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A COMPREHENSIVE SURVEY AND ANALYSIS FOR ENERGY CLUSTERING ALGORITHMS USING DATA TRANSFER FOR WIRELESSSENSOR NETWORKS

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ABSTRACT

In recent years, Wireless Sensor Networks (WSNs) have become increasingly integral to various applications, from environmental monitoring to industrial automation. The challenge of energy efficiency remains paramount, as sensor nodes are often deployed in environments where battery replacement is impractical. This work presents a comprehensive survey and analysis of energy clustering algorithms, focusing on data transfer methodologies within WSNs. The primary objective of these algorithms is to optimize energy consumption, thereby prolonging the network's operational lifespan. This survey categorizes energy clustering algorithms into several key types, including hierarchical, location-based, and hybrid approaches. Hierarchical clustering algorithms, such as Low-Energy Adaptive Clustering Hierarchy (LEACH), Improved low-energy adaptive clustering hierarchy (ILEACH), and Hybrid-Partial Swarm Optimization (PSO)-ILEACH algorithms, are explored in detail. These algorithms emphasize the formation of clusters and the selection of cluster heads to minimize intra-cluster communication costs and reduce the overall energy expenditure. Location-based clustering algorithms leverage geographic information to form clusters, thereby optimizing data routing paths and minimizing energy usage. Additionally, hybrid algorithms combine elements of hierarchical and location-based approaches to further enhance energy efficiency. The survey also examines the role of data transfer mechanisms in energy-efficient clustering. Efficient data aggregation and compression techniques, along with multi-hop communication protocols, are crucial for reducing redundant data transmission and conserving energy. The works discuss various data aggregation strategies, including tree-based, cluster-based, and hybrid aggregation models. Moreover, the impact of communication protocols, such as Time Division Multiple Access (TDMA) and Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), on energy efficiency is thoroughly analyzed. Furthermore, the survey identifies emerging trends and challenges in the field of energy-efficient clustering for WSNs. Also, this survey identifies emerging trends and challenges in the field of energy-efficient clustering for WSNs. The integration of machine learning and artificial intelligence techniques for adaptive clustering and predictive maintenance is discussed as a promising direction for future research. This Work proposes a framework for the systematic evaluation and benchmarking of clustering algorithms, which could serve as a valuable tool for researchers and practitioners in the field.

Keywords: *Wireless Sensor Networks (WSNs),Energy Clustering Algorithms, Hybrid Clustering and Data Aggregation.*

1. INTRODUCTION

Wireless Sensor Networks (WSNs) have emerged as a cornerstone technology in various fields, including environmental monitoring, industrial automation, healthcare, and smart cities. These networks consist of spatially distributed sensor nodes that autonomously collect and transmit data to a central base station or sink. Given the often inaccessible and hostile environments in which WSNs are deployed, the nodes are typically battery-powered, making energy efficiency a critical concern. The limited energy resources of these nodes necessitate the development of sophisticated algorithms to optimize power consumption, thereby prolonging the network's operational lifespan. Energy clustering algorithms have been widely recognized as an effective solution for enhancing energy efficiency in WSNs. By organizing sensor nodes into clusters and designating specific nodes as cluster heads, these algorithms aim to reduce communication overhead and balance energy consumption across the network. The cluster heads aggregate data from their respective clusters and forwards it to the base station, thereby minimizing the number of long-distance transmissions and conserving energy.

This work provides a comprehensive survey and analysis of energy clustering algorithms, focusing on the nuances of data transfer methodologies. It explores various types of clustering algorithms, including hierarchical, location-based, and hybrid approaches, and examines their effectiveness in different network scenarios. Additionally, the study delves into the role of data transfer mechanisms, such as data aggregation and compression techniques, in reducing energy consumption. The interaction between clustering algorithms and communication protocols, such as Time Division Multiple Access (TDMA) and Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), is also analyzed to understand their impact on overall energy efficiency. The significance of this research lies in its detailed evaluation of the trade-offs involved in the design and implementation of energy-efficient WSNs. By identifying key performance metrics such as energy consumption, data accuracy, and latency, this study aims to provide valuable insights into the optimal configuration of WSNs for various applications. Moreover, the paper highlights emerging trends and challenges, such as the integration of machine learning and artificial intelligence for adaptive clustering and predictive maintenance.

In works contribute to the ongoing discourse on energy efficiency in WSNs by offering a thorough examination of existing energy clustering algorithms and their associated data transfer mechanisms. Through this comprehensive survey, the study aims to pave the way for future advancements in the field, ultimately leading to the development of more efficient and sustainable wireless sensor networks.

Based on the functionality, WS are broadly classified into two types: Sensor nodes and Sink nodes. Sensor nodes send the sensed data to the sink node/BS for further processing such as data aggregation, processing, etc. WSN consists of many WS spread over a wide area.

