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An Extended Low-Energy Adaptive Clustering Hierarchy Routing Protocol for Efficient Energy Consumption in Wireless Sensor Networks

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Abstract—In wireless sensor networks (WSNs), a primary objective is to extend the lifespan of sensor nodes. Cluster head selection algorithms play a crucial role in electing and rotating cluster heads among nodes, significantly impacting the network's energy utilization. Over the years, various energy-efficient routing protocols have been developed to reduce energy consumption and thereby prolong the network's lifespan. Current energy-efficient routing protocols, such as HEED, TEEN, APTEEN, SHPER, and LEACH, have not fully addressed the challenge of energy consumption in WSNs. LEACH, which stands for Low Energy Adaptive Clustering Hierarchy, is a well-known clustering protocol designed for energy-efficient data gathering in WSNs. However, the processes of selecting cluster heads and the effectiveness of data aggregation in the basic form of LEACH can be complex. This study aims to develop an extended version of the Low Energy Adaptive Clustering Hierarchy routing protocol that employs an extended K-Means Cluster Head Selection Algorithm to choose cluster heads more effectively. The developed protocol is intended to enhance the longevity of WSNs. A quantitative approach has been utilized to measure performance by simulating various routing protocols. To demonstrate the advantages of the proposed protocol, we compared it against previous protocols using several metrics, including residual node energy, packet delivery ratio, throughput, network longevity, average energy consumption, and the number of live and dead nodes. The results indicate that the proposed protocol outperforms existing protocols, such as LEACH and SEP.

Index Terms—APTEEN, Base station, Cluster Head, HEED, LEACH, nodes, parameters, SHPER, TEEN, Wireless Sensor Network

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I. Introduction

A Wireless Sensor Network (WSN) is made up of thousands of small, low-cost, low-power smart sensor nodes that possess sensing, signal processing, and communication capabilities. These nodes work together to monitor physical and environmental factors such as humidity, temperature, motion, pressure, and water levels across various terrains. The sensors are distributed randomly throughout the area for effective data collection regarding their surroundings. One of the main characteristics of WSNs is that the nodes are equipped with processors that manage the transmission of information to the Base Stations, which are designated sensor nodes. These processors allow for simple processing of data, enabling the conveyance of critical and partially processed information. Additionally, since the network bandwidth is shared among the sensor nodes in the network, the routing protocols need to be smart. This ensures efficient collaboration among nodes, helping to conserve bandwidth and thereby reduce energy consumption. [2].

The nodes in wireless sensor networks (WSNs) are battery-powered and have limited processing abilities. Once deployed in an environment, these nodes remain fixed in their locations. Replacing batteries can be expensive, making the lifespan of wireless sensor networks a challenging yet promising area of research. The energy needed for data transmission is significantly greater than that required for processing, so it's essential to minimize the movement of data between nodes to extend the network's lifespan. [3].

Enhancing energy efficiency is crucial in Wireless Sensor Networks (WSNs), making the creation of power-efficient protocols vital for extending their lifespan. A key strategy for organizing WSNs and prolonging their operational lifetime is through network clustering. HEED [4], TEEN [5], DD [6] and LEACH [7] are examples of the WSN routing protocols that have been developed over the years. There is a need to extend the lifespan of sensor networks.

Low Energy Adaptive Clustering Hierarchy (LEACH) is a WSN procedure that uses clustering methods to distribute cluster head responsibilities across all nodes. [1]. According to [1] "The cluster head selection procedure relies on probability technique, which leads to significant overhead and increase in power consumption which are serious flaws in LEACH." It works pretty well when nodes are homogeneous, but in heterogeneous sensor networks, it does

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not stand well because low-residual-energy nodes fail faster compared to high-residual-energy nodes [8]. Choosing the cluster head is crucial for network performance and lifetime improvement.

This paper presents the X-LEACH protocol, an enhanced version of the Low Energy Adaptive Clustering Hierarchy (LEACH). The protocol integrates the Extended K-Means Cluster Head Selection algorithm with the traditional LEACH routing protocol. This combination aims to extend the network's lifetime by ensuring that all generated clusters maintain a uniform number of nodes.

The structure of this study is organized as follows: Section 2 reviews related works; Section 3 outlines the methodology; Section 4 details the Proposed Extended Low-Energy Adaptive Clustering Hierarchy Routing Protocol; Section 5 discusses the results; Section 6 presents a discussion; and Section 7 concludes with findings and suggestions for future work.

II. RELATED WORK

In this section, we provide a comprehensive review of the current energy-efficient routing protocols in WSN, highlighting their limitations and the criteria they use to select cluster heads.

Younis and Fahmy [1] Proposed a “Hybrid Energy-Efficient Distributed Clustering (HEED)” method to increase network lifetime and allow dynamic scalability. This technique was created for homogeneous WSNs and employs two criteria to determine cluster heads: residual energy and node density. [2]. According to [3]“In this protocol, the CH is chosen regularly based on a combination of residual energy and node degree. It extends the basic LEACH scheme by using residual energy as the primary parameter and network topology features (e.g., node degree and distances to neighbors) as secondary parameters to break ties between candidate cluster heads as a metric for cluster selection to achieve power balancing. The clustering process is divided into iterations, and in each iteration, nodes that are not covered by any cluster head have their chances of becoming a cluster head doubled”. These energy-efficient clustering protocols allow each node to independently and probabilistically decide its role within the clustered network; however, they cannot guarantee an optimally selected set of cluster heads.

When the HEED protocol is executed on nodes, each sensor node generates a random number between zero and one. If this number is less than or equal to the node's Cluster Head (CH) probability, the node will tentatively become a Cluster Head and send alert messages to its neighboring nodes. The likelihood of becoming a CH is calculated as follows [4].

$$E_{prob} = C_{prob} \times \frac{E_{residue}}{E_{max}}$$

[4]

where $E_{residue}$Is the remaining energy of nodes, E_{max}Is the maxmum energy when the battery is filled, and C_{prob} Indicates the main percentage of the number of CHs which is originally set to 5 %. If multiple candidates are applying for the CH position, the ones with the lowest communication costs will be selected. [4].However, in intra-cluster communication, the cluster protocol fails to achieve the lowest energy utilization. Furthermore, clusters created by HEED are unbalanced. [1].

