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In-Depth Analysis of the LEACH Routing Protocol for WSNs

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Abstract:
Wireless sensor networks (WSNs) have broad use in various industries, including the military, healthcare, and automation, because of their ability to assume control without human intervention. Most WSN projects use ambient sensors that take power from various sources to avoid the hassle of constantly replacing or charging batteries. Power efficiency and long network life are directly tied to routing methods. Hierarchical routing has been studied in academia, with the Low Energy Adaptive Clustering Hierarchy (LEACH) being the most popular option for enhancing WSNs' utility. This study includes our review of LEACH and its offspring strategies for WSNs and a historical summary of the protocols developed from LEACH's hierarchical routing design.
Keywords: wireless sensor network, clustering, hierarchical routing, LEACH.

INTRODUCTION:

Over the past few decades, there has been a notable surge in the adoption of Wireless Sensor Networks (WSNs) due to their extensive applications in various domains, including military, civilian, and industrial sectors. WSNs consist of microsensor nodes deployed randomly in a designated area and at least one sink or Base Station (BS). These sensor nodes encompass different types, such as source nodes (normal nodes), intermediate nodes (such as Cluster-Heads in clustered networks), and the BS[1]. These microsensor nodes can monitor physical and environmental phenomena such as temperature, pollution, and heartbeat. Data collected by these sensor nodes is transmitted to the sink, enabling users to access information online, as depicted in Figure 1. The primary objectives of WSNs are to control specific zones, detect and record events within the monitored area, and measure appropriate criteria. In Wireless Sensor Networks (WSNs), sensor nodes rely on batteries for power, which are typically non-rechargeable and non-replaceable.

Energy is consumed during data collection, processing, and transmission or reception of packets. Therefore, energy consumption is a significant constraint in WSNs. Additionally, data redundancy is another factor that negatively affects the energy efficiency of sensor nodes. Consequently, conserving energy to extend the network's lifespan poses a challenge in WSNs. Numerous studies in the field of WSNs emphasize the significance of routing protocols. These protocols involve selecting the optimal path for data transmission from the source to the destination [2]. Routing protocols are crucial in achieving three main goals in Wireless Sensor Networks (WSNs): scalability, efficient data transfer, and energy optimization [3]. Over time, numerous routing protocols have been created for WSNs to prolong the network's lifespan by reducing power consumption. These proposed protocols consider various factors such as communication model, network structure, and topology [4]. The literature review mainly focuses on hierarchical routing and explores various techniques of cluster-based routing protocols [5]. Clustering has proven to be an efficient method for achieving energy balance in WSNs, primarily through data aggregation. Using clustering routing protocols, WSNs can significantly improve energy efficiency, reducing the number of packets transmitted throughout the network. Clustering offers several advantages : scalability, reduced load, lower energy consumption, data aggregation, collision avoidance, load balancing, latency reduction, fault tolerance, robustness, improved connectivity, and extended network lifetime.

Data aggregation reduces energy consumption by minimizing communication data and conserving energy[1][6]. In clustering, the Cluster Heads (CHs) are responsible for aggregating data from their cluster members and forwarding the grouped data to the sink, thereby contributing to energy conservation. Additionally, clustering reduces the transmission data and, as a result, decreases the routing table size on each sensor node since routes are established within clusters [7].

LEACH is a prominent clustering routing protocol used in WSNs [8]. LEACH organizes sensor nodes into clusters, each with a designated Cluster Head (CH) and other nodes as cluster members. The CH collects data from its members, compresses it, and then transmits aggregated data to the sink. Although LEACH improves the WSN's lifetime by reducing the number of transmission packets through clustering, it has some drawbacks. For instance, it randomly selects CHs without considering their distance from the sink or current energy level. Additionally, the single-hop communication CHs use to reach the sink can lead to inefficient energy utilization.

This paper will discuss the LEACH routing protocol and its descendant in wireless sensor networks (WSNs) and show our findings from a literature survey. The remaining sections of the paper are organized as follows: Challenges and design considerations for WSN routing are discussed in Section 2, followed by a description of WSN routing protocols in Section 3, an explanation of hierarchical routing in Section 4, and a comparison of several hierarchical routing protocols in Section 5. The conclusion and analysis can be found in Section 6.