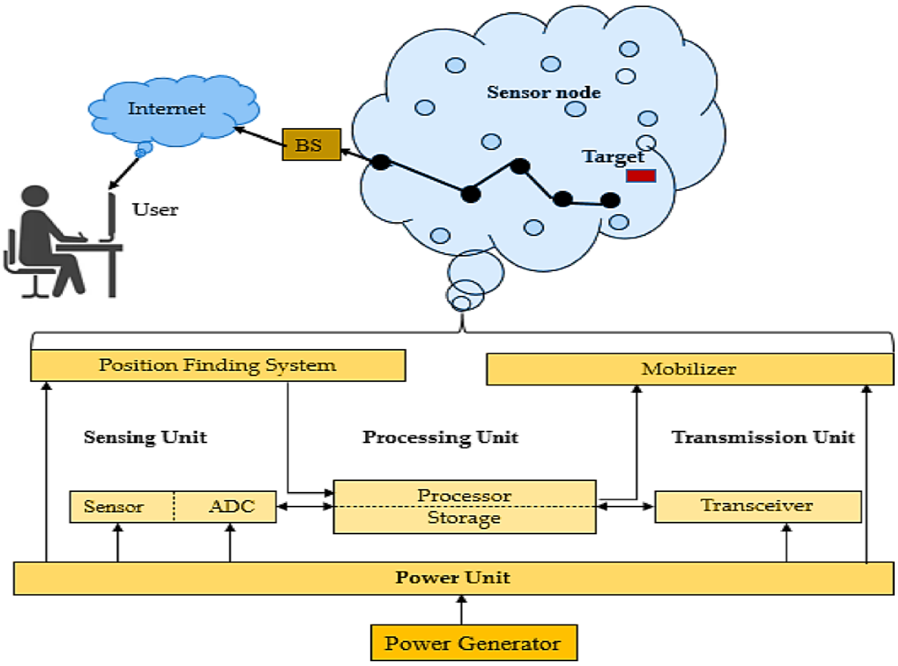

Figure 1: Wireless Sensor Network Architecture

The sensor nodes (motes) consist of four components indicated in **Figure 1** an energy source, a sensing mechanism, a data storage unit, and a transmitter. They can control the number of sensor networks that interact with each other across a larger number of geographical areas, with superior authority for external base stations (BSs). Utilizing hybrid cellular networks with multi-hop VANET and a high volume of traffic information transactions can enhance vehicle communication by minimizing overhead, improving packet delivery and efficiency, and reducing packet loss ratios while reducing median transmission time. Although WSNs are a better choice for routing sensor nodes, they face several disadvantages, including energy consumption, scalability of the network, low memory and storage, interruptions that occur during data collection, and development costs. The large-scale implementation of WSNs requires significant energy, and it is impossible to upgrade the batteries of thousands of small network nodes regularly. WSN nodes use a significant amount of energy for communication in terms of battery capacity, with the duration of packet transmission changing according to the distance between the nodes transmitting and receiving the packet along the route. Several algorithms are still being developed to limit the amount of energy wasted.

To fulfill the architectural requirements of a WSN, different routing methods, and cluster-based approaches have been studied and deployed to prolong the longevity of the network. Clustering is a process of topology control that boosts network interaction by organizing nodes and distributing tasks while optimizing resource utilization. Clustering can collect information into clusters using characteristics such as the shortest distances, concentrations of data sets, graphs, or other statistical distributions, as shown in **Figure 2**. Some studies have addressed clustering techniques for WSNs by assigning all sensor nodes duties. Sensor nodes are widely distributed to reduce resource usage. A sensor node is primarily responsible for data collection within clusters. The nodes that serve as the leaders of a cluster are called cluster heads, abbreviated as CHs. The CH acquires and delivers sensory information to the destination.

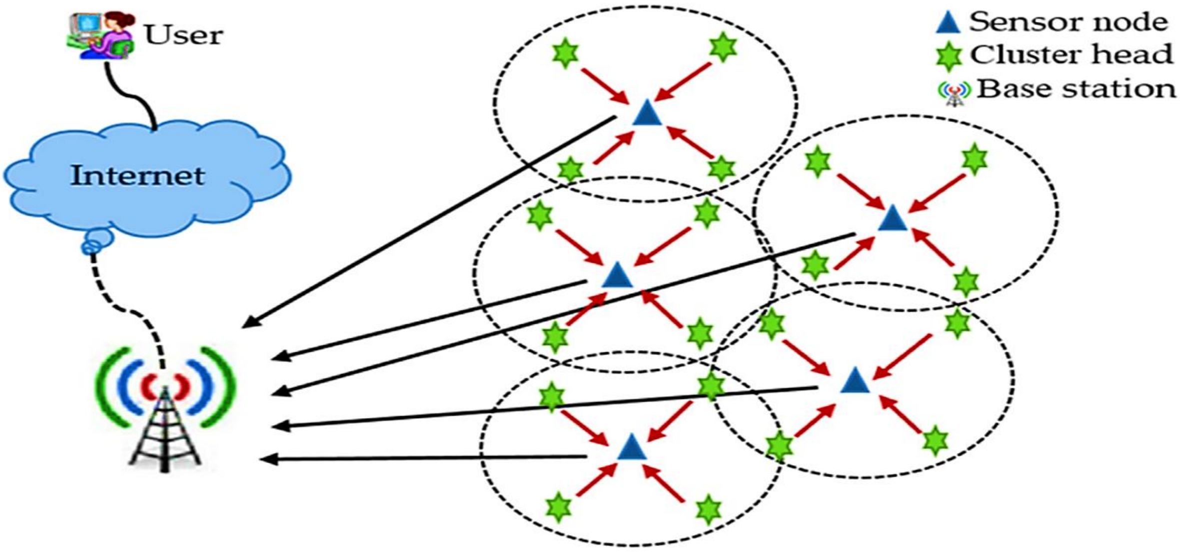

Figure 2: Clustering in WSNs.

Optimizing energy consumption for communication has become an important task for existing research techniques. The amount of energy consumed by each sensor during communication with other sensor nodes is critical to prolonging the network's lifespan. However, route and cluster formation techniques present non-deterministic polynomial-time hardness (NP-hard) optimization challenges. Therefore, it is necessary to use intelligent clustering and routing of sensitive information to reduce the waste of energy of CH in WSNs within a reasonable amount of time.

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2. LITERATURE SURVEY

In recent times numerous researchers have proposed various techniques for energy efficient clustering. Some of the recent and novel work carried out by researchers have been reviewed and presented below in **Table1.**

Heinzelman et al. [1] proposed the first clustering protocol named Low-Energy Adaptive Clustering Hierarchy (LEACH), which distributes CHs randomly based on a predefined probability position is rotated to prevent battery draining WS. CH selection and cluster are formed in the set-up phase and data transmission takes place in the steady phase. Then the current CH coordinates its nodes through time slot allocation to send the data. LEACH uses a Time Division Multiple Access (TDMA) schedule to get a time slot for data transmission. However, LEACH does not work efficiently in WSNs deployed in large geographical areas because of the single-hop communication used in LEACH.Manjeshwar and Agrawal [2] presented a Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN). In TEEN the clustering process uses soft and hard thresholds to transmit data between WS. In hard threshold, data will only be sent if the sensed data value is more than the threshold value. In the soft threshold, data will be sent if the sensed data value is less than the hard threshold and the difference between the two latest recorded values of nodes is more than the soft threshold. In TEEN, if thresholds are not met, the WS will never communicate.

Younis et al. [3] presented a distributed clustering scheme known as Hybrid Energy Efficient Distributed (HEED) that overcomes the problems of LEACH. HEED selects CH by using the residual energy of nodes and intra cluster communication cost. Because of these factors, WS are equally distributed in the network. In HEED, the chances of becoming CH of two nearby WS is low. However, In HEED CH selection process goes through several iterations thus leading to an increase in energy consumption. Mao Ye et al. [4] developed an Energy-efficient clustering scheme (EECS) that elects cluster heads having the highest residual energy. In the cluster head election phase, elected candidate nodes participate in cluster heads according to their residual energy. However, EECS suffers from overheads due to global information for communication and more energy consumption due to single-hop communication. Qing et al. [5] proposed a heterogeneous distributed energy-efficient clustering (DEEC) protocol for WSNs. In DEEC, the election of CHs is the probability-based ratio of the residual energy of all nodes and the average energy of the WSN.