In [5] “Threshold Sensitive Energy Efficient Sensor Network (TEEN) Routing Protocol was developed. At every cluster change time, the cluster head sends attributes to its members. [5]. Nodes are always aware of their environments. When a parameter from the attribute set reaches the hard-threshold value, the node activates its transmitter and sends the detected data. At the node, the sensed value is recorded as a sensed value internal variable (SV).” These protocols have the advantage of delivering time-sensitive data to users almost instantly. Due to the characteristics being broadcast anew at each cluster change, and allowing the user to make adjustments as needed, this technique is well-suited for time-critical data-sensing applications. However, the TEEN protocol has a flaw. [5]: If the thresholds are not met, the nodes cannot interact, resulting in the user obtaining no information from the network, even if all the nodes have failed. Thus, this method is unsuitable for applications where users require information frequently. A practical implementation of this strategy must also ensure that the cluster remains collision-free.

TEEN was improved, and the Adaptive Threshold Sensitive Energy Efficient Sensor Network (APTEEN) According to [6] “the routing Protocol (APTEEN) records routine data collection and responds to time-sensitive occurrences. The cluster heads transmit the attributes, threshold values, and transmission schedules to all nodes as soon as the base station creates clusters. The next step is data aggregation, which is performed by the cluster heads and results in energy savings”. The main advantage of APTEEN over TEEN is that nodes consume less energy. However, APTEEN's complexity and the longer waiting times are significant drawbacks.

Al-Karaki et al [7] Proposed a Virtual Grid Architecture Routing Protocol. The “VGA integrates data aggregation and in-network processing to maximize network longevity and improve energy efficiency [7]. The two phases of the overall plan are the clustering and routing of aggregated data. Because most applications require stationary sensors, the sensors are organized in a fixed topology during the clustering phase. A cluster head, sometimes referred to as a local aggregator, performs an aggregation within each cluster. To perform global or in-cluster aggregation, a subset of these Local Aggregators (LA) is chosen, and its members are referred to as master aggregators (MA). Some heuristics are put forth in the data aggregation phase, which can provide a quick, effective, and nearly perfect answer. The fact that LA nodes create overlapping groups is an illustration of a heuristic. Consequently, the reading of a group’s members may be associated”. The main advantage of this protocol is its potential to enhance network longevity and energy

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efficiency; however, selecting local aggregators as master aggregators optimally remains NP-hard.

According to [8] "To the Scaling Hierarchical Power Efficient Routing (SHPER) Protocol (SHPER) protocol, a base station and a collection of uniform sensor nodes must cohabit. These nodes were randomly dispersed throughout the defined area of interest. The sensor field was located far from the base station. The base station and the collection of sensor nodes should both be fixed in place". Owing to its limitless power source, the base station can also transmit at sufficiently high power to reach all network nodes. [8]. The first advantage of this protocol is that it provides cluster leadership and at the same time assesses the residual energy of the nodes, allowing energy to be balanced and the power depletion to be shared much more evenly in the same nodes. Moreover, data routing is also developed by utilizing a route selection criterion that uses the energy level of both the nodes and the other communication costs of several potential routes. However, the mobility of the nodes was not supported.

Power-efficient Gathering in Sensor Information Systems Routing Protocol (PEGASIS) overcomes the overhead problem of LEACH by allowing close connections between neighboring nodes. [9]. "Data are transmitted in turn from the base station to the base station. The lifespan of sensor nodes has been extended by using a combination of chaotic evolutionary algorithms and fuzzy logic. Three variables, density, energy, and centrality, were used to develop fuzzy logic. Combining these three characteristics aids in identifying the best nodes as cluster head candidates, and the proposed genetic method is used to determine the cluster head position". The suggested approach has a flaw in that it lacks knowledge of cluster formation and energy utilization. [9]. Another drawback of PEGASIS is redundant data transmission. This issue arises because, when one of the nodes is chosen as the head node, the location of the base station about the nodes' energy is ignored. [10].

The Stable Election Protocol (SEP) [11] "Is a hierarchical routing protocol for heterogeneous WSNs with two energy-layered nodes, normal and advanced, which boosts the stable period during the clustering hierarchy process. SEP is a dynamic protocol in the sense that two energy-normalized nodes are deployed randomly. Furthermore, during each cluster head election round, nodes elect themselves as cluster heads based on their initial energy about the energy of other nodes, without the need for global knowledge of the residual energy. SEP obtains the network lifetime extension. Furthermore, global knowledge of residual energy is not required during the round of cluster head election". Its disadvantage is that cluster heads are chosen solely based on their starting energy levels [12].

Heinzelman et al. proposed [13] "Low Energy Adaptive Clustering Hierarchy (LEACH) is a well-known clustering approach. The LEACH algorithm uses a random rotation of the cluster head selection to equitably distribute energy among nodes in a WSN. [14]'. According to [15], "The Stable Election Protocol (SEP) improves LEACH by populating a ratio of SNs with more energy than the remaining nodes in the same network, as LEACH is achieved in standardized types of WSNs." Because of these upgraded nodes, the network is heterogeneous in terms of node energy. In SEP, election probabilities are based on a node's initial energy compared to the energy of other nodes in the network.[16]. This process restricts the lifetime of WSNs since conveying acquired data is more expensive in terms of energy resources in an energy-constrained environment.

From the study [17] and [16] "LEACH can extend the network lifetime by 15% when compared to the general multi-hop routing protocol and static clustering method, and the average proportion of relay communication is accomplished by random selection". This is shown in Figure 1.

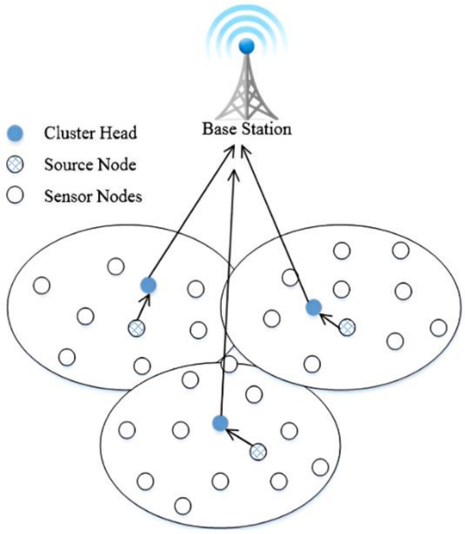

Fig.1. LEACH Clustering Structure Protocol [18]

The LEACH operations are separated into two phases and are divided into rounds. [19] as shown in Figure 2.

Setup phase: Cluster Head (CH) selection phase, Cluster setup phase, and cluster scheduling.