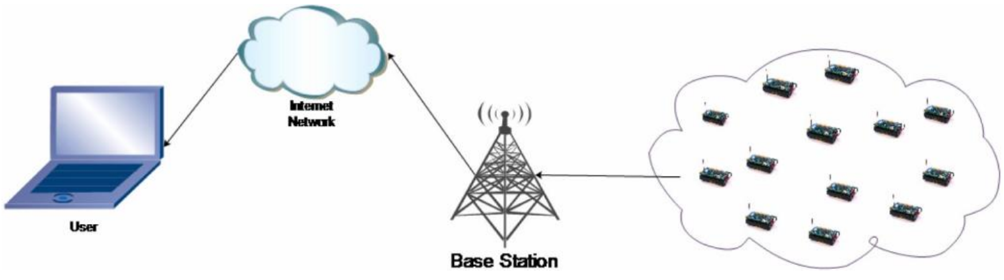

Fig. 1. WSN architecture.

1. Routing Challenges and Design Issues

The fundamentals of what makes a routing protocol reliable will be covered here. ScalabiliThe backbone of Wireless Sensor Networks (WSN) is scalability, efficiency, and management limited in what they can do because of resource issues, including battery life, computational power, and memory. The requirement for efficient resource management to extend the network's lifespan is just one of the many difficulties associated with WSNs [9].

1.1. Deployment of the sensor node

How well a routing protocol works in a WSN affects how the individual nodes are distributed around the network. Deterministic (or manual) deployments and self-organizing (or random) deployments are the most common. Sensors in deterministic deployments are placed by hand, and data flows along predetermined paths. However, in self-organizing systems, the infrastructure is built out of randomly placed sensor nodes. The effectiveness and efficiency of the network as a whole depend on the location of the sink or cluster head. Energy efficiency can be improved when nodes are spread uniformly over the web. Sensor nodes are typically positioned arbitrarily[10] in the circumstances like battlefields and wildlife monitoring.

1.2. Energy consumption

Sensor nodes in a wireless network have limited resources. Thus it is crucial to employ energy-efficient communication and computing methods [11]. Sensor nodes in wireless networks have finite battery life, so minimizing power consumption is essential. Especially in dangerous places like war zones, where getting sensors to recharge their batteries can be challenging, this poses a problem for the people responsible for designing networks. When a sensor's battery life becomes too low, it stops working and negatively affects the entire network. Despite lowering the network's energy consumption, some routing algorithms can cause uneven energy use [12]. Any routing protocols developed for sensors must be as low-power as possible to preserve the sensors' longevity and the network's overall efficiency. Doing so can maximize the sensors' use while maintaining the network's high efficiency.

1.3. Models for data delivery

Data delivery models can provide an alternative solution when protecting data packets from being corrupted due to node or link failures. Not only does this affect the limited energy of the nodes but also security goals, energy consumption, and the inflexibility of the route [13]. This critical element impacts the design of wireless sensor network routing algorithms.

1.4. Tolerance for Flaws

Providing fault tolerance in the face of node failures is a significant obstacle in WSNs. Nodes are vulnerable to hardware failure, physical damage, and battery depletion[14]. Since they are commonly placed in harsh and unmanaged environments like underwater or on rocky terrain, when a single sensing node fails, the routing protocol must create new connections to keep data about the monitored environment from being lost [15].

1.5. Scalability of the WSN

A wireless sensor network (WSN) moves its nodes around to get the best possible resolution from its sensors. Implementing scalable protocols for data retrieval ensures a scalable network and adequate system performance[14]. The area that needs to be monitored may have hundreds, if not tens of thousands, of sensor nodes. Routing protocols must accommodate a sizable number of nodes [15].

1.6. Aggregation and fusion of information

Algorithms for data aggregation are designed to collect and combine data from multiple sources using operations such as suppression, minimum, maximum, and average. This method optimizes network traffic and reduces energy consumption, extending the network's life [13]. Data aggregation is a method for eliminating duplicate data from several sensors. To improve energy efficiency and optimize traffic in routing protocols, which leads to a longer lifespan for the network, packets from different sensor nodes in the network are collected and combined. The most critical aspects of the WSN routing protocol design are shown in a hierarchical taxonomy in Figure 2.