Kumar et al. [6] developed an Energy Efficient Heterogeneous protocol (EEHC) to increase the WSN lifetime. EEHC is an energy-optimized approach in which WSNs are based on weighted election probabilities of each node to become a CH according to the residual energy in each node. Liu et al. [7] proposed an energy-aware routing protocol (EAP) that balances the energy load among the nodes. In EAP, a node to be a CH having a high ratio of residual energy to the average residual energy of neighbor nodes has a high probability in its cluster range. EAP also utilizes a simple but efficient technique to resolve the area coverage problem.

Huan Li et al [8] proposed a scheme to construct optimal clustering architecture (COCA) to deplete the overall energy consumption of nodes. COCA balances the energy consumption by effective CH rotation and inter-communication. In COCA "energy hole" problem is resolved by increasing the number of clusters in unit areas as the distance towards the sink decreases. However, COCA finds optimal value for small WSNs only. Tarhani et al. [9-10] presented a new distributed algorithm named scalable energy-efficient clustering hierarchy (SEECH), which selects CHs and relays different ways based on node degrees. Nodes with higher degrees are selected as cluster heads. The benefit of SEECH is that a lesser number of CHs can handle a larger number of nodes by using low-power communications. Lin et al [11] proposed an energy-efficient algorithm named fan-shaped clustering (FSC) For large networks. FSC divides the network into fan-shaped clusters. FSC benefits: First, due to localized re-clustering signaling cost is reduced. Second, the routing strategy is simple and robust. CH is selected from the central area resulting in optimized intra-communication cost and reduced re-clustering frequency.

Jain [12] proposed a Threshold Sensitive Region-Based Hybrid Routing (TS-RBHR) technique that provides efficient coverage of agricultural areas. To optimize the energy consumption of nodes fuzzy-based hybrid routing technique is used. In this, if the sensed value overdoes the desired threshold, data is sent to the base station which lessens the continuous transmission rate. The clustering algorithm was employed to balance the energy consumption of CH's and WS's lifetime. Elshrkawey et al. [13-14] proposed an enhancement approach to reduce energy consumption and extend the network lifetime. The enhanced approach is based on a cluster head selection method. P.C. Srinivasa Rao in [15], described a PSO-based energy-efficient CH selection algorithm namely PSO-ECHS. PSO algorithm was accomplished with fitness function and particle encoding. The parameters employed to analyze the performance are residual energy, sink distance, and intra-cluster distance. As a result, network lifetime, energy consumption, and received number of data packets were improved. However, it could need considered routing to enhance energy efficiency. A hybrid unequal energy efficient clustering for wireless sensor networks (HEEC) is designed explained in [16] to reduce the unequal clustering overhead.

Table 1: Summary of Clustering Routing Protocols in WSNs

Year	Authors	Literature	Contributions
2000	W. R. Heinzelman	Energy-efficient communication protocol for wireless microsensor networks	The first clustering protocol named Low-Energy Adaptive Clustering Hierarchy (LEACH), which distributes CHs randomly based on a predefined probability.
2001	A. Manjeshwar	TEEN: a routing protocol for enhanced efficiency in wireless sensor networks	uses soft and hard thresholds to transmit data between WS
2004	O. Younis	HEED: A Hybrid, Energy-Efficient, Distributed Clustering Approach for Ad Hoc Sensor Networks	selects CH by using residual energy and intracluster communication cost.
2005	M. Y. M. Ye	EECS: an energy-efficient clustering scheme in wireless sensor networks	selects cluster heads with the highest residual energy Nodes compete on Residual energy level for CH Suffers from global info overhead Single hop comm.
2006	L. Qing	Design of a distributed energy-efficient clustering algorithm for heterogeneous wireless sensor networks	Election of CHs is the probability-based ratio of residual energy of all nodes and the average energy of the WSN advanced nodes die rapidly with residual energy depletion.
2013	H. Li, Y. Liu	COCA: Constructing optimal clustering architecture to maximize sensor network lifetime	Mitigate the energy hole problem by increasing the number of clusters in a unit towards BS. Determines the no. of clusters in a unit
2017	P.S.Rao	PSO-ECHS	Optimized CH selection Parameters chosen residual energy, intra-cluster distance, sink distance

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3. ENERGY UTILIZATION METHODS IN WSN

Energy is the most vital asset to perform all functions in WSN. Each node requires a power supply. Power supply will directly affect node size and sensor network structure depending on the energy capacity related to communication range, computation, and storage capability. One of the main design goals of WSNs is to reduce energy depletion. **Figure 3** represents network design directly following the sensor node performance, mobility of the sensor node within the network, clustering strategy of the sensor node, and power utilization. Structural WSNs have two types: heterogeneous and homogenous. Nodes in the homogeneous configuration have the same storing, computing, and sensing performance, and the nodes are assumed to deplete their energy uniformly, which is the main challenge that reduces the network life of WSNs. This will lead to the collapse of the whole network life after all nodes 'energy is depleted. In a heterogeneous system, on the other hand, WSN scheme nodes with different resources per node are used. The benefit of this type of WSN is the ability to increase the network lifetime and the main roles of the network are delegated to nodes with higher residual energy, usually called cluster heads [18]. Resource allocation is an important issue in WSN, optimal allocation will help increase the lifetime of WSN [17].

