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Conceptual Framework and Comparative Study on Energy-Efficient Routing Protocols in WSN with Special Emphasis on Swarm Intelligence Approaches

Ateka I. Alwan[*], Baraa M. Albaker[**]

[*,**]College of Engineering, Al-Iraqia University, Saba'a Abkar Complex, Baghdad, Iraq

*Email: atika.diazy@gmail.com
https://orcid.org/0009-0007-8760-6935

**Email: baraamalbaker@ymail.com
https://orcid.org/0000-0002-6030-3121

Abstract

Wireless Sensor Networks (WSNs) are gaining popularity due to their low cost and ease of maintenance and management. One of the most challenging issues in WSN is energy conservation. The clustering strategy has the potential to extend the lifespan of WSNs. The selection of Cluster Head (CH) in each cluster is regarded as the capable approach for energy efficient routing in the clustering model, which reduces the transmission latency in the WSN. As a result, the routing method between nodes and sinks must take into account the efficient use of energy. In Low-Energy Adaptive Clustering Hierarchy (LEACH), direct data connection from source cluster head to sink is addressed, leading to inequitable energy consumption of cluster heads CHs and network routing gaps. In this paper, the conceptual framework of clustering in wireless sensor networks based on traditional and optimization categories is explored. In addition, the most relevant up-to-date researches in routing protocols are presented. The study presents a new taxonomy for categorizing current hierarchical energy efficiency routing protocols for WSNs and examines their functionality and performance. Next, the study examines current routing protocols in WSNs, ranging from traditional routing protocols to swarm intelligence-based protocols. LEACH variations are discussed using a taxonomy based on distinct classes, residual energy, centralization, distance, mobility, energy efficiency, and so on. The CH selection, hop count, mobility, scalability, energy efficiency, topology, and deployment are all compared in detail. Finally, Energy efficiency, data aggregation, location awareness, QoS, scalability, load balancing, fault tolerance, query based, and multipath are summarized for the hierarchical routing protocols that fall into both classes.

Keywords- wireless sensor network; energy efficiency; LEACH; routing protocols; swarm intelligence.

I. INTRODUCTION

A wireless sensor network is made up of a hundred units that are dispersed over the field and are used to gather data then data is processed, and transmit to the Base Station Node (BSN) based on a variety of routing algorithm techniques. Sensor devices that have the capability of sensing, storing, and broadcasting data, but are neither rechargeable nor replaceable. Because sensors have limited energy resources, the development of energy-efficient procedures is always encouraged in order to extend the lifetime of WSNs [1]. Fig. 1 demonstrates WSN architecture.

In applications where human interaction is problematic, wireless sensor networks play a significant role. WSN is widely used in real-time applications such as surveillance, environmental monitoring, disaster management, and health monitoring, among other things [2]. Sensor nodes were placed at random in the required field for monitoring and detection purposes, depending on the applications. Service quality in WSNs depends on a number of factors that must be addressed during construction. These factors include, but are not limited to, energy efficiency, load balancing, power consumption, network coverage, latency, and many more.[3].

Because battery replacement is nearly impossible in many circumstances, energy efficiency is the greatest problem. As a result, strategies must be improved so that energy consumption can be decreased significantly. Clustering algorithms have been developed as a result of these challenges. Clustering is used to improve the network's energy efficiency and lengthen its lifespan. A cluster of sensor nodes is a collection of them (See Fig. 2). Clustering divides the entire sensing field containing sensor nodes into a number of clusters. Each cluster contains a cluster head (CH) node [4]. LEACH, DEEC, LEACH-C, T-LEACH, QAC, LESCA, EBUC, BPSO-T, TCH-MAC, HEEC, and other clustering algorithms are only a few examples.

Dynamic and static clustering are the two types of clustering methods. The dynamic clustering is distinguished by an updated formation in each cycle, whereas the static clustering maintains the same formation throughout the lifespan of the network.[5],[6].

The purpose of routing in a WSN is to keep sensors operational for as long as possible, which will increase the network's lifetime. The routing methods are designed to use as little energy as possible for data transfer, allowing the network to remain active for longer periods of time [7]. Because of the network topology, WSN routing protocols can be divided into three categories: flat, hierarchical, and location-based routing. Scalability, increased network longevity, and efficient data aggregation are some of the benefits of cluster-based routing over others [8]. Energy-efficient routing methods have shown to be a powerful mechanism for conserving energy in wireless sensor networks. Furthermore, among all types of routing protocols, hierarchical routing protocols are thought to provide the maximum energy efficiency [9]. Fig. 3 illustrates hierarchical network architecture of a WSN.

Hierarchical techniques improve the network's performance and extend its lifetime in large-scale WSNs. Despite the benefits of clustering on big WSNs, it remains a non-deterministic polynomial hard problem that classical clustering cannot tackle quickly. The optimum clustering algorithms for WSNs have been discovered through recent research on Machine Learning, Artificial Intelligence, and WSNs. These clustering algorithms outperform typical clustering algorithms because they are based on environmental behaviors [10].

The majority of work on WSNs was done by artificial intelligence (AI) systems. Swarm intelligence [11]is a system modeled on the real-world behavior of animal and insect colonies, which involves a large number of individuals working together in a group and coordinating their activity through decentralized control and self-organization. Reduced data transmission delays between network nodes, network balancing, avoidance of network traffic and overhead, energy savings, and maximum network lifespan are just some of the positive effects of AI-based optimization algorithms like Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Artificial Bee Colony (ABC), and so on WSNs. The following will describe the primary objective of this paper:

1-It explains Low Energy Adaptive Clustering Hierarchy (LEACH) and how it differs from the standard LEACH and how its protocols have been improved.

2-Tiered routing protocols classified by their "classical" and "swarm intelligence" approaches.

3- A synopsis of the several kinds of protocols, how they're used, and the benefits and drawbacks of each. Protocols are evaluated using a wide variety of criteria.

4- This analysis summarizes and compares hierarchical routing methods according to parameters including energy efficiency, data aggregation, location awareness, QOS, scalability, load balance, fault tolerance, multipath, and query based.

The rest of this paper is ordered as follows: section 2 presents the related work based on previous survey of routing protocols. Section 3 observes what is the LEACH protocol. Section 3 presents contained taxonomy of derived LEACH protocols and some comparison tables. Section 4 presents the classification of WSN based on two types: classical and swarm intelligence approach. Section 5 summaries and discusses energy efficient hierarchical routing protocols. Section 6 concludes the paper

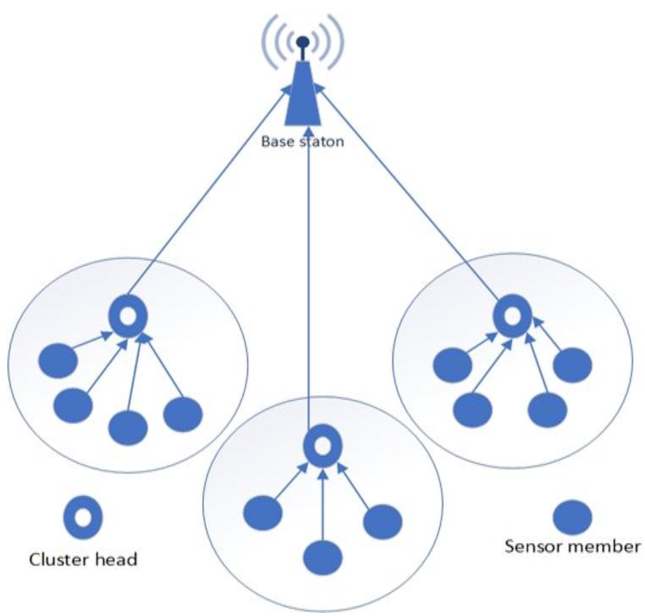

Fig. 2 Clustered WSN [4]

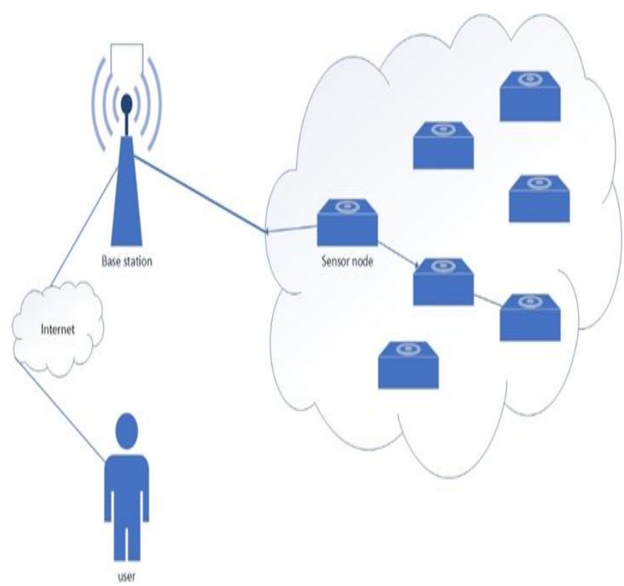

Fig. 1 WSN architecture [1]

II. RELATED WORK

LEACH protocols were used for several of the survey's subjects, classical protocol and swarm intelligence algorithms are documented in the following subsections.