Steady Phase: Data Aggregation, Compression and Data Transmission

The set phase is divided into three sub-phases as shown in the diagram below: advertisement phase, cluster setup phase, and broadcast schedule phase.

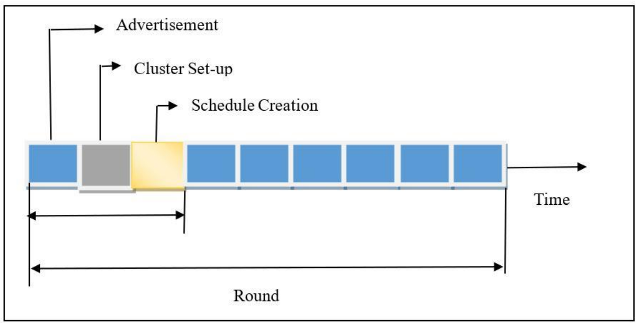

Fig. 2. LEACH Phases

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According to [20] "nodes organize themselves into clusters during the setup phase. Each node makes a P probability decision to become cluster leader and communicates that decision. Each node selects a T number at random (between 0 and 1). If the T number in the equation is less than the threshold in the formulas below, the node in the current cycle round will become the cluster head [20]":

$$T(i) = \begin{cases} \frac{P}{1-p\times\left(r \bmod \frac{1}{p}\right)} & , i \in G \\ 0 & , otherwise \end{cases}$$

[20]":

Where P is the required percentage of cluster head nodes in all sensors

r is the current round number,

G is the set of nodes that are not cluster heads in the previous 1/p round.

Following" the selection of all cluster heads, a message is sent to all other nodes, and non-cluster head nodes choose which cluster to join. Each node chooses a cluster that allows it to communicate with its associated cluster head while consuming the least amount of energy. Non-cluster head nodes will pick up the strongest signal from the cluster head and join it. Each node sends a signal to the head cluster identifying its membership after joining. Once the cluster has been built, the setup process is complete. Network performance is divided into time frames during the steady state phase, with each frame consisting of all nodes in a cluster relaying their data to the head cluster in a predefined period. The length of a time frame is dictated by the number of nodes in the cluster because each node's time shear durability is constant. For its member nodes, the cluster head prepares a TDMA (Time Division Multiple Access) schedule. This lets member nodes conserve energy by lowering their receiving radiations throughout the round schedule for data exchange. When a predetermined length of time has passed, this round end and a new round begins, rotating cluster head duty between cluster nodes and balancing the load. [21]".

The steady phase [21] Consists of the following steps: Sensor nodes begin sensing and transmitting data to cluster heads, which then add up and relay the data to the base station. The network then restarts the setup phase and begins a fresh round of cluster-head selection once a specific amount of time has passed. The flowchart in Figure 3 depicts how Cluster heads are chosen in each phase of the LEACH process.

Some of the major advantages of the LEACH protocol include a kind of confidential routing protocol with an exceptional degree of network, which makes cluster members' jobs easier and eliminates the need to retain complex routing information, lowering the amount of routing control information [9].

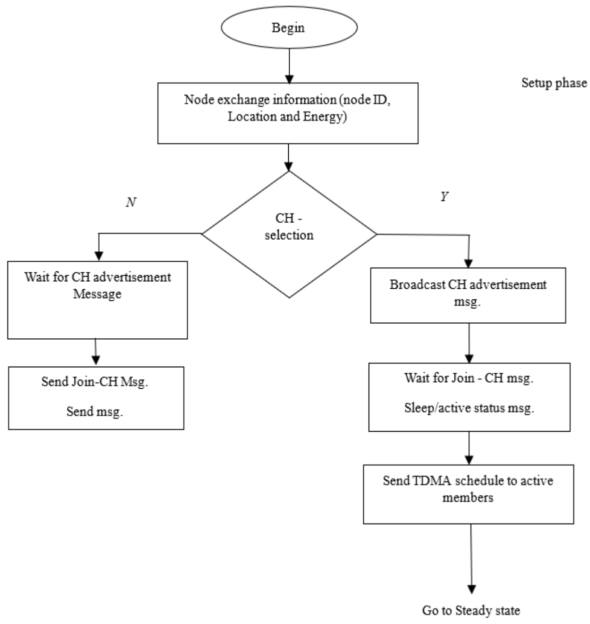

Fig. 3. Flowchart of LEACH Cluster Head Selection Algorithm

Furthermore, the LEACH algorithm selects cluster heads at random and rotates them so that the increased energy consumption is spread throughout the network, extending the network life cycle. [23]. Finally, the LEACH protocol's scalability is arranged. However, LEACH has some limitations which include:

In LEACH, the CH (Cluster Head) selection procedure ignores the node's leftover energy (residual energy function) or location about the CH and BS (Base Station). This method of CH election is unsuccessful at assuring proper CH selection because nodes located further away from the BS and those with lower residual energy are more likely to be chosen as CHs. [24]. As a result, it chooses CH at random, disregarding remaining energy or the elected CH's hop count concerning BS. [25].

There are two energy-utilization shortcomings for cluster heads in LEACH, which is another constraint. The first is the hotspot problem, which occurs as a result of more cluster head tasks that raise their energy consumption. From the study "LEACH protocol proposes a well-planned rotation of the cluster head role among all nodes in a cluster, ensuring that each node serves as a cluster head exactly once during the lifespan of the WSN, but this solution does not address the issue of additional responsibilities". LEACH attempts to balance the long-term energy consumption of all nodes in each cluster in this fashion. This protocol, on the other hand, does not account for the increased energy consumed by nodes during cluster head service. [26].

Sensor nodes broadcast duplicated data to cluster leaders, which is another inefficiency. As a result, the cluster heads are overworked. Faulty node management can result in nodes consuming more energy during cluster head service, as well as providing duplicated data to cluster heads. [26]. LEACH also faces the issue of not knowing how many cluster heads

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are in the network. When the Cluster Head dies, the cluster becomes useless because the data acquired by the cluster nodes never reaches its intended destination. Base Clusters are divided at random, resulting in an unequal distribution of Clusters. [27].

Another disadvantage of the LEACH protocol is that the cluster head not only receives and fuses data from cluster associates, but also sends it to the BS, increasing the energy consumption of the node's ordinary members and, by extension, the network's overall energy consumption. The network node consumption rate is negotiated if the head cost is increased. [28].