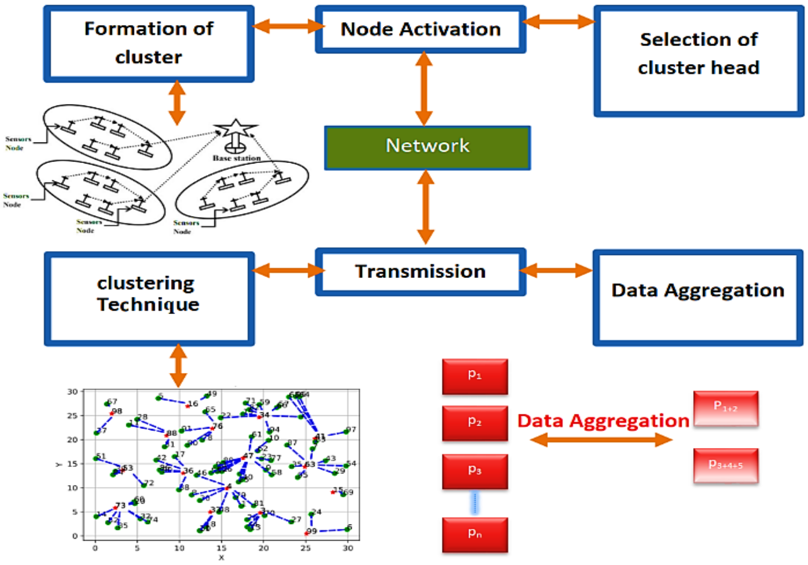

Figure 3: The workflow for energy-efficient clustering in WSNs

Nodes with lower energy and less computational power are used for sensing and recording conditions to optimize power consumption. To effectively manage the heterogeneous WSN, nodes are grouped into non-overlapping groups called clusters. The cluster head is either selected after network startup or statically specified. Nodes in heterogeneous WSN with higher residual power are elected to be CH candidates, the remaining are used for sensing. It is proven that it is a reliable method to save power in WSN nodes[18].In WSN, energy utilization is the most important factor that affects network performance and lifetime. During WSN operation, every electrical-mechanical part of the node consumes energy continuously. This energy is consumed in sensing, analog data to digital conversion, processing, communication, and storing. The lifetime of the network is directly dependent on the residual energy and consumed power. The limitation of Power consumption for nodes is important.

3.1 Clustering process

In most clustering algorithms, the clustering process consists of two phases: setup (initialization) and steady state. The clusters are created in the setup phase through four typical steps: CH selection, CH role advertisement, cluster formation, Time Division Multiple Access (TDMA), and Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)creation. After a CH is selected, it broadcasts an advertisement (ADV) message to all nodes within its communication range, informing them that it is a new CH. Each non-CH node decides to join the best CH based on the distance between them or use weighted metrics. Then, each CH creates a TDMA schedule and broadcasts it to its members. In the steady-state phase, each cluster member wakes up periodically in its designated slot to transmit its sensed data to the CH. In almost all clustering algorithms, the nodes are assumed to be time synchronized, and they can control their transmission power. Also, Direct Sequence Spread Spectrum (DSSS) is used to limit the interference among nearby clusters [19-20]. The CHs consume much higher energy than normal nodes due to their extra communication and computation loads. Therefore, the role of CH is rotated among the nodes periodically to achieve uniform energy dissipation. The network operation is organized into rounds, and during each round, the clustering process is repeated.

3.2 Advantages of clustering

Cluster-based routing algorithms provide several advantages over other routing algorithms, such as flat and location-based routing protocols. These advantages include better resource utilization, efficient topology management, and improved network performance [21].

3.2.1 Efficient resources utilization

Reduced energy consumption: energy efficiency in a cluster-based network can be achieved in different ways. First, the cluster members use multi-level transmission power and send their data to the nearest CH instead of to a distant BS. Second, clustering allows the data to be aggregated in the CHs, which reduces the number of transmitted packets to BS. Third, the TDMA-based [22] access method allows the nodes to switch off their radio and be in sleep mode most of the time, and to wake up only in their designated slots. This mechanism of duty cycling diminishes collision among cluster members and conserves their energy.

- **Bandwidth Reuse:** the cluster members in each cluster control their transmission power and use CDMA to reduce interference between clusters. This scheme enables different clusters to use the same communication bandwidth. On the other hand, the TDMA-based access method allows all cluster members to share the entire communication bandwidth.
- **Small routing table:** a small-sized routing table is required because direct communication between nodes and their CH Localizes the route setup within the cluster boundaries. Also, the CH communicates with BS either directly or through another CH, limiting the routing table's size.

3.2.2 Efficient topology management

Node mobility and failure: topology change due to node failure or mobility is handled at the cluster level without affecting the whole network.

CH failure: periodic re-clustering or backup CH is used to handle the fault in the CHs. Compared with the flat routing method, clustering is more convenient for network topology control.

3.2.3 Improved network performance

Network lifetime: since a cluster-based network dramatically reduces the nodes' energy consumption, it contributes to increasing the lifetime of the network.

- **Load Balancing:** the role of CH is rotated among the nodes to achieve even energy distribution. Sometimes, the size of clusters can be controlled to balance the load among CHs in the network.
- **Network scalability:** The clustering approach forms two-hop clusters (node-CH-BS) when direct communication between CHs and BS is adopted. This scheme increases network coverage four times when compared to a direct transmission flat topology. However, adopting multi-hop transmission can increase the coverage area and improve network scalability.
- **Packet delay:** the routing in a flat topology network is performed hop by hop, while in a cluster-based network, only CH performs data transmissions from one cluster to another, which reduces the route between the node and BS and results in less packet delay.

3.3 Design challenges in clustering

With WSN, an engineer's goal is to enable manufacturers to produce sensor nodes in vast quantities, in small sizes, and in an inexpensive manner. All resources, including energy source, processor, memory, and communication range, are limited to achieve this goal. Only a small memory is available to implement complex networking protocols and store a limited set of data. The processors also have low speed and limited processing capabilities [67]. Therefore, several design challenges present themselves to the designers of clustering algorithms. The main challenges are [23]:

- **Limited energy and hardware resources:** present many challenges in software development and network protocol design. The designer should not consider only the energy constraint in sensor nodes, but also the processing and storage capacities of these nodes.
- **Converge-cast traffics:** Unlike traditional wireless networks, WSNs have many-to-one traffic patterns where all nodes send their data toward the sink, which results in a crowded center effect.
- **Unreliable environment and frequent topology change:** network topology frequently changes due to node failure, add/remove nodes, or node mobility. Also, the network connectivity may be frequently disrupted due to channel fading, signal attenuation, obstructions, or harsh environmental conditions, e.g., high humidity levels, dirt, dust, or other conditions that may cause a portion of the sensor network to malfunction.
- **Quality-of-service (QoS) requirements:** sensor networks have a wide range of applications, and each has different QoS requirements. In some applications, for example, fire-detection systems are delay-sensitive and thus require timely data delivery. Other applications like data collection are delay tolerant, but reliable data transmission is needed. Thus, sensor networks are application-specific, and the designer should consider the QoS required by each application.
- **Security:** the sensor network should introduce an effective security mechanism to prevent the data from unauthorized access or malicious attacks. Security seems to be a significantly difficult problem to solve in WSNs because the nodes are resource-limited while security solutions are resource-hungry. Indeed, most existing clustering algorithms do not address security in the protocol design.

3.4 Clustering-process parameters

The clustering process includes CH selection and cluster formation [24]. This process is characterized by four parameters: clustering method, communication mode, CH replacement, and algorithm complexity.

3.4.1 Clustering method

Several models have been researched to reduce energy expenses and increase network durability. The optimization taxonomy of these techniques is also presented in **Figure 4**. This section, however, focuses on the three most significant methodologies, which were employed in evaluating the performance of the proposed method.