1-LEACH

The best strategy to establish, maintain, preserve, and improve the efficacy of WSN is to group nodes into clusters. Furthermore, clustering algorithms and techniques receive the most attention, with the LEACH protocol being one of the most essential. Fanian et al. [12] took a quick look at a few of improvement protocols of LEACH. These protocols' cluster traits, clustering process, and cluster head potentialities were classified. Multiple criteria such as cluster count, homogeneity or heterogeneity level, multi-level features, the role of cluster head cycle, inter-cluster and intra-cluster connection are explored and compared.

The LEACH protocol has spawned a slew of offshoot protocols. All grandchildren of the LEACH Protocols have been classified. P. Maurya and A. Kaur [13], in their study, used node mobility, location awareness (GPS involvement), and data transmission technique between cluster head nodes and base station. Because of the high energy consumption while sending data from cluster head to base station, derived protocols that use single hop transmission methods are confined to a small network area. Because cluster head sensor nodes consume less energy, protocols using multi-hop communication techniques can be employed for bigger networks.

A. Das and P. N. Astya [14] discussed different LEACH-based routing techniques in a straightforward manner. Indeed, because energy resources are exceedingly limited, the point of least energy use is a major priority while designing WSN routing protocols. Due to the presence of energy resources in sensors, the network's energy efficiency has been put to the test. The primary objective is to prolong the life of the system by keeping the sensors functional for as long as possible. So that sensors can work for a longer period of time, it's important that WSN routing protocols use as little power as feasible. This results in a longer lifespan for the system. The LEACH routing protocol and its many associated protocols are also included for your convenience. There are a few problems with LEACH, and several methods have been devised to fix them.

M. Haque et al. [8] examined and provided a complete overview of well-known hierarchical routing protocols, a taxonomy of hierarchical routing protocols, and a design challenge, as well as a comparative analysis based on their characteristics and limitations. Data analysis demonstrates that wireless sensor networks benefit greatly from using hierarchical routing. For the first time, I. Daanoune et al. [15] classified LEACH-based routing approaches into three groups: CH selection, data transfer, and strategies for both. The data from this survey is compared to data from previous studies. In order to determine which protocols are the best, researchers consider a wide range of factors, such as the CH selection mechanism, communication method, scalability, energy efficiency, mobility, node localization, and so on. Based on these metrics, they compare and contrast various clustered routing approaches. This poll also compares and contrasts the strengths and weaknesses of each LEACH variation protocol. According to the study results presented in [16], the Multi-Hop LEACH protocol significantly improves the energy efficiency of LEACH by making three changes: allocating the inactive TDMA node to the next node if the preceding node has no data to give, carefully selecting the head of the node, and adding a term to the original equation. In subsequent efforts, hopefully, we can implement new protocols in addition to LEACH.

2-CLASSICAL ROUTING PROTOCOLS

The hierarchical routing techniques to combat energy depletion and hence increase network lifetime in [17]. As a result of the research, hierarchical routing algorithms have had various improvements made to them. Jadhav and Satao [18] suggested a conceptual depiction of several different opportunistic routing protocols together with their performance metrics and advantages was offered. The solutions that were discussed had several primary goals in mind, the most important of which were to reduce data redundancy, improve energy efficiency, and boost network utilization. Methods that were more efficient with energy were developed in order to improve throughput, efficiency, and dependability. A comparison of opportunistic protocols was presented, taking into account the forward list selection parameter, the priority metric for node selection, the synchronization parameter, the delay, the duplicate packet measure, the energy efficiency, and the application domain of the protocols.

For Wireless Multimedia Sensor Networks, cursory investigation into multipath routing strategies was carried out in [19] for minimizing transmission delay and congestion and increasing channel usage rate (WMSN). As part of their research, they summarized the working principle, benefits, and drawbacks of multipath routing methods. Clustering is a valuable topology management strategy for reducing communication overhead and exploiting data aggregation in sensor networks, and is best suited for large scale wireless sensor networks. The major issues for clustering algorithms include determining how to handle intra-cluster and inter-cluster transmissions for a good packet delivery ratio with minimal energy consumption, as well as determining how to format the ideal cluster to maximize network lifetime. BADAWY et al. [20] focused on block-based cluster routing protocols and examine the differences across cluster routing categories.

Numerous CH selection approaches in WSN that are based on energy awareness examined by John and Rodrigues [21]. In addition, a fundamental comprehension of CH routing methods is offered by this survey. A categorization hierarchy is presented for multiple CH selection strategies, and it is based on many different aspects that allow the association of several systems that are used to reduce energy consumption in WSN. This hierarchy marks the benefits and drawbacks of each CH selection methodology, and it is based on many different aspects. This survey provides an overview of a variety of CH selection procedures, as well as the respondents' CH selection tactics. In addition, an evaluation is carried out based on the tools that were utilized for the implementation and performance evaluation. This evaluation takes into account the clustering method, energy efficiency, network lifetime, scalability, number of alive and dead nodes, energy consumption, residual energy, and other factors.

A complete survey of hierarchical routing algorithms for WSNs was carried out in [22] by Chan et al. The goal of all strategies is to extend the lifetime of the WSN while maintaining data delivery performance. Furthermore, depending on the routing approaches, they categorized hierarchical routing techniques. They also emphasized some of the most important routing metrics, as well as the benefits and drawbacks of each routing strategy. Finally, they offered a more detailed examination of the most recent enhancements to the LEACH procedure. When building routing protocols, WSN faces a number of concerns and obstacles that should be taken into account. As a result, multiple types of WSN routing protocols have been identified and covered in [23]. These protocols are flat, hierarchical, topology-based, energy-aware, and secure routing protocols. Several energy-efficient routing protocols based on single-path and multi-path routing were studied and examined by Maratha and Gupta in their study [24]. After evaluating articles based on single path and multi-path routing protocols, routing protocols based on operations and aims are classified. Following that, the protocols based on a variety of factors are examined. Next, a new taxonomy for diverse ways to achieving a certain goal was proposed, which is adopted by the researchers in their publications addressed in the review. Also, a thorough comparison of single path and multi-path routing protocols, outlining their strengths and weaknesses based on the objectives was conducted.

3- SWARM-INTELLEGENCE ROUTINGS PROTOCOLS

Gui et al.[25] covered the groundwork for a SI-based meta-heuristic. The authors emphasized ACO (PSO), BFO (Bacterial foraging optimization), and ABC (artificial bee colony) (ABC). The fission-fusion theory was introduced, and then optimization strategies inspired by termite colonies and spider monkeys were discussed. During optimal path selection, spider monkey optimization does not pick nodes with low residual energy to prevent path failures or network breakdown. Several SI-based methods were compared and contrasted according to their individual characteristics. Swarm intelligence algorithms and multi-objective optimization (MOO) methods were introduced to kick off the surveillance and monitoring research and development efforts [26].The compromise between packet loss rate, lifetime, energy dissipation, and coverage was a frequent problem in WSN. The needs of various optimization approaches, including heuristics/metaheuristics-based optimization and mathematical programming, were analyzed in the context of sophisticated optimizations.

A. Chakraborty and A. K. Kar [27] provided a thorough examination of a subset of well-known swarm intelligence algorithms, from which only insect- and animal-based algorithms were chosen. The study showed that a handful of the algorithms addressed, such as ant colony, bee colony, firefly-, and bat-based algorithms, are particularly popular and well-studied, with numerous papers on the subject. The authors also included insights on lesser-known algorithms, such as glow-worm, monkey, lion, and wolf-based algorithms, in their research. Basic information about all of these algorithms has been supplied, followed by a current literature analysis and identification of prospective applications for each of them. D. Wohwe Sambo et al. [10] conducted a comprehensive assessment of contemporary hierarchical techniques based on CI or ML. To do so, they categorized the algorithms based on the CI they utilized, which may be FL, GA, NN, RL, or SI. They consider ten parameters in order to evaluate and compare them: The data delivery rate; data aggregation; the energy consumption that characterizes the network lifetime; the algorithm's scalability as the number of nodes grows; the algorithm's approach, which can be either centralized or distributed; homogeneity or network heterogeneity, which evaluates whether sensors have the same performance or not; the radio model, which is employed by the optimized algorithms to represent the energy model; multi-hop to determine whether or not an optimum solution takes into account multi-hop communications; Algorithm fault tolerance with multipath.