In addition, [28] The LEACH protocol works well for small-scale wireless sensor networks, but it is not ideal for larger networks. Because the original data is successfully transferred to the cluster head and then communicated to the BS in a single hop, the cluster member, cluster head, and BS must all be in communication range.

In addition, [24] Multiple cluster heads may be placed close together in LEACH, reducing clustering efficacy and forcing cluster members to send to cluster heads located far away. Furthermore, LEACH's clusters are unequal, with the cluster head not positioned in the center of the cluster member nodes. These clusters require more energy during intra-cluster communications because they increase the overall transmission distance between nodes and the cluster head.

According to many research, LEACH is the optimum technique for conserving energy and extending the lifetime of WSNs [30] . As a result, several LEACH variants have emerged to capitalize on LEACH's advantages while minimizing its drawbacks. The enhancements to LEACH and their downsides are discussed in Table 1.

The limits of LEACH have been discovered by the researcher, and numerous variants of LEACH procedures have been produced to address these shortcomings. However, additional study is needed to find a more efficient, scalable, and robust clustering technique that will reduce energy consumption and increase network lifetime in both small and big WSNs [31].

TABLE 1: COMPARES SEVERAL LEACH PROTOCOL VARIATIONS:

Author	Proposed Algorithm	Communication pattern	Advantages	Limitations
Khan et al. (2013)	Ad-LEACH	Single hop	The network life duration is increased by 66% compared to LEACH. Increases the number of rounds from 1500 to 2500.	The cost of surviving in an unstable environment is 40% more than the cost of servicing in a LEACH environment.
Dakshayini et al. (2013)	E-LEACH	Single hop	By properly selecting CH, the radio transmission range is reduced. The number of rounds is 200 percent higher than LEACH.	The network should be GPS-enabled to maintain track of the node's location.
Nguyen et al. (2008)	LEACH-C	Chain based	The number of data obtained at the base station is 8% higher than LEACH.	If the nodes are portable, the performance is poor.
Arumugam et al. (2015)	EE-LEACH	Single Hop	The amount of energy utilized is reduced by up to 43% for 100 nodes and 44% for 200 nodes.	CH should be evenly distributed.
Taneja et al. (2013)	TLHCLP	Multipath model	For 100 nodes, the node lifetime has increased by 20-42%.	The algorithm should ensure that all nodes join the cluster.
Gupta et al. (2012)	LEACH-A*	Chain based	The network's life is extended by 80%, and throughput is increased by 1.2 times when compared to LEACH.	To reduce energy usage, a multi-path route algorithm based on energy hops is developed.

III. METHODOLOGY

A. *Simulation Environment*

A structured algorithm and flow chart were used to develop the Extended Low Energy Adaptive Clustering Hierarchy (X-LEACH) routing protocol. A simulation experiment was conducted with MATLAB R2017a to evaluate and compare the proposed Extended Low Energy Adaptive Clustering Hierarchy (X-LEACH) routing protocol with other benchmark protocols.

A sensor network made up of 100 sensor nodes was deployed in a field with an area of 100mx100m, with each node initialized with 0.5 Joules of energy, a data packet of size 100 bytes, and 2000 rounds. A summary of simulation parameters is shown in Table 2.

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TABLE 2: SIMULATION PARAMETERS

Parameters	Values
Sensor deployment area	100 M*100 M
Base Station Location	50M * 50M
Number of nodes	100
Data packet size	100 bytes
Control packet size	25 bytes
Initial energy	0.5J
Maximum number of rounds	2000
Aggregated packet size from cluster head	500 bytes
Electronics Energy	50nJ/bit
Free space factor	10, 255 pJ / bit / m2
Multipath factor	0.0013, 0.0050, 0.0063 pJ / bit / m4

Figure 4 depicts an illustration of the simulation parameters of 100 nodes and a base station distributed at random in geographical areas of X and Y coordinates measured in meters.

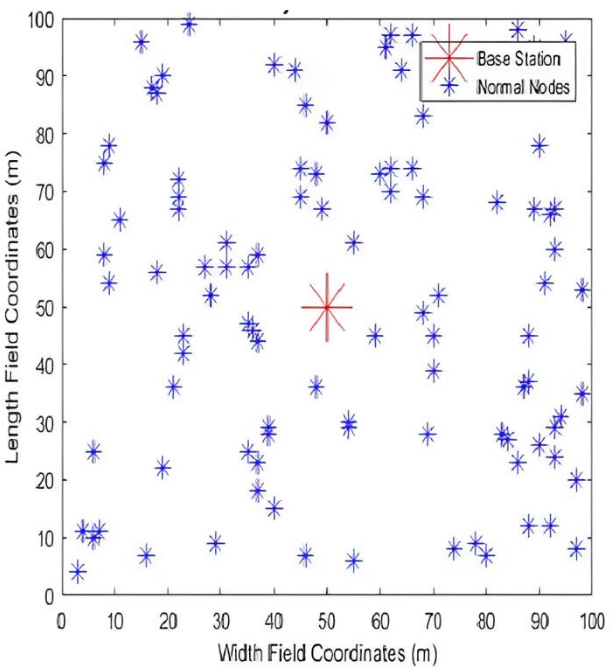

Fig. 4. Simulation setup

B. *Performance Metrics*

In this research, the performance of the X-LEACH routing protocols has been analyzed based on several performance metrics: the number of live nodes, the number of dead nodes, the average energy consumed, network lifetime, throughput, the number of packets transferred to CH, and remaining energy.

IV. ROPOSED EXTENDED LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY ROUTING PROTOCOL

A. *The Architecture of the Proposed Routing Protocol*

The architecture of the expanded Low Energy Adaptive Clustering Hierarchy Routing protocol includes base station normal nodes, the elected cluster head, and the centroid. Figure 5 depicts this. The cluster head is that node that is nearest to the K-Means centroid and also fulfills all other parameters. These parameters include remaining energy, the distance between node and base station, the distance between nodes and neighbor's nodes, node density, node degree, received signal strength indicator (RSSI), and Signal Noise Ratio. Compare routing methods based on performance criteria such as [32]. These metrics are discussed in Table 3.