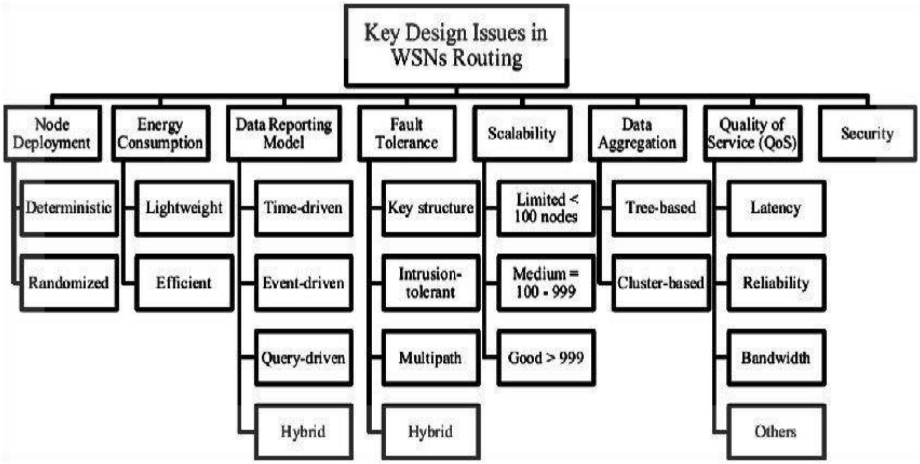

Fig. 2. Classification scheme of significant protocol design challenges for WSN routing.

2. Routing protocols in wireless sensor networks

WSN routing protocols can be broken into four categories [10] based on the routing pathway building, network architecture, protocol operation, and communication initiator. Figure 3 shows a classification scheme for WSN routing protocols.

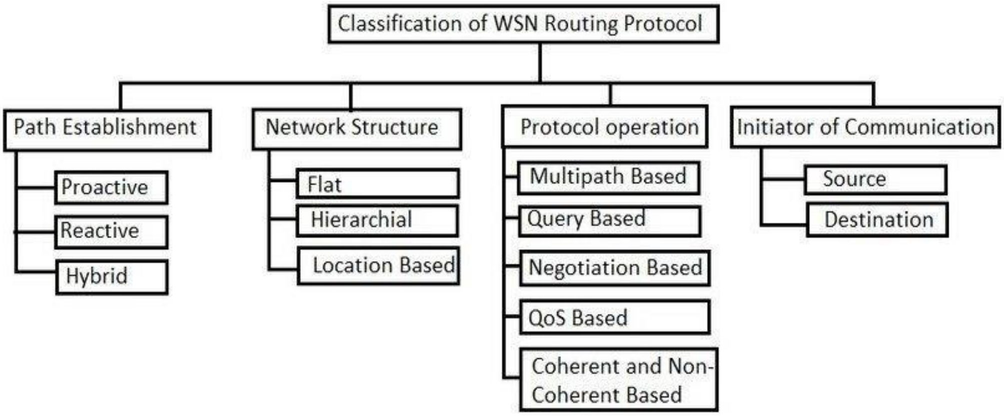

Fig.3. Classification of Routing Protocols in Wireless Sensor Networks.

3. Hierarchical protocols

Hierarchical routing in wireless sensor networks is the topic of this research. Well-known systems prioritizing hierarchical or cluster-based architectures excel in scalability and communication because of these design choices. Each node in the network serves multiple purposes. Hierarchical routing helps reduce the number of messages sent to the base station by aggregating data from various sensor nodes and keeping their power usage constant. According to the rules stipulations, the whole WSN is divided into different groups. Several hierarchical protocols[16] are discussed in this article. Those at higher levels in a hierarchical technique, such as clustering, are prioritized above those at lower levels[17].

Nodes organize the network as a set of groups using hierarchical routing methods. Each cluster has a single point of contact who has been given responsibility for running day-to-day activities. Reduce the data transfer between the cluster's command node and central location. The cluster master, compressed periodically, gathers data from all cluster nodes, and then any duplicates are removed [16]. Normal nodes can significantly minimize their routing costs by only sending data to CH [18]. The following section will go through some hierarchical routing protocols.

3.1.LEACH (Low energy adaptive clustering hierarchy) and its variants

The more robust hierarchical clustering approach, LEACH, will be available initially. Because the sensors share the load, the network is powered by nodes with finite lifetimes [19]. The following objectives[18] are served by LEACH, a routing system that collects and delivers information to base stations.

- Enhancements to the network's longevity are crucial.
- The goal is to reduce the demand for the power sources of the sensor nodes.
- Cut back on your everyday texting activity.