D. Mehta and S. Saxena [9] classified swarm intelligence-oriented protocols and delves into the details of swarm intelligence-based hierarchical routing protocols. These protocols have been evaluated on a variety of levels, including route selection, data aggregation, query-based, location awareness, and energy efficiency, to gain a better understanding of how they work.

The majority of proposed works used the ACO technique in their routing protocols [28], while only a few used the bee colony algorithm. The PSO-based method was overlooked. This is because ACO and ABC-based routing protocols are severely lacking in numerous aspects such as energy, resilience, and scalability, and hence function best in complex transmission situations. As a result, considerable effort has gone into developing effective and efficient routing protocols for WMSNs. As a result, they stated that SI, as a novel and bio-inspired field, has made significant contributions to the improvement of sensor network routing challenges. R. K. Yadav and R. P. Mahapatra [29] used a new hybrid optimization model to offer a new energy-aware CH selection via hierarchical routing in WSN. Furthermore, some criteria are used in the selection process, such as energy stabilization, node distance minimizing, and data transmission latency reduction. By picking the best CH, the defined non-linear objective function achieves lifespan extension. The new algorithm, known as Cuckoo Insisted-Rider Optimization Algorithm (CI-ROA), is a mix of the Rider Optimization Algorithm (ROA) and the Cuckoo Search (CS) Algorithm. Finally, the proposed work's performance is compared to and proven against other traditional models.

4- COMBINED ROUTING PROTOCOLS

In another sight the researchers Asif et al. [30] looked at the history of QoS support and the significance of QoS at each protocol layer. Many traditional protocols based on swarm intelligence that consider quality of service were analyzed, and their pros and downsides were compared. Quality-of-service (QoS) metrics were compared to show how well each protocol performed. In order to facilitate proper QoS management, the prerequisites and research problems of several CI approaches were presented. K. Guleria and A. K. Verma [31] provided a comprehensive analysis of classical and swarm-based hierarchical routing techniques that conserve energy. This article compares numerous conventional and SI based hierarchical routing protocols with regards to energy efficiency, data aggregation, QoS, scalability, load balancing, fault tolerance, location awareness, multipath, and query-based performance measurements. Traditional hierarchical routing prioritizes optimal clustering, load balancing, and evolutionary approaches to build a better trade-off between energy efficiency and network performance. By suggesting enhancements at the design and algorithmic levels using biologically inspired meta-heuristic techniques to provide better solutions to optimization difficulties, Swarm Intelligence-based hierarchical routing contributes significantly.

III. TAXONOMY OFWSNs ROUTINGS PROTOCOLS

WSNs have deployed a variety of routing protocols to improve networks performance in recent years. Figs. 4 and 5 depict the taxonomy of routing protocols. The network structure, network operation, route processing, and communication initiator are all used to classify these protocols. The network structure was classified based on node homogeneity. The primary characteristic of these protocols is how data is sent between nodes based on the network's connectivity structure.

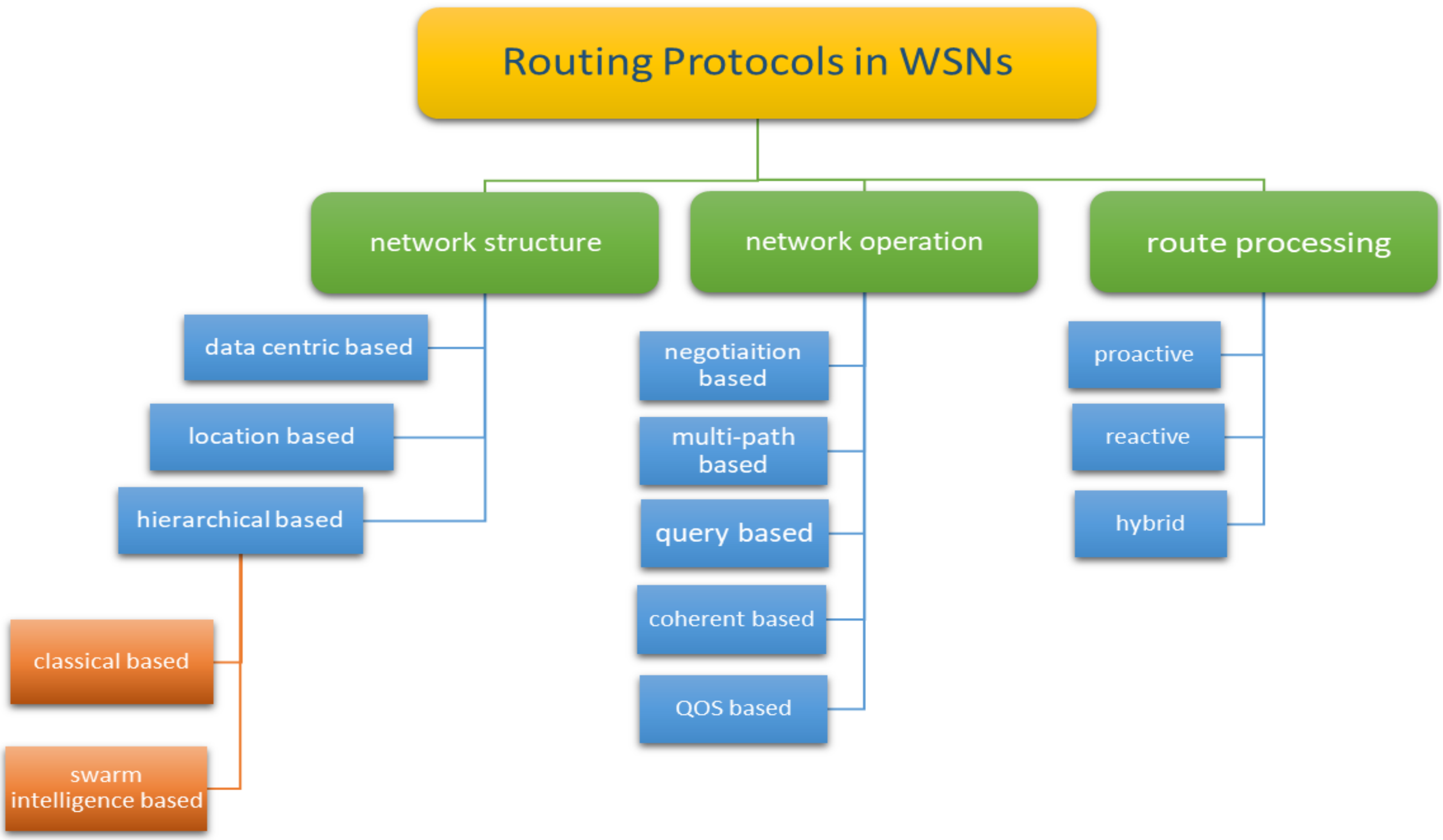

Fig.4: A taxonomy of routing protocols in WSNs

3.1 Structure-based Routing

The homogeneity of a network's nodes can be used to classify its structure. The way nodes are connected is the key characteristic of routing protocols in this category, and they route information based on the network architecture. The structure-based protocols are organized in three ways: flat, hierarchical, and location [32].

3.1.1 Data centric routing protocols

In a data-centric or flat algorithm, data is transferred from a source node to a destination node, with intermediate nodes performing aggregation on data or information from several sources before sending the results on to the final nodes [3]. Unfortunately, there is a memory crunch in data processing. In this scenario, data recovery and data dissemination were the primary focuses of data-centric algorithms.

3.1.2 Hierarchical routing algorithms

By constructing a hierarchy of sensor nodes, cluster-based hierarchical routing algorithms divide a network into different clusters. One cluster head (CH) and several sensor nodes make up each cluster. Each sensor node takes data and sends it to its respective CH. On the basis of a specified routing algorithm, CHs perform aggregation on the acquired data and transfer aggregated data to the next hop or main station, referred to as BS, as shown in Fig. 3 [33].

3.1.3 Location-based routing algorithms

Location-based protocols determine how messages should be transmitted based on where the nodes in their networks are located. The Geographical and Energy Aware Routing (GEAR) [23] protocol is one example of a location-based routing system [23]. This particular protocol transmits messages based on the location of nodes as well as their current energy levels.

3.2 Property-based routing protocols

The functions that each activity serves serve to categorize the WSN activities. The purpose of property-based routing is to safeguard the limited resources of a sensor network while still achieving the highest possible level of performance. In addition to negotiation-based, multi-path-based, query-based, and coherent-based routing protocols, property-based routing protocols also include query-based routing protocols.

3.2.1 Negotiation-based routing protocols

The elimination of the transmission of redundant data through the utilization of high-level data descriptors is the fundamental objective of these protocols. By delivering a list of negotiation messages before the start of the real data transmission, negotiation-based routing strives to achieve its objective of preventing the transmission of false data and controlling redundant information to the subsequent sensor network or BS.

