhanced unequal clustering algorithm (EUCA). This protocol is the enhanced form of the UCA protocol. In UCA protocol CHs closer to the BS has to forward more data as compared to the other so the energy of the CHs closer to the BS drain out very quickly and causes the hot-spot issues. In this protocol, we have enhanced the UCA protocol in-order to overcome this burden. The clusters closer to the BS are smaller in size as compared to the far away from the BS so that less energy is consumed in this case.

Y. EECPK-MEANS

In [49], the author has provided the explanation of the structure model, optimized solution for the selection of CH node and efficient energy usage while communication with the sink node. Midpoint initialization algorithm is utilized for selection of CH sensor node for improvement of network lifespan. But it fails to determine energy optimized CH sensor node at stage of basic cluster formation. This algorithm deals with the remaining energy of sensor nodes for CH selection.

Z. CREEP

In a recent research [52], the investigators introduced a Tree-Based Energy Balance Routing in which each node identifies its parent between its peers depending on the transmission distance among the nodes and the BS, the remaining energy level of the nodes, the energy needed to transfer the data to the BS, and the number of dependent child sensor nodes. The researchers assume that this results in uniform use of energy and provides a better strategy for energy balance relative with the other traditional routing protocols.

XIII. Open Issues

This article analyses the performance of some selected heterogeneous protocols in terms of, energy efficiency, cluster head selection parameter, data transmission, network lifetime, stable region and unstable region Though the existing protocols have successfully enhanced the network lifetime still there are open issues which need to be addressed.

A. OPTIMAL CLUSTER HEAD SELECTION PER ROUND

The networks become unstable when the nodes tend to die, and optimal CH selection criteria [53] become void. Since the energy dissipation of the CHs is almost twice as compared to other nodes due to an extra number of CHs the energy depletion of the network is increased, and the network lifespan is decreased.

B. NODE DEPLOYMENT

In heterogeneous clustering, the nodes having more energy levels are chosen as CH. Since HWSN are comprised of multi-tier nodes having different energy levels, random organization of the sensor nodes is not a feasible solution. However, the node deployment [54] significance on the lifespan of the devices in a randomly deployed network has been mainly unaddressed in clustering protocols. Subsequently in clustering protocols long haul transmission is involved, the inappropriate deployment of the nodes will affect the network coverage, transmission rate and as well as lifetime of the overall network, making the nodes deployment vital problem in clustering protocols.

C. CLUSTER COMMUNICATION RANGE

The cluster communication range and the comparative CHs vicinity to the BS are vital problems that need be considered [42, 43]. Cluster range is typically restricted and due to which a CH might not be capable to connect with the BS, even if it is directly connected with the BS [50, 51].

D. CLUSTER HEAD FORMATION OVERHEAD

Cluster member nodes have various framework to join a suitable cluster The main challenges of cluster formation head formation is, cluster member distance, number of hops, cluster size, cluster head overhead, cluster head distance.

a) CLUSTER MEMBER DISTANCE

The transmission distance between the cluster member and its CHs affects the power depletion of the network. The cluster member connects with the nearest CH based on the minimum distance. Due to random deployment, the location of the node may be located at a distance from the CH, so it will use extra energy to convey its data to the CH as related to other cluster members.

b) NUMBER OF HOPS

It depends on the network scenario to connect directly or indirectly with the CH based on the number of hops between them i.e., single or multiple nodes [55]. The number of nodes between the CMs and CH affects the CH selection

c) CLUSTER SIZE

The cluster size plays a critical part in the stability of the network and energy efficiency. If the cluster size is not optimal it could lead to serious energy issues. The cluster with the maximum number of CMs will lead to high energy ingesting [44].

d) CLUSTER HEAD OVERHEAD

The CH selection process introduces additional overhead in the network which is also the source of energy depletion. The volume of CH overhead is dependent on the parameters related to the CH election, cluster formation and network complexity.

e) CLUSTER HEAD DISTANCE

The CHs performs multiple tasks, it communicates with its cluster members and also with the BS. Since the cluster head is involved in long haul communication, its energy is depleted faster, and the rate of energy depletion is higher the intra-cluster communication distance is maximum.

XIV. CONCLUSION

This article provides the overview of overall clustering process in HWSN, cluster heads selection plays a vital role in the enhancement of the network lifetime, besides the CH selection parameters other parameters like Intra and inter-cluster communication, an optimum number of CHs per round and data transmission should also be considered for the improvement of network lifespan.

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