The protocol causes groups of sensing nodes to form. In a sensor network, the CH is a particular node performing additional duties beyond the other member nodes. CH is the only person who can use the sink without going through CH. CH functions as a router between the member nodes and the sink. Data from the network's nodes can be gathered, integrated, and steered with the help of CH before being compressed and transmitted to the sink [18]. Combining data transmissions that only need one hop can significantly save energy consumption. There are two distinct phases in LEACH: the launch and the maintenance. Selecting a cluster head and developing clusters are two further early-stage classifications. This method of selecting a cluster leader ensures that the energy and resources required to perform leadership duties are distributed equitably across the sensor nodes in the network. The cluster head role is rotated among other nodes so that it does not become stale after just one cycle. Node "n" calculates a random number between 0 and 1 and compares it to the cluster-head selection threshold T(n) to determine if it is time to take charge of the cluster. The node (n) with the lowest output in comparison to T is the cluster head [19]. When you set the cluster-head threshold, you know two things: First, there is a fixed percentage (P) of cluster-head nodes. Second, the node that led the cluster in the previous 1/P rounds is not guaranteed to lead the group in the current game. The required cutoff is determined by the following.

$$:T(n) = \begin{cases} \frac{P}{1-P\left(r \bmod \frac{1}{P}\right)} & if\ n \in G \\ 0 & otherwise \end{cases} \qquad (1)$$

The current round, denoted by r, contrasts with G, representing the nodes not grouped in the previous 1/p rounds. Each picked node then announces to the rest of the network that it has assumed the role of cluster head. The remaining nodes, having received the cluster-head advertisement, choose a cluster to join based on the strength of the signal received and then communicate their choice to participate to the chosen cluster-head. When a cluster is formed, the leaders will each make a TDMA (Time Division Multiple Access) schedule and distribute it to the members. With everything wrapped up, we can go on to the setup state. Each sensor node regularly transmits sensing data to the cluster leader during the steady state. The TDMA schedule allows member nodes to enter a sleep state to prevent data collisions during transmission. During the steady-state phase, nodes observe and report data to their CH on a TDMA-scheduled basis. A member node will only send data to the CH when its turn comes up in the time slot. A cluster member's sleep time is not interrupted when that member's node transfers data to the CH within its designated period. LEACH can increase the runtime of all nodes since it decreases the chances of collisions and energy loss inside the cluster[20] [14]. The CHS collects data and sends it to the BS for processing. After a predetermined length of time elapses, the network starts a new round, which includes the startup and steady-state stages [21]. The LEACH communication hierarchy is depicted in Figure 4.

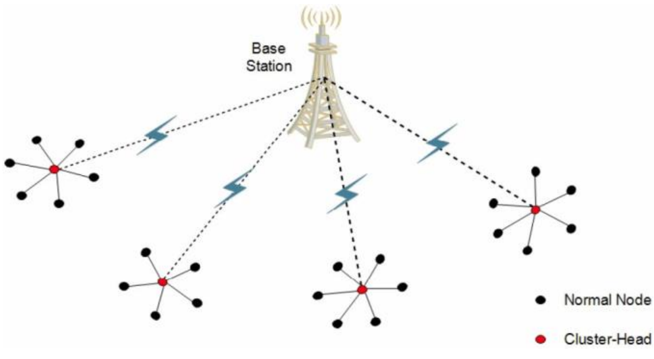

Fig.4. LEACH procedure illustration.

3.2. LEACH-B (Balanced Low Energy Adaptive Clustering Hierarchy)

A LEACH variation with a near-optimal number of CHs, LEACH-B (LEACH-Balanced), was introduced [21]. One new suggestion is to use a decentralized cluster construction strategy, in which each sensor node is only aware of its location and the location of the final receiver [22]. LEACH-B entails cluster formation, multiple-access data transfer, and CH selection. The CH of each sensor node may be calculated by measuring the power loss between the end receiver and the node itself. The network benefits from higher energy efficiency because the CH energy is quickly dissipated despite LEACH. The following are some applications for Leach-B. Collaboration on data through subgrouping, clustering, and a chosen leader. Each sensor node determines the cluster head by assessing the quantity of energy reflected from the far-end receiver. According to[23], the Leach-effectiveness of B is superior to that of LEACH.

3.3. LEACH-C (Centralized Low Energy Adaptive Clustering Hierarchy)

Each LEACH node independently chooses whether to take charge of the cluster. The difficulty in counting the number of nodes in each cluster and determining who the leaders of those clusters are presents a significant obstacle. That is to say. LEACH cannot tell you where the cluster head will be during any given iteration, which can significantly impact how well things go. As a result, the LEACH approach can stop working [16]. LEACH-C, a centralized technique, handles clustering at the BS. While all nodes participate in the Leach-C initialization process, the steady state remains unchanged. Signal strength and location data from the base station are transmitted.