3.2.2 Multipath-based routing protocols

Sensor networks use multiple pathways rather than a single one to boost performance. If the main connection between the nodes is ever disrupted, a backup route is built. By reserving multiple pathways between the transmitter and receiver nodes, fault tolerance is improved at the expense of network control packet overhead and wasted energy. Frequent control messages are sent out to maintain the availability of secondary communication channels. Hence, it improves network resilience at the cost of more network management traffic in order to keep several routes to the target online.

3.2.3 Query-based routing protocols

A query to the sender is started by the receiving node in order to retrieve information from it. High-level languages are used to express queries as they are sent across the network.

3.2.4 Coherent-based routing protocols

After going through a minimum amount of processing in the coherence-based routing system, information is distributed to aggregators. The majority of the time, features such as time stamping, duplicate suppression, and others are incorporated. The majority of the time, this approach is used in energy-efficient routing.

3.2.5 QoS based routing protocols

QoS ensures that a wireless network delivers the expected results. Latency (delay), throughput, error rate, and energy consumption are a few QoS parameters in WSN. These differentiate traffic flows by treating packets differently depending on their nature. It's also in charge of prioritizing data flows in order to maintain a certain level of performance. QoS can help with a variety of things. It improves bandwidth and network resource consumption, for starters. Second, it is in charge of supplying high-level services in multimedia applications, such as video, pictures, and audio. Third, it classifies network traffic and assigns a priority to each traffic type [34].

3.3 Route processing

WSN protocols can be categorized according to their processing into reactive, proactive and hybrid protocols. The following subsections explain these categories.

3.3.1 Reactive Routing Protocol

When a packet needs to be forwarded, the reactive protocol finds alternate routes. It keeps track of the routes that are currently active. As a result, when a node is swamped with route requests and route replies, routes are constructed on-demand [35]. It must be determined by the route right before packet transmission begins, resulting in a delay in receiving the first data packet. These offices have a low overhead and reduce network demand.

3.3.2 Proactive Routing Protocol

These protocols are also known as table-driven protocols and perform similarly to wire networks. The nodes' routing table and path to any destination are built on the basis of periodic information routing among the nodes. Nodes keep one or more tables to store routing information in order to find the destination [34]. These nodes also communicate updates in response to network topology changes, ensuring a consistent network throughout. The overhead of route discovery is reduced because the path to any destination is already known. The main disadvantage of this technology is that it consumes a significant amount of bandwidth and battery power, both of which are always limited in WSNs.

3.3.3 Hybrid Routing Protocols

Zone Routing Protocol (ZRP) is a wireless hybrid routing technology for data transfer over the network that combines proactive and reactive routing protocols. The ZRP protocol is designed to reduce the control overhead of proactive routing systems while also reducing the latency caused by routing discover in reactive routing strategies [36].

IV. CLASSICAL HIERARCHICAL ROUTING PROTOCOLS

One of the most famous protocols that helps in the conservation of energy in WSNs and improves network output, is the Low Energy Adaptive Clustering Hierarchy (LEACH). It is generally considered as a pioneer in the field of hierarchical routing protocols. Clusters go through two distinct stages when using the LEACH method: initialization and maintenance. This protocol is designed to ensure that all devices in a network receive their fair share of power. After selecting cluster leaders, the remaining nodes create subclusters around the chosen leaders [37]. The threshold T(n) for cluster head selection is given by: where p is the probability of the desired percentage of cluster head, G is the total number of nodes in the sensor network, and r is the number of current rounds.

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

The cluster head is chosen, the cluster is formed, and the TDMA schedule is assigned all during the setup phase. Centralized, decentralized, and hybrid models are used to build the clusters. Deterministic, random, and probabilistic methods are all used to select the cluster head. During the steady-state phase, data is transmitted based on communications between and within clusters. Data is sent from the cluster head to the sink through a TDMA schedule. Fig. 6 presents the LEACH cluster. The LEACH algorithm provides a number of benefits, including increased network longevity, lower energy usage and hence energy efficiency, longer battery life due to fewer intra-cluster collisions, and high throughput. However, there are a few drawbacks to using the LEACH algorithm, such as network robustness being greatly exaggerated and thus network lifetime being tainted when a low energy node is chosen as cluster head, increased intra cluster communication due to the change in cluster head location, and thus increased energy dissipation, etc. [38].

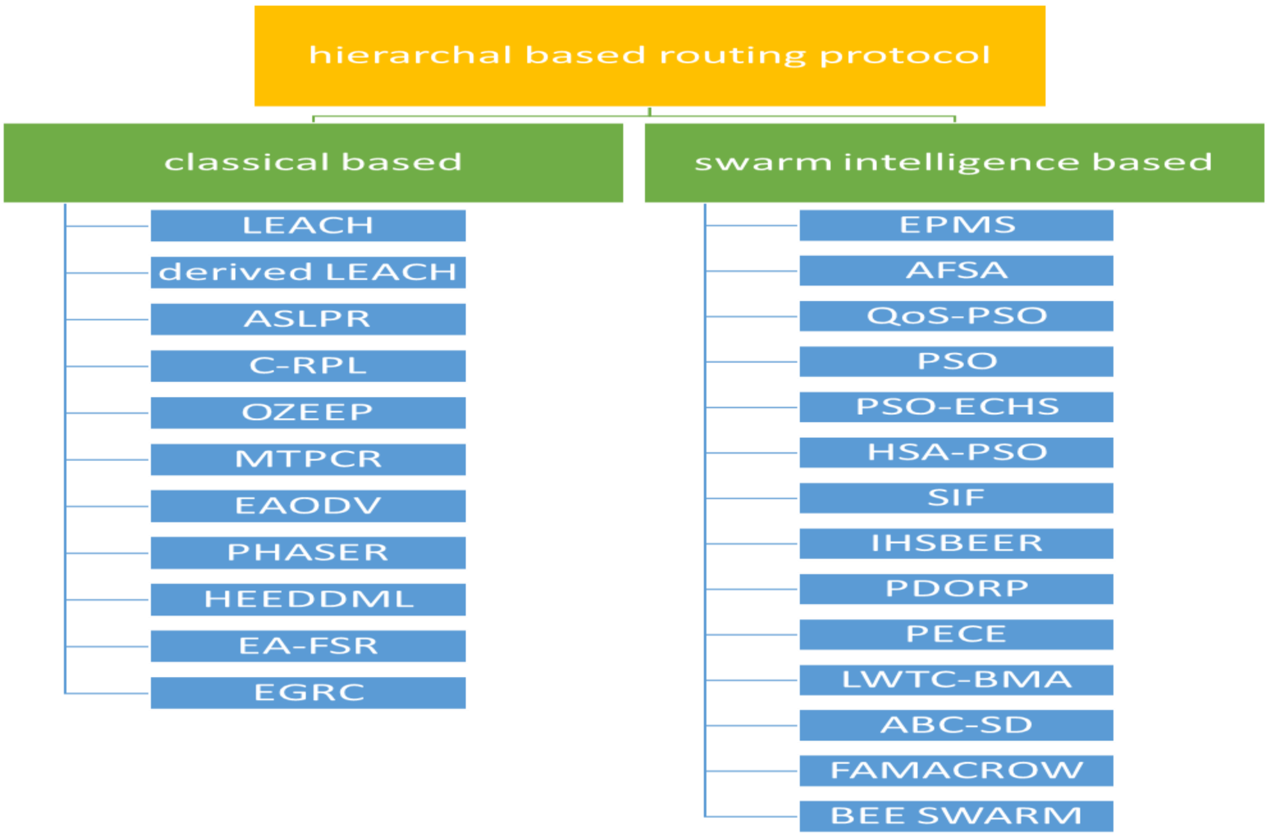

Fig. 5 Taxonomy of hierarchal based routing protocol

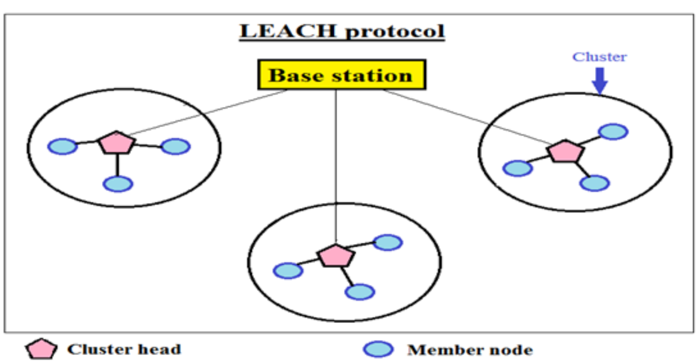

Fig. 6 LEACH cluster

4.1 LEACH descent protocols

In this study, we suggest a new classification of LEACH descendant protocols based on the metrics and methods that are utilized, such as residual energy, energy efficiency, single-hop, multi-hop, and so on. Fig. 7 depicts the suggested LEACH descendant protocols. Further details on each division is presented in the following subsections. Table1 summaries main factors of the derived LEACH protocols including cluster head selection, hop count, scalability, mobility, energy efficiency, network topology, and spread sensors.