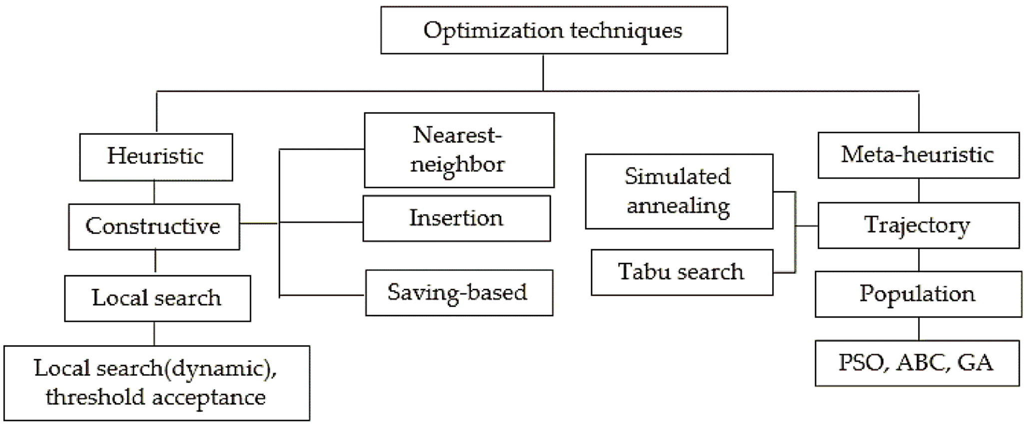

Figure 4: Taxonomy of Optimization Techniques.

A. Low Energy Adaptive Clustering Hierarchy (LEACH)

The clustering-founded LEACH protocol is one of the earliest and most extensively utilized routing protocols for WSNs. LEACH provides a simple and power-saving method for data forwarding. During the network lifecycle, the procedure is divided into multiple rounds, each consisting of two parts: a setup phase and a steady stage. **Figure 5** describes the different stages of the processing the first stage, the nodes decide whether to become a CH or a normal node. This decision is based on a probabilistic model where every node is guaranteed an equal probability of turning into a CH. Upon selecting CHs, they broadcast a message to all the nodes in their vicinity to form clusters. The nodes then join the cluster of the nearest CH. In each round, the CHs gather information from respective cluster

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members and then relay the aggregated information to the BS. The nodes in the clusters use TDMA to transmit their data to the CH. To balance energy consumption, the CHs are rotated in each round. This ensures that the nodes do not deplete their energy reserves too quickly. The algorithm can be modified to suit different requirements, such as extending the network lifetime or reducing energy consumption.

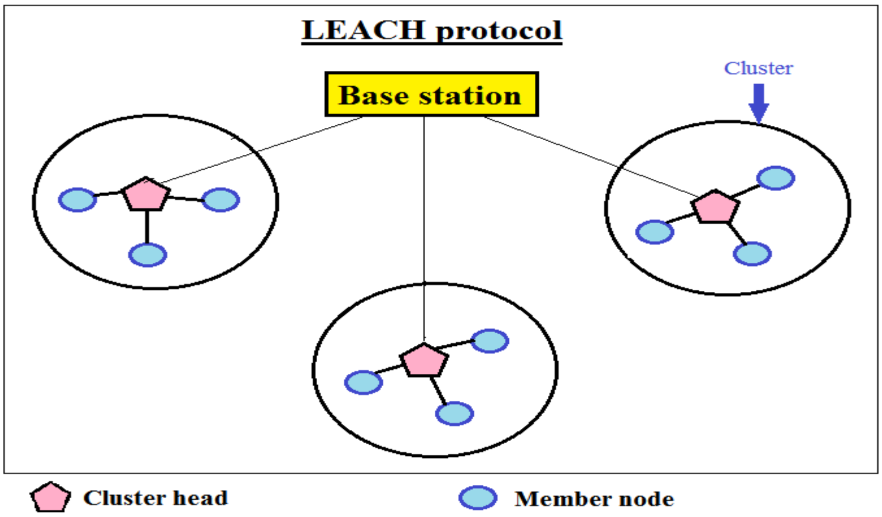

Figure 5: LEACH Protocol functional architecture

B. Improved low-energy adaptive clustering hierarchy (ILEACH)

The improved LEACH (ILEACH) protocol is a modification of the LEACH protocol for wireless sensor networks flow chart is shown in **Figure 6**. It aims to enrich the network's life by balancing the power utilization of nodes and cutting the overhead of cluster formation. The ILEACH protocol is the computation of the probability that a node becomes a CH in each round. In ILEACH, nodes are divided into clusters, and a CH is elected in each round. The CH collects data from its member nodes and forwards it to the BS. To balance the energy consumption of nodes, ILEACH rotates the job of CH among nodes, ensuring that all nodes have an equal chance to become CHs. ILEACH reduces the overhead of cluster formation by using a deterministic approach to cluster formation, where each node determines its cluster membership based on its location and residual energy, rather than relying on the global knowledge of the network. This reduces the number of control messages needed for cluster formation, thereby diminishing the power expenditure and strengthening the network's life.

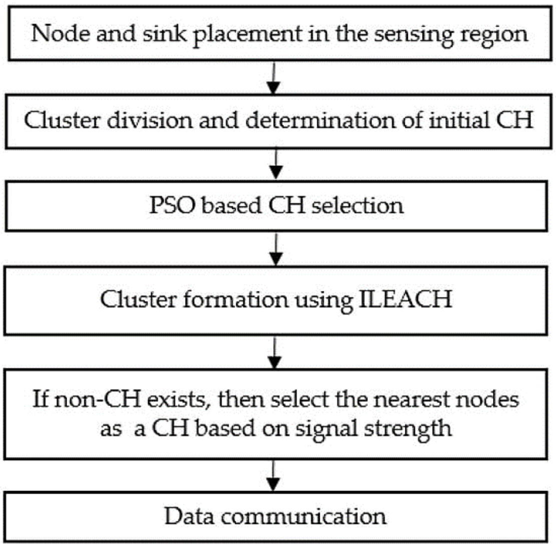

Figure 6: Flow chart for the ILEACH Protocol

C. Energy storage overflow_ Low Energy Adaptive Clustering Hierarchy (ESO-LEACH)

ESO-LEACH is a modified version of the LEACH protocol that uses PSO procedures that optimize the election of CHs. **Figure 7** ESO-LEACH models, the network is initialized with a set of SNs, and the PSO algorithm is initialized with a swarm of particles. In each round, the PSO technique optimizes the CHs depending on the residual energy of the nodes and the distance between nodes. The PSO updates the position along with velocity for each particle toward exploration for an ideal output. The nodes having the greatest fitness scores are chosen as CHs once the PSO converges. The CHs acquire input among these nodes of their members and provide it to the BS. To balance the energy consumption of nodes, the task of CH is rotated among nodes in each round. This method lessens the amount of energy each node has as they receive equivalent opportunities to turn into the CH. ESO-LEACH was adjusted to pick the CHs using the PSO approach, which enriches the network's endurance and diminishes power consumption.