Thus, when the network's global data of enhanced clusters are implemented, less energy is needed for data transmission [24]. You will want to use GPS or some other location-tracking technology. The nodes with sufficient power should be allowed to vote for the cluster leader by the hub. The data is sent from the base station to all connected devices[24]. Each sensor node communicates its location (through GPS) and remaining battery life to the central hub. Cluster leaders cannot be nodes with energies below the average calculated by the base station. The cluster head's unique identifier was broadcast to all other nodes in the network by the base station shortly after its creation. The node that shared its ID with the sender took over as round's cluster leader while the others rested up for their turn to transmit. The clusters created by this approach outperform LEACH clusters in performance [8]. When LEACH-C is in its steady-state phase, all nodes send their data to the cluster head, which sends the aggregated data to the base station in a compressed format. Considering node placements inside networks and constructing cluster heads in a way that aids in load distribution equally across the cluster heads, LEACH-C surpasses LEACH overall [16].

3.4. Adaptive Clustering Hierarchy with Low Energy

Regarding enhancing the CH selection procedure, LEACH-E is preferable to LEACH. The Leach-E is segmented into smaller pieces using the LEACH method. Each sensor node has an equal chance of becoming CH in the first round. Each node's residual energy dropped after the initial transmission, and the node with the highest residual point determined the leader. Meanwhile, the remaining nodes in the cluster were classified as having a low energy level. Despite its higher energy requirements compared to LEACH and multi-hop-LEACH, simulated results by the authors show that E-LEACH is superior [22].

3.5. LEACH-F (Fixed number of clusters in Low-Energy Adaptive Clustering Hierarchy)

The LEACH-F protocol (fixed number of clusters-LEACH) works in a way that is similar to the LEACH-C method in that it establishes clusters and chooses CH centralized. Since clusters do not disappear at the beginning of each epoch, there is no reclustering stage. The cluster itself does not move, but the CH's position does. In addition, the LEACH technique is unaffected by the steady phase [21]. The primary benefit of this approach over LEACH is that cycle-to-cycle initialization is unnecessary. LEACH-F uses a centralized method, similar to LEACH-C, to generate clusters. LEACH-F's fixed clusters do not react to changes in the network, such as the loss of a node or the introduction of additional ones, which is a drawback. The LEACH-F protocol preserves the previously formed clusters across the network, thus avoiding the time-consuming process of reclustering [20].

3.6. I-LEACH (Improved Low Energy Adaptive Clustering Hierarchy)

Improved LEACH [21] is one of the routing strategies for clustering based on the closeness of selected CHs in the network. I-LEACH takes a more decentralized approach to cluster than LEACH. The entire sensor field is divided into equal-sized sections. Each subdivision's CH is selected using a threshold method from the LEACH technique. Using a simulation, the authors evaluate the proposed I-LEACH protocol's average energy usage compared to the standard LEACH procedure. When compared to LEACH, I-LEACH offers superior energy performance [20].

3.7. LEACH-M (Mobile Low Energy Adaptive Clustering Hierarchy)

The proposed Leach-M addresses the critical problem of mobility support in Leach. Leach-M necessitates both cluster heads and non-cluster heads to move to various nodes throughout the initialization and steady-state stages. Using global positioning system technology, the precise location of Leach-M nodes may be determined. The modes with the lowest mobility and attenuation can be used to determine the cluster leader. All other nodes in the network are updated on the current status of the chosen cluster leaders [24]. The LEACH-M authors propose utilizing GPS to locate individual sensor nodes on the assumption that all nodes are initially similar. LEACH-M uses the LEACH threshold function, although measuring node mobility differently than LEACH does during the data transmission stage[21].

3.8. LEACH-ME (Mobile Enhanced Level Low Energy Adaptive Cluster Hierarchy)

An upgrade to LEACH-M, LEACH-ME provides even more enhancements than its predecessor. To enhance LEACH-M, it was proposed that CHs with lower mobility relative to their neighbors be selected. During the steady-state phase, data is transferred between nodes via CH transitions. During the TDMA time frame, nodes update their CH with a transition count. The CH calculates the average number of changes experienced by each member throughout the most recent cycles. Different amounts of energy are lost for each data packet sent using the LEACH-M and LEACH-ME protocols, with LEACH-ME being the more efficient [8].

3.9. V-LEACH (Vice Cluster Level Low Energy Adaptive Cluster Hierarchy)

V-LEACH offers many benefits as an improved version of the LEACH strategy. It is common knowledge that the energy of the cluster leader depletes more quickly than that of the regular nodes because it is responsible for collecting data from the ordinary nodes and transmitting it to the monitoring station. As a result, it will stop working before the rest of the cluster and render the whole thing useless because it cannot talk to the central node. To prevent such an occurrence, this method was put in place. When a CH dies, its responsibilities are taken on by a successor. The network always works well since all information is sent to the command center, as shown in Figure 4. When the vice-CH passes away, this protocol does not resolve the problem [15].