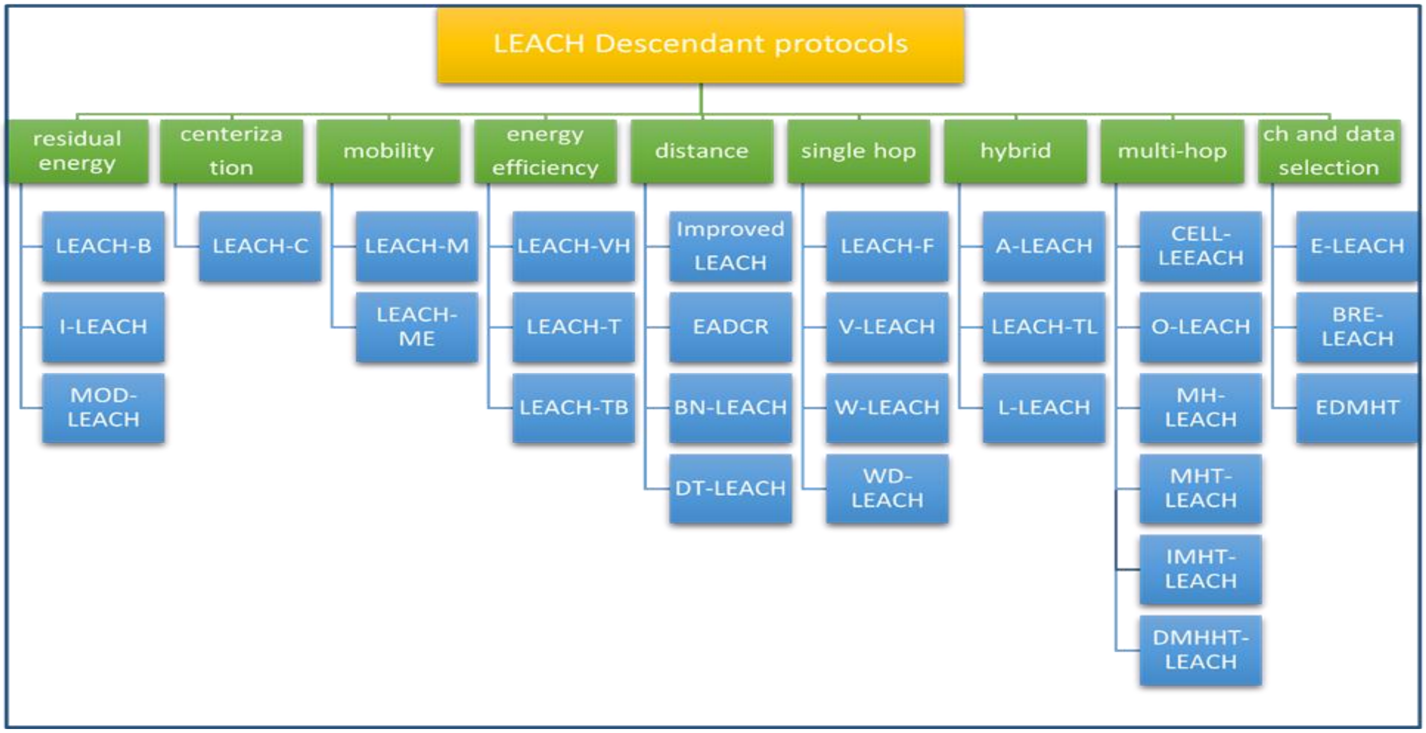

Fig. 7 Taxonomy of descendant LEACH protocols

4.1.1 Residual energy

Protocols such as balanced energy LEACH, Improved LEACH, and MODLEACH are examples of residual energy LEACH methods. In order to make LEACH a better routing mechanism, Salim, Osamy, and Khedr [39] suggested Intra-balance IB-LEACH, a protocol for WSNs with balanced energy consumption. The primary goal of the proposed protocol is to reduce CH energy consumption by distributing work across CHs and their cluster members (CMs), hence reducing energy consumption at all sensor nodes. Each non-CH modifies its transmission power according to the volume of the received CH advertisement. Furthermore, the suggested protocol can be utilized to satisfy energy balancing between CH and CM by any other cluster-based routing protocol, as it is not dependent on CH's election technique.

To guarantee that the elected cluster-heads are spread out evenly over the network, D. Dembla and H. Shivam [40] devised I-LEACH (Improved LEACH). That's why it's impossible for there to be a centralization of cluster leaders. Average energy consumption, average throughput, and network lifetime are the primary measures used to assess the effectiveness of the proposed I-LEACH protocol. I-LEACH makes use of a decentralized clustering strategy. The full range of sensors is partitioned into uniform sub-areas. Like the LEACH methodology, the CH is selected from each sub-region using a threshold method.

D. Mahmood et al. [41] proposed MODLEACH, which is considered as a fast cluster head replacement after the first round and dual transmission power levels for intra cluster and cluster head to base station communication to reduce network energy consumption. A cluster head in MODLEACH will only be changed if its energy falls below a particular level, reducing protocol routing burden. As a result, the cluster head replacement method incorporates the cluster head's leftover energy at the start of each round. In order to evaluate the effectiveness of these protocols in terms of their throughput and their energy consumption, MODLEACH includes both a soft and a hard (MODLEACHST AND MODLEACHHT) threshold.

4.1.2 Centralization

W. B. Heinzelman et al. [42] developed LEACH-Centralized protocol. The location or quantity of cluster heads is not guaranteed by the LEACH-C protocol. A poor clustering configuration in a single cycle will not have a dramatic effect on the total performance of the clusters because of their flexibility. Yet, implementing a central control mechanism to construct the clusters by dispersing the cluster head nodes over the network can result in better clusters. Using the same steady-state methodology as LEACH, but with a centralized clustering approach, LEACH-centralized LEACH-C was developed from here.

4.1.3 Mobility

LEACH-Mobile protocol was developed by Kim and Chung[43] and used for wireless sensor networks that prioritizes mobility and can support nodes that move around a typical "hot area." In order to reduce data packet loss for mobile nodes, LEACH-Mobile sends a message to the cluster head within the TDMA schedule's allotted time window, requesting that data be transferred back to the mobile sensor node. The network performance is enhanced in comparison to the non-mobility centric LEACH Protocol because both the non-cluster head node and the cluster head check to see if a mobile node is a member of a given cluster within the same time slot in the TDMA schedule. The energy dissipation is higher in LEACH-Mobile than in LEACH, which is a disadvantage.

In order to enhance LEACH-M, Kumar, et al. [44] introduced a new protocol dubbed LEACH-ME (Mobile Enhanced-LEACH). As CHs, it chooses nodes that are less mobile than their neighbors. When in the steady state, each node keeps account of the CH transitions it made to transmit data. LEACH-primary ME's objective is to minimize the impact of cluster migration and node relocation by making CH mobility as low as practically practicable relative to other network nodes.

4.1.4 Energy-efficiency

Several energy-efficient routing protocols were proposed such as LEACH-VH, T-LEACH, and TB-LEACH. Vice-Cluster Head, called V–LEACH or LEACH-VH, was proposed by Mehmood et al.[45]. It is a novel technique suggested to prevent CHs from dying too soon since they consume more energy than member nodes. Because a vice CH is used instead of a re-clustering operation in V–LEACH, the network lifespan is greatly enhanced, conserving energy across the network. Furthermore, the efficiency of delivering data to the BS is improved since data is transferred to the BS even when a CH dies when the vice CH is used. As a result, this protocol ensures that packets are sent to the BS. The transmission cost, on the other hand, is not taken into account in this protocol [46].

Hong et al.[47] proposed T-LEACH, a threshold-based cluster head replacement approach. To limit the amount of cluster heads chosen, T-LEACH applies a threshold based on leftover energy. By decreasing the frequency of head selection and the expense of replacing heads, this form of clustering has the potential to extend the life of a whole network. T-LEACH is superior to LEACH because it strikes a better balance between energy efficiency and network lifespan.

A Time-based Cluster-Head Selection Algorithm (TB-LEACH) was developed by Junping et al. [48]. TB-LEACH is the one responsible for building the cluster by utilizing an algorithm-based random timer, which does not need any global knowledge. When compared to LEACH, TB-LEACH possesses superior energy efficiency as well as a longer lifespan for the network.