In terms of the correlation between LEACH, ILEACH, and ESO-LEACH, it can be noted that ILEACH is a modification of LEACH that addresses some of its drawbacks, such as the selection of low-energy cluster heads. These protocols do not scale well when the number of sensor nodes in the network is significantly high. Communication is limited to a single hop, which can result in reduced network coverage and decreased network connectivity. The initial clustering process in these protocols requires a considerable amount of energy and can lead to uneven energy distribution among the nodes, which can significantly impact the network lifetime. These protocols are not designed to adapt to dynamically changing network conditions, which can result in suboptimal network performance in such

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environments. These protocols are not suitable for applications that require a high degree of data aggregation, as they lack the necessary mechanisms to efficiently aggregate large amounts of data. ESO-LEACH, on the other hand, is a further modification of LEACH that attempts to improve its energy efficiency using a different optimization algorithm. However, the ESO-LEACH method involves various parameters that need to be optimized, which can make it challenging to implement and optimize.

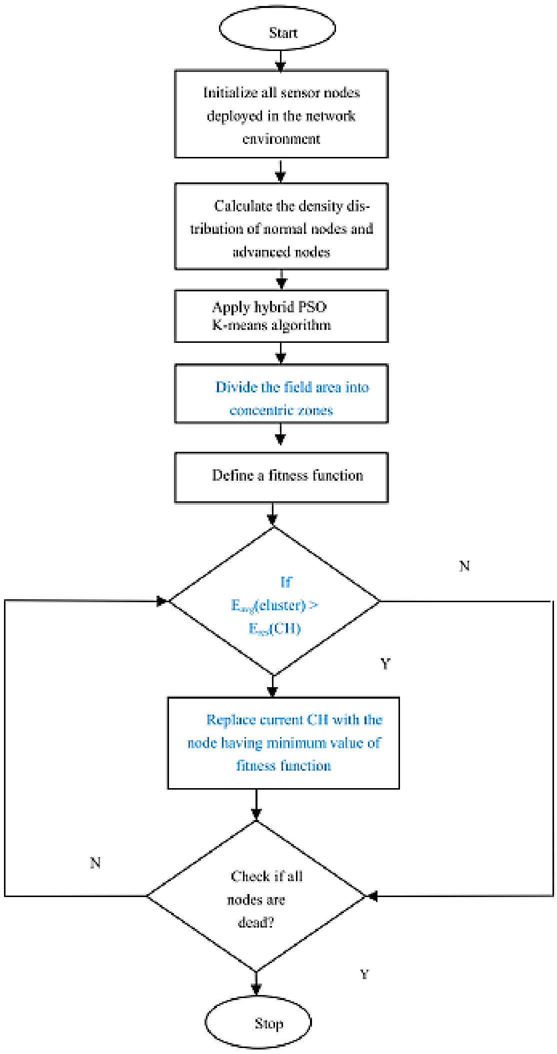

Figure 7: Flowchart of the ESO-LEACH algorithm.

Enhanced PSO-LEACH requires a high computational cost, which can increase the time and resources required to execute the algorithm. The algorithm's performance is highly dependent on the initial parameters, and choosing suboptimal values can lead to a suboptimal solution. The algorithm may struggle to provide satisfactory results in dynamic environments with frequently changing network conditions, which can significantly impact the algorithm's performance.

However, to address the drawbacks of existing models, we propose Hybrid-PSO-ILEACH, a novel model that combines the PSO algorithm with ILEACH to enrich energy efficiency. Hybrid PSO-ILEACH aims to overcome the limitations of the PSO-LEACH, LEACH, and ILEACH protocols by combining the strengths of particle swarm optimization (PSO) and ILEACH protocols. The PSO algorithm optimizes the cluster head selection process to reduce energy consumption and prolong the network lifetime. Meanwhile, ILEACH introduces an adaptive selection of CH parameters to overcome scalability issues and adapt to changing network conditions. This hybrid approach also incorporates multi-hop communication and improved data aggregation mechanisms to address the single-hop communication and limited data aggregation limitations of LEACH and ILEACH. Therefore, the Hybrid Energy-Efficient Distributed (HEED) protocol performs better in terms of energy efficiency and network longevity, making it a promising solution for wireless sensor networks. Also, **Table 2** describes the List of the current survey publications that concentrate on clustering

The contributions of the proposed model include:

1. The hybrid model improves the clustering performance of ILEACH by using PSO to optimize the selection of CHs.
2. The hybrid model extends the network life of WSNs by cutting energy expenditure and increasing the time before battery replacement or recharging is required.
3. The use of PSO to optimize CHs potentially results in more accurate data transmission, since better CHs are selected, and more data are accurately transmitted.
4. The hybrid model enhances network durability by allowing for better distribution of cluster heads and better load balancing across the network.
5. The hybrid model presents a comparison of the results between the current experiment and LEACH, ESO-LEACH, and ILEACH, covering the six parameters: alive node, dead node, throughput, energy consumption, residual energy, and delay.

Table 2: List of the current survey publications that concentrate on clustering

Year	Authors	Literature	Contributions
2018	S. K and V. Vaidehi[25]	Clustering and Data Aggregation in Wireless Sensor Networks Using Machine Learning Algorithms	Presents a literature review of different machine learning-based methods that are used for clustering and data aggregation in WSN and proposes an improved similarity-based clustering and data aggregation
2017	H. Lin, R. Xie and L. Wei,[26]	Density, distance, and energy-based clustering algorithm for data aggregation in wireless sensor networks	propose a new clustering method called Density, Distance, and Energy Clustering (DDEC) to improve network performance. DDEC partitions the network into clusters with similar member numbers, to achieve load balancing.
2016	M. Mittal and K. Kumar[27]	self-organization feature map (SOFM) neural network.	In this network, all the sensor nodes communicate with each other via radio signals. The sensor nodes have the capability of sensing, data storage, and processing.
2015	K. Desai and K. Rana[28]	5 Clustering technique for Wireless Sensor Network	proposed algorithm cluster head (CH) selection is carried out using the distance between nodes and the energy of the nodes.
2012	B. Jeon, B. Kang, and S. Park[29]	Density-centered clustering routing	propose high event density area-centeredclustering-based routing (HEDACR) for efficient energy consumption in WSN.