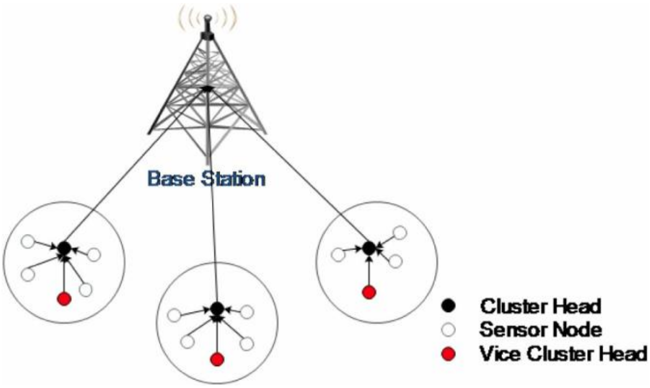

Fig. 4. V-LEACH architecture.

3.10. Cell-LEACH (Cell Low Energy Adaptive Clustering Hierarchy)

The original LEACH protocol [15], derived from this one, partitions the network into cells. Each of the seven neighboring cells formed a cluster with a CH. Each cell is comprised of a few sensor nodes and a designated head. The LEACH strategy employs a cell head that functions similarly to CH, as shown in Figure 5. That is to say, it creates a TDMA schedule, gives each cell member a period, collects data from those data sources by the TDMA schedule, and then transmits the data to the CH member. The CH collects data from its cell heads the same way a cell head would, then transfers it down the quickest route possible to the sink. After the network has been built, only the CHs and cell heads change dynamically over their lifespan; everything else remains static[21].

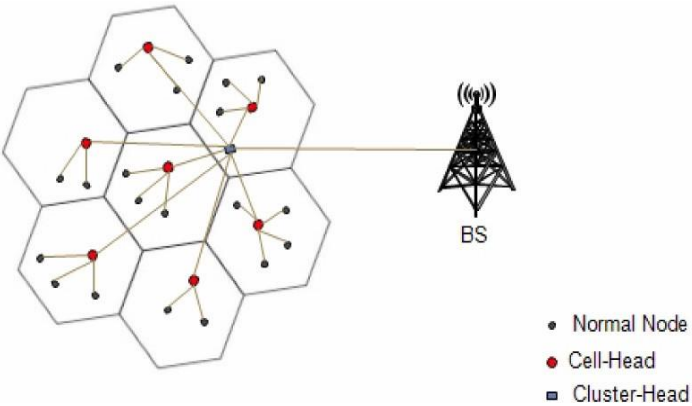

Fig. 5. Cell-LEACH architecture.

3.11. Multiple-Hop Low-Energy Adaptive Clustering Hierarchy (MHLEACH)

A multi-hop strategy between the nodes and the BS expands the transmission range. The MHLEACH (Multi-Hop-LEACH) technique [25] is described for selecting the best target while communicating data from the CH to the BS via intermediate CHs. Using a multi-hop method to get to the sink and (i) making it easier for CHs to talk to each other are two of the main focuses of this protocol.

3.12 MHT-LEACH (Multi-Hop Technique-LEACH)

The MHT-LEACH (Multi-Hop Technique-LEACH) is based on the LEACH technique for discussing routing by dividing the network into two levels according to the path length between the CHs, and the BS [26] procedure is now in place. MHT-LEACH's CH selection and cluster formation are similar to LEACH's initial setup. Based on the CHs' relative proximity to the washbasin, MHT-LEACH classified them as internal or exterior[27] instead of sending all CHs data simultaneously. This CH is part of the inner group that talks directly to the sink if the distance is less than d0.

On the other hand, the CH belongs to the outer group if and only if it is located above or at d0. An external CH may construct a routing table using the data from internal CHs' announcement messages. When transmitting data to the BS or another external CH, each external CH first consults its routing database to determine the quickest route. For energy fairness in the network, the MHT-LEACH protocol splits the CHs in half and delivers data to the BS through the halves [28]. However, MHT-LEACH's effectiveness could be improved in large-scale network [29]. The method and flowchart for the MHT-LEACH are provided for your reference.