4.1.5 Distance

Amirthalingam and Anuratha [49] suggested model "Improved LEACH" to consider the LEACH Protocol for dynamic clustering, as well as improvements in CH election based on node energy, distance to other nodes, and distance to BS. These enhancements result in a better load balancing outcome, indicating that the network's longevity and scalability have improved.

Another protocol, Energy Aware Distance-based Cluster Head Selection and Routing (EADCR), used the FCM approach, residual energy of the nodes, and their respective Euclidean distances from the Base Station (BS) and cluster centroid to increase the lifespan of WSN. Panchal and Singh [50] proposed a novel clustering strategy where the CH selection is now based on the newly proposed fitness function to avoid the nodes consuming a significant amount of energy during the clustering phase. They also provide a new packet routing strategy that employs multi-hop communication and uses the shortest path technique for routing between nodes and their destinations, reducing the energy consumption of the CHs. They also save energy by using their Euclidean distances between nodes, as well as their CH and BS. Under many conditions, EADCR outperforms other comparable algorithms such as FCM, REHR, UCRA–GSO, and CCA–GWO in terms of network lifespan. It also preserves the network's leftover energy and improves network coverage.

Using a Bayesian Network (BN) model, Ghasemzadeh et al. [51] described the BN-LEACH protocol, which selects cluster-heads based on their proximity to the Base Station (BS), the amount of energy left in the nodes, and the overall density of the network. This model assesses how likely it is that a given sensor node will become the cluster leader. Using a dynamic zoning strategy and a greedy technique, we can select suitable cluster heads and distribute them fairly. When compared to LEACH, LEACH-C, and WEEC, all of which are enhancements of LEACH, the suggested protocol strikes a better balance between the energy needs of the sensor nodes, increases the lifespan of the network, and pushes back the time until the first node dies.

Kang and Nguyen [52] developed a distributed LEACH-DT algorithm that is based on the LEACH algorithm. In LEACH-DT, a node's likelihood of becoming a CH increase with its distance from the BS. In terms of energy efficiency, this algorithm is on par with LEACH. CH sends information to BS using the multi-path idea (d4 power loss). Each node's likelihood of becoming a CH is calculated based on its distance from the BS. This means that the chances of any given node becoming a CH are not uniform across the network. Using a single-hop sensor network to relay signals over a great distance from sensors positioned far from the BS is inefficient and wasteful of energy. In order to reduce power consumption, sensors are organized into sensor groups (SG) according to their distance from the BS. Each SG, similar to before, selects the CH using the suggested single-hop LEACH-DT. The information gathered by CH is shared with BS either directly or through intermediate entities in CH's organizational structure [53].

4.1.6 Single-hop

Fixed number of cluster LEACH (LEACH-F) was implemented to avoids re-clustering by employing a stable cluster with a rotating cluster head that remains in place throughout. The LEACH-C method is used to create clusters and cluster heads at first. The most significant limitation of this protocol is that, once formed, clusters cannot be modified and additional nodes cannot be added to clusters in which nodes have been removed owing to loss of energy [54].

With the improved V-LEACH process [55], the cluster now has both a CH and a vice-CH. Ahlawat and Malik suggested it [55]. The vice-CH is responsible for taking over for the CH in the event that the CH passes away. The strategy that uses the cluster head selection criterion is one of a kind. The lowest distance traveled, the maximum amount of residual energy, and the amount of energy expended are the three parameters that decide the outcome. Each non-cluster head node determines its cluster head based on received signal intensity; higher signal strength equals shorter distance between them, and if distance is modest, less energy is required for transmission. The proposed method will extend the network's life since the cluster head will never die. When a cluster head dies, it's vice Cluster head takes its position.

Weighted-LEACH (W-LEACH) [56] is one of the types of single hop protocols that has a fundamental contribution in presenting a data aggregation technique for WSNs with the goal of reducing sensor energy consumption and thereby increasing network life time without compromising data accuracy. Because the algorithm is complicated, we'll break it down into three parts. The first step introduces the Weighted Low Energy Aggregation Clustering Hierarchy, a novel algorithm (W-LEACH). The second phase improves the algorithm's technical components in order to attain a longer network lifetime. We call this phase's method Dynamic W-LEACH because it adds a dynamic character to one of WLEACH's most critical parameters. The final phase examines data correctness while using Dynamic W-LEACH on non-uniform WSNs, demonstrating that the method has no significant impact on the acquired data's overall accuracy.

The new protocol WD-LEACH described by Abdelhalim [57], it is a decentralized approach for extending the network lifespan of sensor nodes in wireless sensor networks established in abandoned mines or mapping caves. This approach uses sensor density (the number of sensors near together) to put certain nodes to sleep if they detect a lot of neighbors. The strength of our concept is that it may be employed in situations when the position of nodes cannot be determined. Furthermore, each node has the ability to decide whether to remain active or inactive on its own. The network lifetime will be greatly prolonged in this manner.

4.1.7 multi-hop

One of this type is Cell-LEACH protocol, which was proposed by Yektaparast et al. [58]. The Cell-LEACH protocol further separates clusters into smaller cells to minimize energy usage. Cluster and cell creation happens just once during the setup phase and is preserved throughout the network's lifecycle, whereas cell and cluster heads are constantly picked and updated. Through their cell heads, the cell members relay their sensed data to the corresponding cluster heads [59].

The Orphan Nodes protocol (called Orphan-LEACH protocol or simply O-LEACH) [60] is developed to reduce the amount of outlier sensor nodes. There are two scenarios in O-LEACH. In the first case, a cluster node can serve as a gateway for joining isolated nodes. The gateway node is sometimes abbreviated as CH' for connected orphans due to the fact that it connects several isolated nodes. Hence, orphan nodes can communicate with the CH', which will aggregate their data before forwarding the resulting data message to the CH. In a second scenario, a sub-cluster will be formed if the number of cluster members is greater than the number of orphan nodes in an unprotected region. The first unrelated node to arrive at the hub will be a CH' (cluster member). O-Leach paves the way for a new clustering strategy to be built, which has a high lifetime and low power consumption. Energy harvesting from the network is a viable option for orphaned nodes. Covering the whole network with few isolated nodes, its connection rate is extremely high.

Multi-hop LEACH (MH-LEACH) proposed by G. Wang et al. [61] is a new algorithm based on LEACH. The protocol chooses the cluster head based on energy and multi-hop combination with simple hops in the cluster. MH-LEACH has a greater effect on extending network lifetime and enhancing energy usage rate than LEACH. The goal of MHT-LEACH protocol is to create a multi-hop connection between CHs and BS in order to transmit aggregated data. The network data is sent from distant CHs to CHs that are closer to the BS. As a result, there is a requirement to reduce CH's energy use by identifying the greatest source of energy consumption. In compared to the LEACH protocol, MHT-LEACH extends the network's longevity, stability, and throughput [62]. The Dynamic Multi-Hop Technique-LEACH (DMHT-LEACH) developed by Alnawafa and Marghescu [63] used a dynamic multi-hop technique for delivering the CHs data to the BS, which takes into consideration: the remaining energy of CHs during the round and the distances between them. Based on that, each CH may change its routes dynamically in the same round.

P-LEACH is one of the developed multi hop protocols by Cho et al. [64]. It divides the network into the same size partition cluster (PC) and employs the sink tracking for reducing the energy expenditure by activating only a few nodes, It divides the network into partition clusters (PCs) of the same size and uses sink tracking to reduce energy consumption by activating just a few nodes.

4.1.8 Hybrid-hop

Using the distinctive factors of heterogeneity in networks, Abdellah et al. suggested A-LEACH [65] to enhance the stable region of the clustering hierarchy and decreases the chance of failure nodes. In these networks, some high-energy nodes known as CAG nodes become cluster heads, aggregating data from their cluster members and transmitting it to the sink or Gateways to reduce cluster head energy consumption because it is used to route information from cluster head to the sink, lowering cluster head failure probability and increasing network lifetime.

TL-LEACH proposed by Loscri et al. [66] to rotate local cluster base stations at random (primary cluster-heads and secondary cluster-heads). It creates a two-level hierarchy when it is possible. This allows the energy burden to be distributed more evenly across the sensors in the network, which is especially useful when the network density is large. To achieve scalability and resilience, TL-LEACH employs localized coordination.

LEACH-L [67] is an advanced multi-hop cluster-based routing system that is energy balanced. It is merely a matter of distance. The ideal hop counts are assumed in LEACH-L. When cluster heads are placed close to a BS (Base Station), they may communicate with it directly. When cluster heads are located distant from the BS and the shortest communication path is constrained, they communicate using multi hop mode. Sensor nodes in the LEACH-L system interact with BS at different frequencies. Each round reorganizes the clusters, and each round comprises two phases: a set-up phase and a steady phase. In each round, new CHs are chosen.