3.4.2. Clustering attributes

Each clustering algorithm has different characteristics and is described by several parameters. These parameters are divided into three groups related to sensor node characteristics, created clusters, and clustering algorithms. This section outlines [30] these parameters because each has a relative impact on network operation and performance.

A. Characteristics of sensor node

Each node is characterized by four parameters: type, role, location awareness, and mobility. In this section, each of these parameters is explained, showing their impact on network operation.

B. Node type

Depending on the resources and capabilities of sensor nodes, the network can be either homogeneous or heterogeneous. In the homogeneous WSN, all nodes are identical and have the same resources and capabilities. Heterogeneous WSN consists of different types of nodes, which may differ in their processing capability, energy, bandwidth, transmission range, sensor type, and mobility. Energy heterogeneity is the most critical factor because both computation and communication heterogeneity consume more energy [75]. In the context of clustering, energy heterogeneity should be considered because more powerful nodes are preferred to play the role of CH.

C. Node role

The typical roles of the nodes in the earliest clustering algorithms are normal nodes and CHs. Recently; some other roles have been assigned to these nodes based on the designer's objective, such as vice-CH, assistant-CH, relay, and management nodes. Vice-CH acts as a backup node and takes over the role of CH when the main CH fails. Assistant-CH is presented in to share the load of the main CH aiming to reduce its energy consumption and reduce the rate of re-clustering by extending the round period. There are two heads in each cluster; one is responsible for receiving data packets from cluster members while the second head forwards the aggregated data to BS. Relay nodes are presented in several works to increase network scalability or address connectivity issues. The relay node can be either a CH, special node or cluster member. In a multi-hop network, the distant CH transmits its data to the nearest relay node closer to BS. Moreover, the isolated CHs may use one of its members as a relay node to provide a path toward BS, or the isolated nodes may use a cluster member as a relay node to reach the nearest CH. Management nodes have different roles according to the designer's objective. In it controls the clustering process in the setup phase to create the desired number of clusters in each round. In the management nodes are selected by BS. They are responsible for organizing nodes into clusters and selecting a CH for each cluster. Also, it replaces the current CH when its energy drops below a threshold. In the management node is responsible for monitoring the energy of the cluster and selecting a new CH for the next round.

D. Location Awareness

In some clustering algorithms, sensor nodes need to be aware of their location to calculate the distance from their neighbors/CHs/BS. Hence, it is required to install a Global Positioning System (GPS) on each sensor node [33]. GPS modules are quite expensive and energy-consuming. Recently, many localization algorithms [92,93] have been proposed as an alternative to GPS. However, both methods increase energy waste. Therefore, many authors evade this extra cost and energy waste by designing their protocols so that the nodes do not need to know their exact physical locations or even their neighbors' locations. They estimate their relative distance from the CH/BS using received signal strength (RSS).

E. Mobility

In most clustering algorithms, the nodes are stationary, and most existing clustering protocols are unable to support the node's mobility because they do not consider the nodes' movements after clustering [94]. Recently, some clustering algorithms have considered mobility in their design to expand the applications' range of WSNs or to enhance network performance.

3.5 Energy consumption model

The exact energy consumption model requires computing the energy consumed by all parts of the system. Most authors emphasize only the energy consumed by the transceiver and ignore other units. The transceiver's energy consumption is characterized by four different basic states: transmission, reception, idle listening, and sleeping. The first-order radio model proposed in [38,69] is a common model used by many researchers to estimate the transceiver's energy consumption. Two propagation models are adopted: the free space propagation model and the 2-ray ground reflection model, depending on the distance between the transmitter and receiver. The energy cost $E_c$to transmit–receive$l$-bit message over a distance $d$abe expressed as shown in Eq. (1) [31].

$$E_c = E_{tx}(l, d + E_{rx})\text{---} \quad (1)$$

Where E_{tx} and $E_{rx}$are the energy consumption of the transmitter and receiver respectively.$E_{tx}$is further decomposed into two parts (Eq. (2)), representing the energy required by an electronic circuit$\mathrm{E_{tx}} - \mathrm{elect}$ and power amplifier of the transceiver$\mathrm{E_{tx}} - \mathrm{amp}$.

$$E_{tx}(l, d) = \mathrm{E_{tx}} - \mathrm{elect}\ (1)) + \mathrm{E_{tx}} - \mathrm{amp}(\mathrm{i}, \mathrm{d}) \quad \text{---} \quad \text{-(2)}$$

and this can be further expanded to,

$$E_{tx}(l, d) = \begin{matrix} l\,Eelect + \varepsilon fs\ ld^2 & for\ d<d_0 \\ lelect + \varepsilon mp\ l4 & for\ d<d_0 \end{matrix} \quad - \quad \text{--(3)}$$

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Where $Eelect$is energy consumption per bit by an electronic circuit, while εfs, and $\varepsilon mp$are the energy consumption per bit per distance for the power amplifier in free space and multi-path respectively. The cross-over distance $d_0$between these models is defined by:

$$d_0 \frac{\varepsilon fs}{\varepsilon mp} \quad ---(4)$$

The required energy to receive an l -bit message is given by:

$$E_{rx}(l) = l\, Eelect \quad - \quad --(5)$$

3.6 Evaluation metrics of clustering algorithms

This section discusses various metrics to evaluate the performance of routing protocols. The most common metrics are energy consumption/energy efficiency, network lifetime, packet delivery ratio, packet delay, throughput, and standard deviation [32].