TABLE 3: PERFORMANCE METRICS

Metrics	Description
Number of live nodes in the network	These are the nodes that remain alive at the end of the simulation. At the end of the simulation, a significant number of active nodes improves network efficiency.
Number of dead nodes in the network	This is determined by the number of nodes that have used up all of their energy. The network's efficiency is determined by the low number of dead nodes at the end of the simulation.
Average energy consumption:	This is the overall amount of energy utilized by nodes when transmitting and receiving data.
Network lifetime	The amount of time that a network remains operational is referred to as its lifetime. It has also been referred to as the time interval between the deaths of the first and last nodes. As the network remains operational for a longer period, more data is exchanged.
Throughput:	This is the average number of packets received per round by the base station and cluster heads and nodes to cluster heads.
Packet delivery ratio	The ratio of packets received by a destination node (R1) to packets generated by a source node (R2).
Number of clusters formed per round	This shows the number of clusters formed per round.

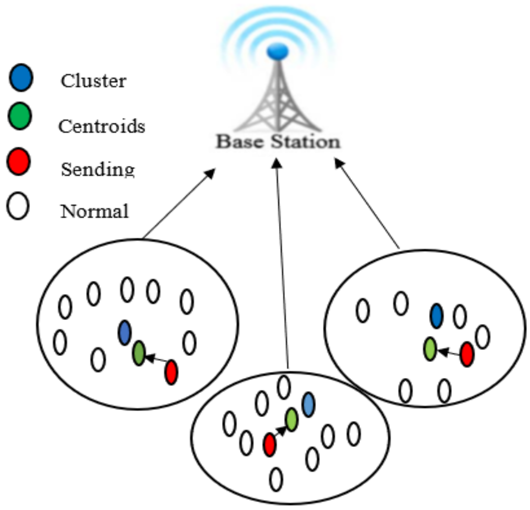

Fig. 5. Architecture of X-LEACH

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B. *Operation of the Proposed Routing Protocol*

The Extended Low Energy Adaptive Clustering hierarchy (X-LEACH) routing protocol's operations are similar to the original LEACH in that they are separated into two phases. The setup phase and the steady phase constitute the two of these phases.

The setup step of X-LEACH is separated into three phases: advertisement, cluster setup cluster election, and broadcast. While in a steady state, there are three phases: data aggregation, compression, and transmission.

The first phase is the cluster head advertisement phase. During cluster head advertisement, one node acts as a cluster leader in the current cluster. Before the next round of operation, the current cluster head has to advertise a message for the centroid to nominate a new cluster head for the next round of operation. The advertisement, unlike in traditional LEACH, will be forwarded to the centroid, not all other nodes. The centroid will collect, intern, the information of all nodes in the cluster including nodes and centroid distance, remaining energy, distance from the node to the base station, the distance between nodes and neighbors' nodes, node density is the number of nodes around a particular radius, node degree is how many nodes identify as neighbors, received signal strength indicator (RSSI), and Signal to Noise Ratio. This, the centroid does by broadcasting a message to all its neighboring nodes. This extracted information will then be used in the second step for leader selection.

The second step is cluster setup and cluster head election during the setup phase, using the selection algorithm known as Extended K-Means. The selection algorithm primarily initiates this with the initialization of k centroids with K-Means. This involves the generation of k centroids through K-Means clustering, which is carried out by dividing WSN into k clusters. After specifying an initial value of k, the algorithm starts by randomly choosing k cluster centers. Every data point will be assigned to a cluster based on the most similar centroid, using some distance metric like Euclidean distance. Finally, for each cluster, it updates the centroid to be the average of the data points that are part of the cluster. The procedure repeats itself by reassigning the data points to groups and updating the group centroids until convergence occurs. In the end, print centroids and clusters. Once a centroid and clusters have been printed out, a node is assigned to its cluster based on the decision which is based on the closeness of nodes. The final step is selecting cluster leaders, assessment, and preparation of a transmission schedule. Cluster leaders should be as close as possible to the centroid, and the centroid should consider other parameters like remaining energy, the distance between node and base station, the distance between nodes and neighbors' nodes, node density, node degree, Maximum Cluster size, received signal strength indicator RSSI, and Signal to Noise Ratio. After the selection of a cluster head within a cluster, the responsibility of developing and maintaining a TDMA schedule falls upon the heads. The rest of the nodes within that cluster are cluster members. Here, in the above-mentioned parameters, the elected cluster head is supposed to have a higher threshold value than the other nodes.

Thirdly, at this stage of setup, transmission schedule preparation will be done. It is meant to avoid nodes submitting the collected data to cluster heads at the same time and hence causing collision. The collision can be avoided by allowing each node to have a time window. To provide an appropriate time slot in each node, a Time Division Multiple Access system was used where time slots were assigned to each member node for it to transmit data. Due to this, each member node will only wake up during sensing and transmission, and sleep during all remaining times, hence guaranteeing that nodes save energy for the elongated life of the Wireless sensor networks.

Figure 6 illustrates that the set phase is divided into three sub-sets of phases, namely, advertisement, cluster setup, and schedule generation. The cluster setup phase is further divided into three stages: assignment of nodes to clusters; and cluster head election within k-formed clusters, whereas the newly proposed LEACH contains three phases in which the setup phase fails to sub-divide the cluster setup phase.

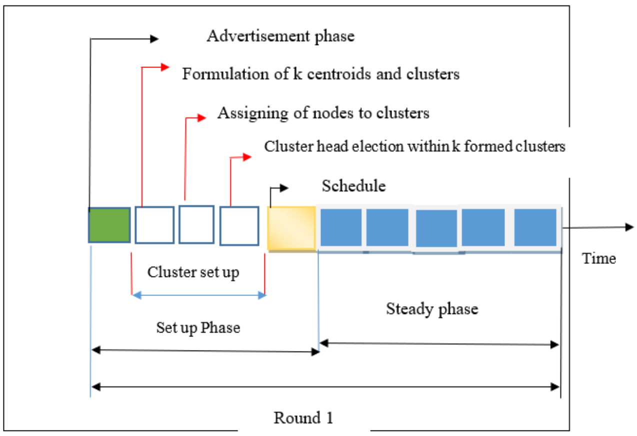

Fig. 6. X-LEACH Phases

A. *The Proposed X-Leach Design*

The researchers developed the Extended Low Energy Adaptive Clustering Hierarchy (X-LEACH) protocol, which combines the LEACH protocol with the Extended K-Means Cluster head selection (EKCHS) algorithm described in the preceding chapter. By providing a new cluster head selection mechanism, X-LEACH enhances the original LEACH procedure. The original LEACH protocol randomly selects nodes to be Cluster Heads, which can result in uneven energy consumption among nodes, leading to node deaths and unstable WSN The X-LEACH overcomes this problem by employing a more advanced cluster selection technique that depends on each node's remaining node energy, density, degree, maximum cluster size, RSSI, and SNR, as well as the K-Means machine learning algorithm. The node closest to the centroid with the highest threshold value in all parameters in the extended K-Means cluster selection process is chosen as

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the Cluster leader for each round in extended-LEACH. This strategy contributes to ensuring that Cluster leaders are evenly distributed in terms of energy consumption, hence extending network lifetime. The researcher employed step-by-step techniques and flow charts to build the Extended Low Energy Adaptive Clustering Hierarchy (X-LEACH) routing protocol. The process below shows step-by-step pseudocode for the Extended Low Energy Adaptive Clustering Hierarchy (X-LEACH) Protocol.