3.13 BRE-LEACH (Balanced Residual Energy-LEACH)

Researchers in [30] have presented a new protocol, BRE-LEACH (Balanced Residual Energy-LEACH), that improves network stability and longevity while reducing energy expenses. An energy imbalance occurs between nodes in conventional LEACH because CHs are chosen randomly without regard to the remaining energy, resulting in some nodes draining their energy faster than others. BRE-LEACH solves this issue by selecting CHs based on their remaining power and using a threshold function introduced in Equation 2 [30].

$$T_1(n) = \begin{cases} \frac{P}{1-P*(r \ mod(1/P))} * \frac{E_{res}}{E_0}, n \in G \\ 0 \qquad \text{else} \end{cases}$$

(2

The chance of the number of CHs in the entire network is denoted by P, r represents the current round, E_{res} is the residual energy of nodes, E_0 defines the starting power, and G represents the set of nodes that have not been selected as CHs in the last 1/P rounds. BRE-LEACH works, in turn, divided into four phases : Cluster setup, TDMA (Time Division Multiple Access) scheduling, Root CH selection, and Data transmission phase. After CHs are selected based on their remaining energy, each sensor node joins the cluster of the CH with the strongest received signal. CHs provide TDMA schedules for their cluster members. The algorithm selects a root CH with more than average remaining energy and closer to the sink than average to regroup data from other CHs and forward it to the sink. Non-root CHs use multi-hop routing to reach the parent CH. The architecture of BRE-LEACH is shown in Figure 6, and simulation results in[31] indicate that BRE-LEACH performs better than LEACH in reducing energy consumption costs and increasing the network lifetime by 55.73%.

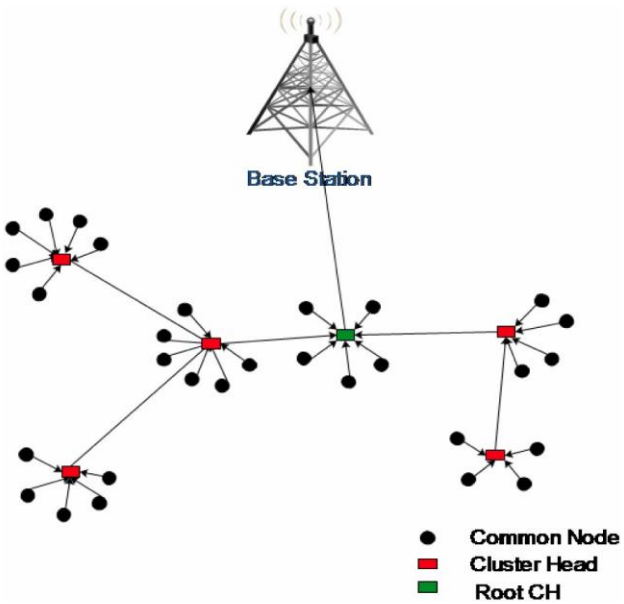

Fig. 6. BRE-LEACH architecture.

Table 1. Advantages and disadvantages of LEACH-based protocols

S.No.	LEACH & its Descendant	Clustering method	Strengths	limitations
1	LEACH	Distributed	uses a TDMA schedule to extend the life of a network. Achieves a neutral energy balance. Fewer data is transmitted in each communication. cuts down on the energy used by the nodes	Also, assuming that the placement of CH nodes varies. Choosing CH at random. There is always an odd number of nodes in each cluster. Only one hop is used.
2	LEACH-B	Distributed	Each CH Has the Same Number. After making the initial adjustment, consider how much energy is still available. It keeps the network running longer.	Increased general expenditures
3	LEACH-C	Centralized	reaches an unmanageable level of complexity in a localized region of the network. CH residual energy choice. The centralization method yields a more optimal distribution of CHs. shows the optimum cluster size	The positions of nodes are essential. Centralization creates a top-heavy situation. More processing time is needed for single-hop transmission.

4	LEACH-E	Distributed	achieving a stable level of energy usage across the network. The nodes' remaining power determines which CHs will be used.	Selecting CH based on energy could lead you even further from the BS. Chooses a root-CH entirely on energy, independent of its proximity to the BS.
5	LEACH-F	Centralized	Better distribution of CHs can be achieved by centralization. Speeds up the process after the initial setup	The initial configuration of clusters. There is no reclustering phase. There is no way to modify an existing cluster by adding or removing nodes.
6	LEACH-I	Distributed	Increased network efficiency as a result of meticulous CH selection.	The difficulty of the math involved.
7	LEACH-M	Distributed	The ability to move both CHs and non-CH nodes. Extraordinary low-energy consumption	Costs That Are On Top Of That.
8	LEACH-ME	Distributed	helps to get nodes moving about. CHS is selected from the minor mobile population.	Costs have risen.