4.1.9 CH and Data Transmission

Enhanced-LEACH protocol was proposed Xu et al. [68] to select the optimal nodes as cluster heads and change the round time in every round. They used the minimum spanning tree to send data messages to the base station. So, the nodes' die rate will decrease and eventually the network life time will increase.

Idaanoune el. al. [69] designed BRE-LEACH protocol to extend the life of networks by consuming less power. Its foundation is LEACH's restrictions and those of related algorithms. Three factors remaining energy, distance to the BS (Base Station), and multi-hop—determine how effective the strategy is. In order to prevent low-energy sensor nodes from acting as the CH, residual energy is employed as the primary criterion in the cluster head (CH) selection method. Selecting the CH closest to the BS with the highest residual energy as the root CH to integrate data from other CHs and deliver to the BS is how the BRE-LEACH determines the optimal path. Those farthest from the root CH must resort to the multi-hop in order to reach it.
Enhanced Dynamic Multi-Hop Technique-LEACH (EDMHT-LEACH) that is proposed by lnawafa and Marghescu [70] is used for selection the CHs and forming the clusters in the network. Also, it introduces a new modification for the dynamic mechanism that is used in selecting the routes during the same round. The proposed protocol consists of four phases Initial Phase, Announcement Phase, Selection Phase and Routing Phase.

Table.1 summary of derived LEACH protocol

protocol	Ch selection	Hop count	mobility	scalability	Energy-efficiency	Topology D\C	Spread sensors
LEACH	Random	one hop	fixed	Limited	High	D	randomly
LEACH-B	Random, Residual-energy	one hop	fixed	Good	Very high	D	=
I-LEACH	Residual energy	one hop	fixed	V-good	Very high	D	=
MOD-LEACH	Residual-energy, threshold level	one hop	fixed	limited	High	D	=
LEACH-C	Residual energy	one hop	fixed	Good	Very high	C	=
LEACH-M	Residual-energy, mobility	one hop	mobile	v-good	Very high	D	=
LEACH-ME	Residual-energy, mobility	one hop	mobile	Limited	High	D	=
VH-LEACH	Residual energy	one hop	fixed	v-good	Very high	D	=
LEACH-T	Residual energy	one hop	fixed	Good	High	D	=
TB-LEACH	Random	one hop	fixed	Limited	High	D	=
Improved-LEACH	Residual-energy, distance	one hop	fixed	Good	High	D	=
EADCR	Residual-energy, Euclidean- distance	one hop	fixed	Good	Very high	D	=
BN-LEACH	Residual-energy, density	one hop	fixed	Good	High	D	=
DT-LEACH	Residual-energy, distance	one hop	fixed	Good	High	D	=
LEACH-F	random	one hop	fixed	Limited	Very high	D	=
V-LEACH	same	one hop	fixed	Good	Very high	D	=
W-LEACH	same	one hop	fixed	Good	High	D	=
WD-LEACH	same	one hop	fixed	Good	High	D	=
LEACH-Cell	same	multiple	fixed	v-good	Very high	D	=
O-LEACH	same	multiple	fixed	Good	High	D	=
MH-LEACH	same	multiple	fixed	Good	Very high	D	=
MHT-LEACH	same	multiple	fixed	Good	Very high	D	=
IMHT-LEACH	same	multiple	fixed	Good	Very high	D	=
DMHT-LEACH	same	multiple	fixed	Good	Very high	D	=
A-LEACH	same	Hybrid	fixed	Good	Very high	D	=
LEACH-TL	same	Hybrid	fixed	v-good	Very high	D	=
L-LEACH	same	Hybrid	fixed	v-good	Very high	D	=
E-LEACH	same	multiple	fixed	v-good	Very high	D	=
BRE-LEACH	same	multiple	fixed	v-good	Very high	D	=
EDMHT-LEACH	same	multiple	fixed	Good	Very high	D	=

4.2 Other Classical Routing Protocols

For low-power and lossy networks, a cooperative IPv6 C-RPL routing protocol suggested by Barcelo et al. [71] to establish numerous instances using a cooperative technique among nodes with various sensing roles. As a consequence, the nodes' energy usage, complexity, and cost are lowered when compared to RPL, because they are active for less time, do fewer functions, and have less sensing gear. They also developed a new fairness analysis for networks with numerous instances, demonstrating that C-RPL provides a better performance-energy tradeoff than RPL with non-cooperative instances.

Srivastava and Sudarshan [72] proposed Optimized zone-based energy efficient routing protocol (OZEEP) for Mobile Sensor Networks. It is an expanded version of dubbed the Zone-based Energy Efficient Routing Protocol (ZEEP). Using a Genetic Fuzzy System, they devised an approach that improved ZEEP's clustering and cluster head selection. In the first part of the algorithm's two-step clustering procedure, a Fuzzy Inference System is used to identify ideal nodes that can be cluster heads based on criteria including energy, distance, density, and mobility. In the second stage, they employed a genetic algorithm to select a final cluster head from among the nominated candidates offered by the fuzzy system, resulting in an ideal solution consisting of a uniformly distributed balanced collection of clusters aimed at extending network lifetime.

Chen and Weng [73] developed Minimum transmission power consumption routing (MTPCR) in 2012 by analyzing power usage during data transmission with the aid of surrounding nodes and employing a path maintenance method to keep good path bandwidth, MTPCR is an asset to a network. Whether a network's path maintenance mechanism should be activated to minimize its overhead is determined by the number of nodes in the network. The suggested path maintenance technique effectively lessens both power usage and the number of paths breaks during data transmission.

Kim, et al. [74] proposed an Enhanced Ad hoc On-demand Distance Vector (EAODV) routing protocol with a selective route caching mechanism based on a source/destination pair for use in the route discovery approach. By using the selective route cache method, EAODV may retain the benefits of the route cache system while addressing its drawbacks. Simulation results show that EAODV outperforms conventional AODV in terms of packet delivery ratio, average end-to-end delay, and normalized routing overhead because EAODV can get the effect of route distribution in the route discovery procedure by using a selective route cache mechanism based on a source/destination pair.

Hayes and Ali [75] developed Proactive Highly Ambulatory Sensor Routing (PHASeR) in 2015 for the purpose of radiation mapping. Messages are transmitted in a multipath manner through the use of blind forwarding methods in PHASeR, and blind forwarding is carried out by the utilization of the Hop-count gradient. The transmission is being listened to by every node in the network, but only the nodes that are receiving it have the authority to determine whether or not to forward the data further in the network. PHASeR is subjected to mathematical analysis in order to investigate its scalability, as well as its mobility and traffic load. This strategy fares better in terms of performance when contrasted with AOVD and OLSR.

Singh el al. [76] proposed Multi-level Hybrid Energy Efficient Distributed clustering protocol (HEEDML) using a heterogeneous network energy model with a single parameter. This parameter helps the model detect various levels of node heterogeneity, ranging from zero to four levels, based on its value in terms of energy. This parameter can be implemented in a fuzzy manner or in a non-fuzzy manner.

K. Wang et al. [77] suggested Energy-efficiency Grid Routing based on 3D Cubes (EGRC) to improve energy-efficient data transmission approach in which the entire 3D network is partitioned into multiple SCs, each of which forms a cluster. The goal of this technique is to maximize the amount of data that can be transmitted while minimizing energy consumption. Every cluster has what's called a cluster-head node, which is the node most responsible for aggregating data and facilitating communication amongst cluster members. A novel approach to selecting cluster heads is proposed; according to this method, the cluster head node that has the greatest amount of remaining energy and the shortest distance to the base station would be selected. We also give a method for locating the next-hop node, which is dependent on the amount of energy that is left over, the distance between the nodes, and the end-to-end latency.

V. SWARM INTELLIGENCE HIERARCHICAL ROUTING PROTOCOLS

Due to the outstanding performance of artificial intelligence and its significant progress in the last few decades, several researches were carried out to develop new hierarchical routing protocols based on swarm intelligence. Table 2 list major efforts done to address the development of hierarchical routing protocols based on swarm intelligence. J. Wang et al. [78] suggested EPMS protocol based on an Energy Efficient PSO Based routing Algorithm for WSNs with Mobile Sink Support. During the routing phase, the EPMS routing algorithm primarily uses virtual clustering and mobile sink approaches. To begin, it divides the network into various areas using the PSO method. The EPMS selects the cluster head nodes within each cluster using a comparable clustering technique in each area. It combines the two conditions of the gravity center of the distance area and the node's energy. The EPMS then specifies three different data packet formats: Hello, Message-s, and Message-h. The Hello packet is used to determine which cluster area is responsible for sending data to the mobile sink. The Message-s packet transmits information to the cluster head, whereas the Message-h packet provides data to the sink node. EPMS is capable of balancing energy usage, extending network lifetime, and reducing transmission latency.