Algorithm for the proposed routing protocol (X-LEACH)

Step 1. Initialize the network, set the initial energy of each node.
Step 2. Current CH Sends CH advertisement Message to centroid
Step 3. Formulate K centroid and Clusters using K-Means
Step 4. Assign nodes to their clusters
Step 5 Cluster head election using EKCHS
If node threshold value is greater than other nodes then.
Print Cluster heads
Broadcast CH Advertisement Message
Wait for join CH request from nodes
Send transmission schedule
Else
Wait for CH advertisement message
Send join CH Message
Step 6. Data aggregation to BS
Step 7. End of Steady state

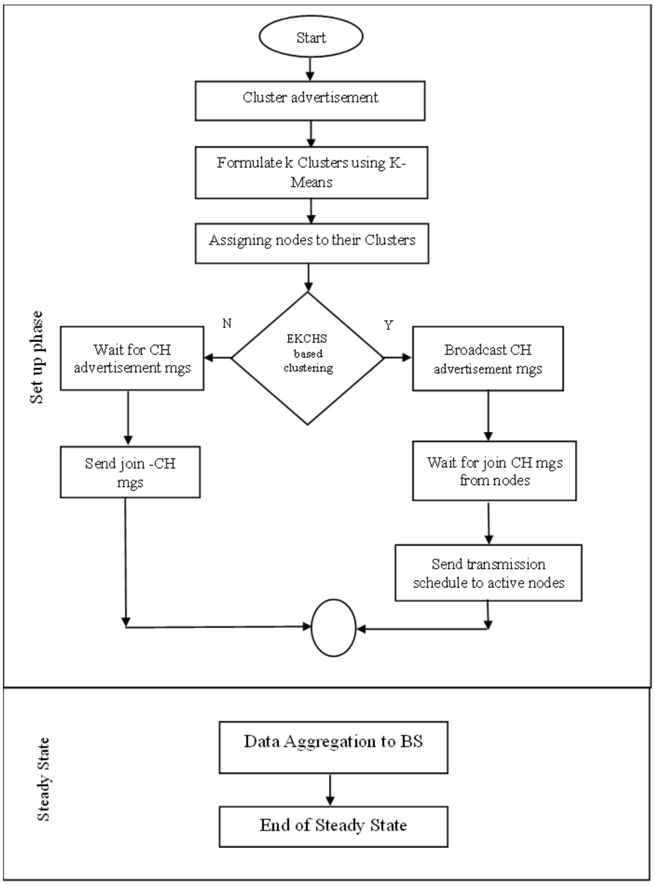

Fig. 7. Flowchart for Extended Low Energy Adaptive Clustering Hierarchy (X-LEACH) Protocol

V.RESULTS

This section portrays the results of the proposed X-LEACH routing protocol using various performance criteria. In this regard, the researcher has implemented two benchmark protocols with which the performance of the proposed protocol has been compared based on actual or traditional LEACH and Stable Election Protocol (SEP) for Clustered Heterogeneous Wireless Sensor Networks.

The extended LEACH protocol performance may be examined in terms of a wide range of metrics, one of which can also include the number of nodes that have died. The number of dead nodes is directly related to network reliability, coverage, and overall performance. It is evident from Figure 8 that the number of nodes that died in the proposed work is lesser as compared to the actual LEACH and SEP. With the increase in dead nodes, the lifetime of the network is increased. There are various parameters based on which the performance of the extended protocols in LEACH can be measured, and the number of dead nodes is one of them. The number of dead nodes will directly affect network dependability, coverage, and overall performance. It is observed from the graph that the number of nodes that died is less in the proposed work compared to actual LEACH and SEP, shown in Figure 8. The lifetime of a network reduces with an increase in the number of dead nodes.

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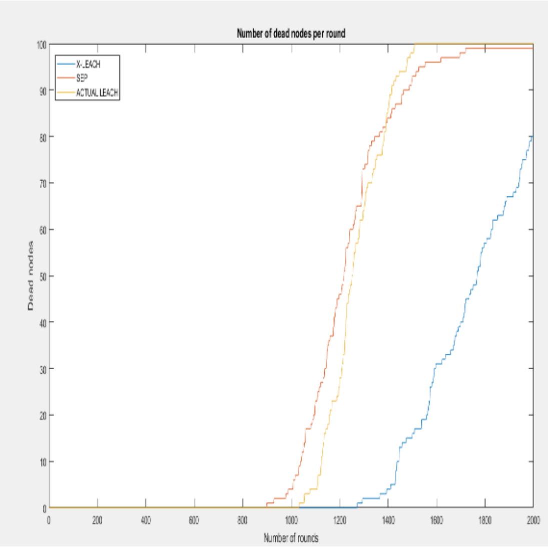

Fig. 8. Number of Dead Nodes per Round in X-LEACH, actual LEACH, and SEP

The first node in the X-LEACH protocol died at roughly 1300 rounds, actual Leach 1050 rounds, and SEP 900 rounds, respectively. At the end of the simulation, it is evident that the number of dead nodes in X-LEACH was 80, SEP was 95, and all nodes in actual LEACH had died. The extended LEACH protocol is intended to further improve energy efficiency and network life compared to the basic LEACH protocol and SEP. In selecting cluster heads, the employment of the extended K-Means cluster head selection algorithm improves the distribution of energy usage among sensor nodes. This greatly reduces the number of dead nodes in the network. The primary purpose of the Extended Low-Energy Adaptive Clustering routing protocol was to increase network lifetime by conserving energy and optimizing sensor node utilization, as shown in the graph, which reveals that actual LEACH and SEP had more dead nodes than X-LEACH. This implies that we've enhanced the lifetime of wireless sensor networks, resulting in decreased energy use.