9	LEACH-V	Distributed	Vice CH takes over for primary CH in the event of primary CH's death. Lengthen people's retirement years. When a CH passes away, selecting a new one is unnecessary.	When the CH moves further from the BS, it dies out quickly—the addition of CH treatment for vice.
10	Cell- LEACH	Distributed	Extensive network coverage. Improvement in energy productivity.	Choices of CH and cell head are made at random. Control packet overflow is available on cell heads (CHs) and CHs.
11	MH- LEACH	Distributed	in terms of energy efficiency and effectiveness. Use a series of jumps.	Selecting the CHs at Random. Energy consumption increases for CHS that act as data aggregators for other CHS.
12	MHT-LEACH	Distributed	Extremely efficient use of energy. To connect many CHs via a multi-hop method. CHs are divided into two categories according to their proximity to the sink.	Selects CHs without taking into account the energy. The no. of CHs in each turn may not be the same. Only two levels, CHs at the edge of the network, consume more energy

13	BRE-LEACH	Distributed	It helps networks last longer. Choosing a CH based on the amount of energy left behind. Choose a parent CH based on the amount of energy left and the BS's location.	The number of nodes in each cluster varies. The potential number of CHs changes at each possible branch.

4. Evaluation of LEACH and Related Wireless Sensor Network Protocols

The underlying LEACH method limits network lifetime and increases energy consumption by restricting CH selection and data transmission technology. Several LEACH-based solutions were implemented to improve the traditional LEACH technique to decrease energy consumption and increase the lifetime of WSNs. The LEACH offspring given here is an upgrade on the original LEACH protocol regarding the CH selection process and data transmission techniques. The main changes made to LEACH over the years are summarized in Table 2.

Table 2. LEACH and its offspring were compared.

Protocol	A Change from the Standard LEACH
LEACH	CAG nodes can increase stability, energy savings, and failure prevention.
LEACH-B	When using LEACH-B, the CH count is virtually optimal with each iteration. The remaining energy determines which CHs will be used after the first spin.
LEACH-C	When using LEACH-B, the CH count is virtually optimal with each iteration. The remaining energy determines which CHs will be used after the first spin.
LEACH-E	The packets from the other CHs are gathered by the best CH (with the most significant available energy) and then transmitted in a single stream to the sink.
LEACH-F	The centralizing strategy underpins the CHS selection procedure and cluster formation. This is why it is impossible to change the composition of a cluster once it is established.
LEACH-I	CHS Election factors include remaining energy, node location, and neighbor count. The remaining power is then incorporated into the

	threshold function for a new and improved version. Therefore, I-LEACH takes into account a uniform size distribution across clusters.
LEACH-M	LEACH-M uses the movability of normal nodes and CHs while relaying data to the BS. Because of this, it can function in dynamic urban environments.
LEACH-ME	To be chosen as CHs, sensor nodes must have low mobility compared to their neighbors.
LEACH-V	When a Cluster-Head passes away, the Vice Cluster-Head automatically becomes the next Cluster-Head.
Cell- LEACH	To achieve this, LEACH-Cell divides the network into "cells," or smaller parts, and then forms clusters every seven cells. There is a cell head (CH) in every cluster and a cell head (CH) in every cell.
MH- LEACH	To take advantage of the multi-hop technique between CHs to reach the sink, rather than immediately forwarding packets to the sink, MH-LEACH uses a routing table for each CH.
MHT-LEACH	Based on their proximity to the BS, MHT-LEACH classifies CHs into one of two categories. It takes advantage of many hops through different CHs to get to the BS.
BRE-LEACH	In CH selection, only nodes with sufficient available energy may take part. BRE-LEACH has updated the threshold formula to include the residual energy/initial energy ratio. To aggregate data from CHs and deliver it to the sink, it chooses the root CH with the highest energy and closest proximity to the BS.

CONCLUSION

Sensors have limited power sources, which has made network energy efficiency an issue. Due to the scarcity of energy sources, routing protocols for WSNs must be designed with this constraint in mind. The primary goal of the routing protocol is to extend the network's lifetime by making the most of the sensors' availability. The sensors spend most of their power on data transmission and receiving. Therefore, routing protocols must impact the energy resources of the sensors and the network as a whole. In this article, we quickly looked at the many LEACH-based methods available.

In addition to a table summarizing the survey's findings, we provide some context about LEACH and the routing system it inspired. Other protocols have been developed to address the shortcomings of LEACH. The search for an efficient, scalable, and trustworthy clustering technique that can extend the life of wireless sensor networks (WSNs) of all sizes continues.

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