The Artificial Fish-swarm Method (AFSA) [79]is a random search algorithm based on replicating fish-swarm behaviors such as searching, swarming, and pursuing. It first develops the simple bottom behaviors of artificial fish (AF), and then, based on animal individuals' local seeking behaviors, it generates the global optimal. The AFSA is capable of searching for global optimums and has some space-seeking adaptability.

X. Zhang and Xu [80] introduced a QoS-based routine approach with particle swarm optimization in this study (PSO). The particle swarm behavior used in this technique ensures that WSN maintains appropriate QoS network routing. The particle swarm optimum based routing strategy would provide higher QoS performance for WSN application than the QoS-AODV approach.

Since the optimal solution is a point in the parameter space, this global optimization procedure is well-suited to finding it. Particle Swarm Optimization (PSO) can be used as a global optimization method that excels at situations in which the optimal solution is a point in a multidimensional space of the parameter space, and it was motivated in [81] by the information-sharing and social behavior seen in animal groups such as flocks of birds and schools of fish (real-valued optimization). Natural analogs, such as schooling or flocking, provide inspiration for the feature where agents (particles) are characterized not only by a position, but also by a velocity and are allowed to move around in the search space [82].

Rao, Jana, and Banka [83] proposed PSO-ECHS for the energy-efficient selection of CH that is based on PSO and includes an efficient particle representation as well as a fitness function. For calculating the algorithm's energy efficiency, they took into account intra-cluster distance, sink distance, and node residual energy.

Geem et al. [84] proposed HSA-PSO protocol. The HSA derives its ideas from the musical process of attempting to find the most harmonious condition possible. In the HAS, musical performance aims to achieve a state of perfect harmony, which is decided by aesthetic estimation. Similarly, the optimization algorithm seeks to achieve the best state (also known as the global optimum), which is determined by the value of the objective function. It has proven to be quite effective in solving a wide range of optimization issues, and in comparison to more conventional optimization strategies, it offers a number of advantages [85].

Another protocol, named SIF routing protocol [86], employs the FCM method for cluster formation in clustered WSNs, resulting in network-wide balanced clusters. A hybrid swarm intelligence method known as FA-SA was used to improve the fuzzy rule basis table in SIF. SIF can respond to changes in the network environment as well as lifespan specification. In other words, based on the application parameters, SIF may be optimized for every application to extend the network lifespan. As a result, the optimization algorithm's fitness function should be tailored to the application. The suggested fuzzy rule base table optimization approach may also be used to tweak the fuzzy rules of existing fuzzy-based protocols (E.g. CHEF, LEACH-ERE, UADCF, etc.) in order to increase their performance and extend the network lifetime.

In PECE routing protocol [87], Cluster creation and reliable data transport are the two processes. They create an energy-saving clustering routing technique based on node degree, relative distance between nodes, and node rest energy during the cluster formation stage. When this approach chooses the cluster head, the node degree and relative distance between nodes are both taken into account, resulting in a cluster that not only has superior coverage but also has a low average distance from other formative cluster member nodes. Using the bee colony optimization (BCO) algorithm in the steady data transmission stage, the PECE method not only drastically decreases the network's energy consumption, but also improves the network's energy balance and extends the network's lifetime.

IHSBEER protocol is based on a newer version of the HS algorithm [88]. First, based on the features of routing in WSNs, the encoding of harmony memory has been enhanced, and the roulette wheel selection technique is used to initialize the HM, which adds to the routing algorithm's convergence speed. Second, the ability to improvise a new harmony has been enhanced. For various sized WSNs, the IHSBEER algorithm performs considerably better in terms of balancing energy consumption, conserving energy, and prolonging network lifetime.

Brar et al. [89] introduced a PEGASIS-DSR optimized routing protocol (PDORP) based on hybrid optimization, which uses the cache and directional transmission concepts of both proactive and reactive routing protocols. It outperforms the competition in the majority of key metrics, including bit error rate, end-to-end transmission latency, energy usage, and throughput.

Using the Honey Bee Mating Algorithm, Sahoo et al. [90] offered a clustering technique for WSNs that is trust-based, safe, and energy-efficient (LWTC-BMA). They have also developed a practical energy consumption model for precisely calculating network life lifetime. The proposed LWTC-BMA extends the network's life by preventing malevolent nodes from becoming cluster heads.

Shankar and Jaisankar [91] offered ABC-DS based protocol, a variation of the meta-heuristic search method for selecting the best cluster head. To pick the cluster head in the proposed ABC-DS method, the selection criteria are based on three parameters: delay, energy, and distance. As a result, the number of active nodes and cluster head energy both grow.

In order to improve its energy efficiency and network lifetime, the cross-layer protocol known as FAMACROW was proposed by Gajjar el al. [92]. It combines the concepts of energy-efficient hierarchical cluster routing with media access. It does this by unequally clustering the data in order to avoid hot spots, and it employs computational intelligence techniques like as fuzzy logic and ACO in order to select cluster heads and route data between clusters. The increased reliability of the protocol is due to the utilization of LQI for the selection of cluster heads as well as delivery likelihood for inter-cluster routing.

Akbari el al. described [93] proposed a routing protocol based on honey bees' cognitive behavior. The Bee swarm optimization (BSO) is a new optimization method based on honey bee foraging behavior. Three sorts of bees fly in a D-dimensional search space to locate the best solution in the BSO algorithm: expert foragers, onlookers, and scout bees. By introducing variation into the swarm of bees, the BSO algorithm aims to maintain a good balance between global and local search. The BSO algorithms are efficient and reliable.

Table 2: Summary of different hierarchical routing protocols

PROTOCOL	Energy efficiency	Data aggregation	Location awareness	QoS	Scalability	Load balance	Fault tolerance	Multi path	Query based
ASLPR	Good	✓	✘	✘	Moderate	✓	✓	✓	No
C-RPL	Good	✓	✓	✓	Moderate	✓	✘	✘	✘
OZEEP	Very good	✓	✓	✓	Very good	✓	✓	✓	✓
MTPCR	Very good	✘	✘	✘	Very good	✓	✓	✓	✓
EAODV	Good	✓	✘	✓	Limited	✓	✘	✘	✓
PHASeR	Good	✓	✓	✘	Very good	✓	✓	✓	✘
HEEDML	Very good	✓	✓	✘	Limited	✓	✘	✘	✘
EA-FSR	Good	✘	✓	✘	Good	✓	✘	✘	✘
EGRC	Very good	✓	✓	✘	Good	✓	✓	✓	✘
EPMS	Good	✘	✓	✘	Limited	✓	✘	✘	✘
AFSA	Good	✓	✓	✘	Good	✓	✘	✘	✘
QoS-PSO	Good	✘	✘	✓	Very good	✓	✓	✓	✘
PSO	Good	✓	✘	✘	Good	✓	✘	✘	✘
PSO-ECHS	Very good	✓	✘	✘	Good	✓	✘	✘	✘
HAS-PSO	Very good	✓	✘	✘	Limited	✓	✘	✘	✘
SIF	Good	✓	✓	✘	Limited	✓	✘	✘	✘
PECE	Very good	✘	✘	✘	Limited	✓	✓	✓	✘
IHSBEER	Very good	✘	✘	✘	Limited	✓	✘	✘	✘
PDORP	Good	✓	✘	✓	Very good	✓	✘	✘	✘
LWTC-BMA	Good	✓	✘	✘	Good	✓	✘	✘	✘
ABC-SD	Very good	✓	✘	✓	Good	✓	✘	✘	✘
FAMACROW	Very good	✓	✘	✘	Very good	✓	✘	✘	✘
BEE SWARM	Very good	✓	✘	✘	Limited	✓	✘	✘	✘

VI. CONCLUSION

In recent years, wireless sensor networks have emerged as an increasingly useful tool for a variety of applications, including the tracking and monitoring of faraway places. It is clear from the protocols that have been evaluated those significant efforts have been made so far to address the techniques for effectively creating efficient routing protocols for wireless sensor networks (WSNs). This type of research is still considered to be in its infancy as a result of the rapid pace at which many computer disciplines, new technological developments, and numerous ongoing applications are all moving forward. Within the scope of this study, we have shown a portion of what is connected to the various routing protocols and made an effort to illustrate what factors contribute to improve the total energy usage of the network. As a result of the findings, which demonstrated that utilizing enhanced LEACH would result in a more energy-efficient protocol than the utilization of other types, a number of recent studies attempted to design an enhanced leach protocol. In addition, swarm-based protocols are considered a hot topic in the industry because they assist researchers in selecting and designing an appropriate protocol or routing mechanism depending on the network application. This is done with the intention of extending the life duration of wireless sensor networks and improving their quality of service.

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