The performance of the expanded LEACH protocol was also evaluated utilizing the number of live nodes in each cycle. The graph observations in Figure 9 show that the number of active nodes in the X-LEACH is bigger than in the actual LEACH and SEP at the end of the simulation.

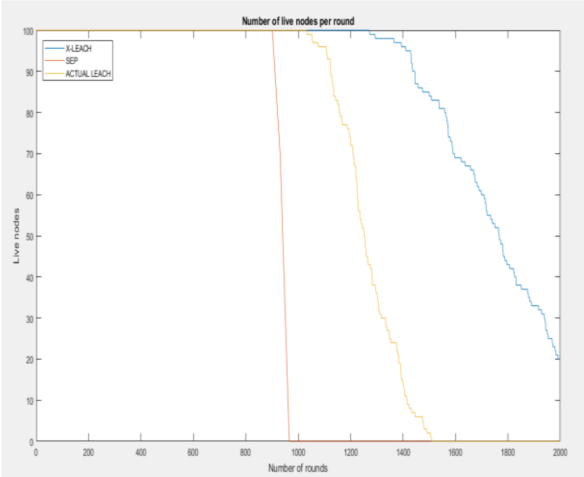

Fig. 9. Number of Live Nodes per Round in X-LEACH, Actual LEACH, and SEP

According to the graph, at the end of the experiment, there were around 20 nodes active in X-LEACH and zero nodes active in LEACH and SEP routing protocols. This means that in LEACH and SEP, the entire network was idle, whereas, in X-LEACH, a few nodes were active. This suggests that there are more live nodes per round in X-LEACH, indicating better network coverage and lifespan.

The extended LEACH protocol's performance was evaluated as well using the total remaining energy of nodes every round. In X-LEACH, the total remaining energy of nodes per round is more than in LEACH and SEP. This indicates better energy conservation and utilization in X-LEACH is higher compared to others as shown in Figure 10.

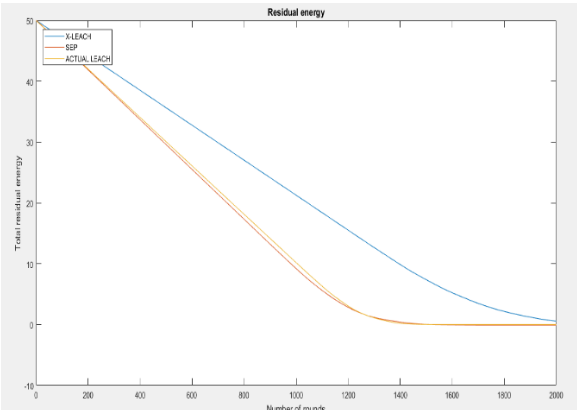

Fig. 10. Total Remaining Energy in X-LEACH, LEACH, and SEP

The total remaining energy in WSN for the proposed X-LEACH was around 25 joules at 1000 rounds, followed by LEACH with approximately 15 joules and SEP with approximately 13 joules. At the end of the simulation, all of the energy had been consumed in LEACH and SEP, but just about 2 joules remained in X-LEACH. A comparison of the remaining energy and number of rounds in the Wireless Sensor Network is demonstrated in Figure 7.

The extended LEACH protocol's performance was evaluated as well based on the number of packets transmitted from nodes to cluster leaders per round. This measure gives

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information on the efficiency of data transmission and network resource utilization. There were roughly 10*104 total data packets supplied to the CH in Extended LEACH at around 1000 rounds, while in real Leach 7.8*104 and SEP 8.5*104 data packets were transmitted to cluster heads, respectively. When comparing our suggested protocol to actual Leach and SEP, it can be seen that more packets were forwarded to CH. The results for the total data packet sent from nodes to CH of the three presented routing protocols are shown in Figure 11.

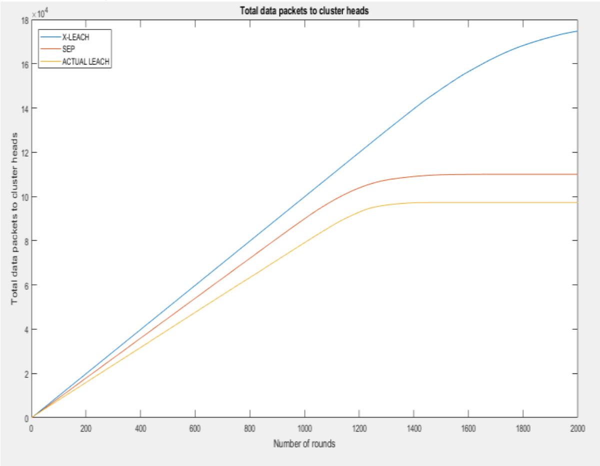

Fig. 11. Total Data Packets Sent to Cluster Head per Round in X-LEACH, LEACH, and SEP

This indicates that the X-LEACH protocol increases the number of packets transmitted to cluster heads while minimizing energy wastage. This improves the trade-off between data aggregation and energy efficiency based on the specific requirements of the wireless sensor network application.

The performance of the extended LEACH protocol was also evaluated based on the throughput per round. In terms of throughput, the X-LEACH did better compared to, Actual LEACH and SEP, where at the end of the simulation proposed XLEACH protocol had a total throughput 1.9*105, LEACH 1.2*105, and SEP 1.0 *105. The throughput performance of the suggested protocol and other conventional systems is shown in Figure 12.

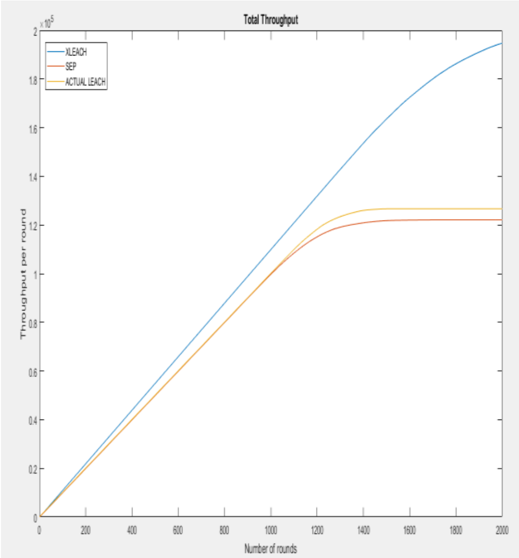

Fig. 12. Total Throughput per Round in X-LEACH, LEACH, and SEP

The extended LEACH protocol enhanced data transmission efficiency compared to the original LEACH protocol and SEP.

Lastly, the performance of the extended LEACH protocol was evaluated based on the number of cluster heads formed per round. The graph shows that at round 1000 there were approximately 10 clusters and cluster heads in X-LEACH, in there were LEACH 17 cluster and cluster heads, and in SEP there were 13 clusters and cluster heads respectively while at 1500 round there were approximately 10 clusters and cluster heads in X-LEACH, in LEACH there 2 cluster and cluster heads and in SEP there were 3 clusters and cluster heads respectively as shown in Figure 13.

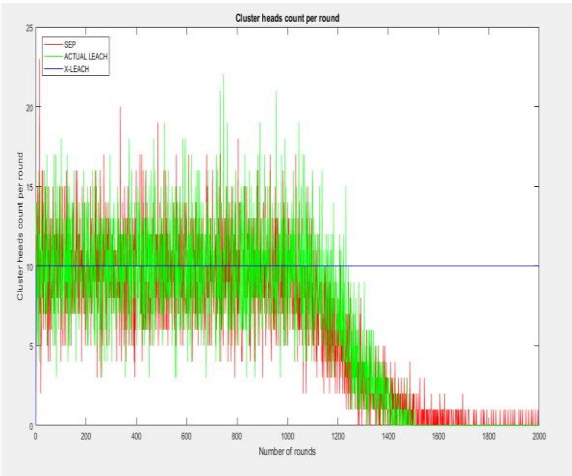

Fig. 13. Number of Cluster Head Formed per Round in X-LEACH, LEACH, and SEP

VI. DISCUSSION

The study aims to design an X-LEACH routing protocol that can extend the lifetime of WSNs. We have evaluated the proposed routing protocol through simulation runs and compared the results with other benchmarked routing protocols such as LEACH, and SEP. The proposed routing

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protocol was compared based on various performance indications, such as the number of live nodes, the number of dead nodes, average energy consumed, network lifetime, throughput, the number of packets transmitted to CH, and remaining energy. Here, one can find a description of the findings regarding these comparisons.

The proposed X-LEACH routing protocol outperforms others in the test for the number of dead nodes at the end of the simulation, with approximately 80 nodes dead, compared to SEP 95 nodes dead and actual Leach where all nodes had died. The first node in the X-LEACH routing protocol perished at about 1300 rounds, SEP at 900 rounds, and actual LEACH at around 1050 rounds. This demonstrates that the number of dead nodes at the end of the simulation is lower when compared to other benchmark methods. This also means that the number of live nodes is significantly higher than in SEP and LEACH. The suggested X-LEACH protocol outperforms existing simulated protocols in terms of the number of dead nodes and the number of live nodes, extending the lifetime of WSNs.

The results of the total remaining energy test revealed that the suggested X-LEACH has a lower energy dissipation rate than SEP and LEACH. At the end of the simulation, the suggested X-LEACH had around 2 joules remaining, whereas SEP and LEACH had used all of their energy. This demonstrates that the proposed X-LEACH uses relatively little energy, hence increasing and prolonging the lifetime of WSNs.

In the test of the total data packet sent from nodes to cluster head, the results indicate that, at the end of the simulation, the proposed routing protocol outperforms others where there were approximately 17*104 data packets in X-LEACH compared to SEP that forwarded approximately 11* 104 data packets and LEACH 9.9* 104 data packets sent to cluster head respectively. It means that our proposed X-LEACH is forwarding more data packets to the cluster head in comparison with others; hence, it improves the performance of the network.

In the test of the total data packet sent from the cluster head to the base station the results indicate that at the end of the simulation, the X-LEACH forwarded a few packets to the base station from cluster heads. The results show that in the proposed X-LEACH where there were approximately 2*104 packets sent to the base station (sink), SEP 1.5*104 packets were sent to the base station (sink), and LEACH 2.9*104 packets were sent from cluster heads to the base station. The X-LEACH protocol was second in terms of data forwarded to sink compared to actual LEACH which was first and SEP which came last. This is because our proposed protocol was able to reduce the size and number of packets sent from the cluster head to the cluster base station compared to the actual LEACH. This is done by using data aggregation and compression techniques. An efficient data aggregation and compression lead to a lower number of packets transmitted, reducing network congestion and improving overall data transmission efficiency.

In the test of throughput of the entire network, the results show that at the end of the simulation experiment, the proposed X-LEACH routing protocol outperforms others, whereas at the end of the simulation proposed X-LEACH routing protocol had a total throughput of 1.9*105, SEP1.0 *105 and LEACH 1.2*105. This reveals that, with the proposed X-LECH, more work is done, thereby improving the throughput of the whole network. This shows that the performance of the entire network was improved. This means that the proposed X-LEACH routing protocol enhanced the total throughput of the network while minimizing energy consumption thus prolonging the network lifespan.

In terms of cluster head election, the proposed extended Low Energy Adaptive Clustering Hierarchy (X-LEACH) routing protocol generates an even number of clusters in each round, that is, 10 clusters in each round, as opposed to SEP and LEACH, which generated a non-uniform number of clusters, with some rounds having many clusters and others having few clusters. This means that the proposed X-LEACH routing protocol ensures a consistent number of clusters in each round.

VII. CONCLUSION AND FUTURE WORKS

The work proposed an enhanced version of the extended Low Energy Adaptive Clustering Hierarchy protocol. In the proposed protocol, the extended K-Means clustering is used for energy efficiency. The results have shown the efficiency of the protocol in extending the network lifetime, reducing energy consumption, and enhancing network performance.

The number of live nodes, the number of dead nodes, average energy consumed, network lifetime, throughput, number of packets sent to CH, and remaining energy are some of the performance metric criteria used in gauging the performance of the proposed Low Energy Adaptive Clustering Hierarchy routing protocol. From these results, it is quite obvious that the proposed extended X-LEACH outperforms the other proposed protocols. Due to this, the study's contribution has been done in an attempt to improve the lifetime of the WSN network.

In the future, the researcher intends to ensure that the Proposed protocol can perform adaptive adjustment of clustering parameters. Future works can also be geared towards energy harvesting and power management. Lastly, future works can also be geared towards enhancing Security and privacy of data forwarded from node to cluster heads and cluster heads to base station within the extended LEACH protocol.

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