- **Network Lifetime** is determined by many authors at the instant when the energy of the first node is depleted. Other definitions of network lifetime consider the time when half of the nodes die, the last node dies, or the time when the rate of message loss exceeds a given threshold. Other definitions of network lifetime are presented in [33-35]. Also, the number of alive nodes during network operation is used by many authors to compare the efficiency of their proposal with benchmark protocols like LEACH or HEED.
- **Energy consumption and energy efficiency** are two metrics widely used in evaluating the efficiency of clustering algorithms. Energy consumption is the total energy used by sensor nodes during network operation, while energy efficiency is measured as a ratio of total energy consumed by sensor nodes to the number of data packets delivered to the sink node. These metrics are affected by the distance between source and destination, re-transmission rate, and control messages. Minimizing this ratio indicates better energy utilization.
- **Packet delivery ratio** is defined as the number of packets received by BS divided by the number of packets sent from the sources. This metric indicates the quality of the routing protocol. It depends on the quality of the wireless link and the level of congestion in the network. Generally, network performance is better when the packet delivery ratio is high.
- **End-to-end delay** is defined as the average time for a data packet to arrive at the destination. It includes queuing, processing, and propagation time. Delay is an important factor for real-time applications where immediate delivery of data is required.
- **Throughput** is defined as the total number of data packets or the number of bits received by BS per time unit. The unit for measurement is Kbps (Kilobits per second). It is an important performance metric because it indicates system productivity and can show the number of successful packets per second arrived at BS. A higher throughput demonstrates that the framework sustained better steering for information and control messages. It is affected by the available number of sensor nodes and the traffic rate.
- **Standard Deviation** is the average variation among the energy levels of the nodes in the network. It reflects how well the protocol balances the energy dissipation among the nodes and gives a good measure of the network's lifetime.

4. ANALYZING THE ENERGY EFFICIENT CLUSTERING TECHNIQUES-BASED RESULTS

Here, an analysis of the protocols is conducted because there have been many proposed ideas for improving the efficiency of the sensor nodes by clustering techniques over the past decade, but it is observed that all these protocols concentrated on the death of the first node in the clusters. In an analysis of protocols, the first node dies. In this, a small comparison of some of the mentioned protocols is observed, when the first node dies. Because energy efficiency is dependent on the cluster heads and the number of clusters, a comparative analysis of the energy consumption of different protocols is shown. These protocols primarily focus on determining the cluster heads and the number of clusters., many protocols primarily propose that if it reduces the time of transmission, they are accepted, and some suggest that it increases the overall life by reducing the hop count, and some significant distance between the clusters, and some protocols consider residual energy for the cluster head and the recharging of the battery. While considering many parameters, the energy consumption of the nodes will also be a key factor in observing their performance on the WSN Network.

Table 3: Comparison of energy consumption (MJ)

Number of Clusters	LEACH	ILEACH	ESO-LEACH	PSO-LEACH
100	90	70	55	35
200	144	95	60	67
300	186	130	77	89
400	210	186	119	130
500	290	210	190	150

Table 3 represents the comparison to other existing approaches;the created technology used less energy (150 mJ) in 500 nodes.

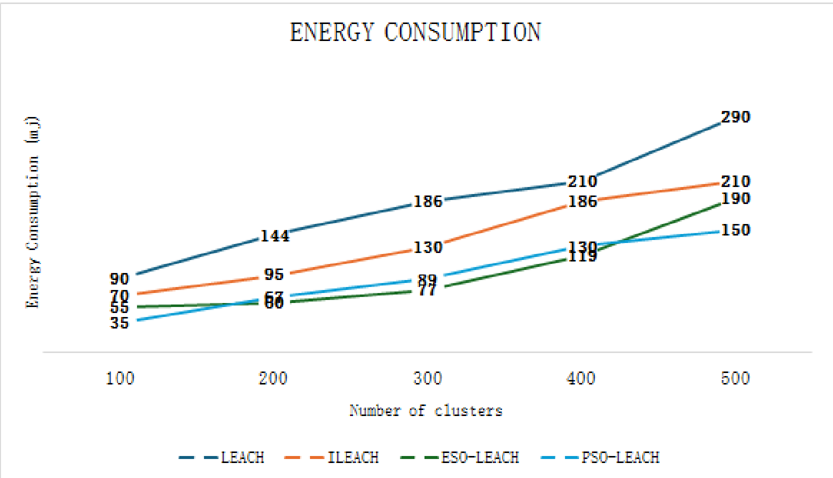

Figure 8: Number of Clusters vs. Evaluation of Network Lifetime

The graph above8 shows how the planned methodology is expressively boosted when compared to others. The quantity of SN upsurges will raise the amount of energy used.

Table 4: End-To-End Delay

Number of Clusters	LEACH	ILEACH	ESO-LEACH	PSO-LEACH
100	6	4	3	2
200	7	5	4.9	4.5
300	8.5	6.2	5.3	5
400	9	7	6.8	5.5
500	10	9.5	8	6

Table 4 represents the ratio of the entire time taken to deliver a packet to a receiver to the number of packets received.

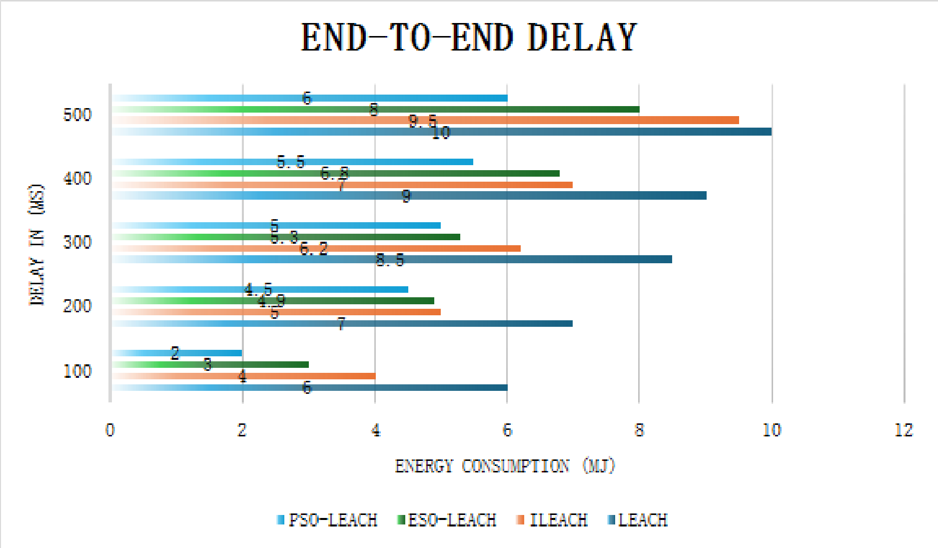

Figure 9: Number of Clusters vs. End-To-End Delay

Figure 9 expresses the comparison of the Number of clusters vs. end-to-end delayIt is the ratio of the entire time taken to deliver a packet to a receiver to the number of received.

Table 5: Comparison of network lifetime

Number of Clusters	LEACH	ILEACH	ESO-LEACH	PSO-LEACH
20	4500	4700	4900	5300
40	4200	4500	4700	4900
60	3800	4000	4300	4500
80	3500	3700	4000	4100
100	3200	3500	3700	3900

The system lifespan is the amount of time it can operate during which it can do the devoted task(s). Table 5 compares the performance of the created method and the existing technique during the lifetime of a network.

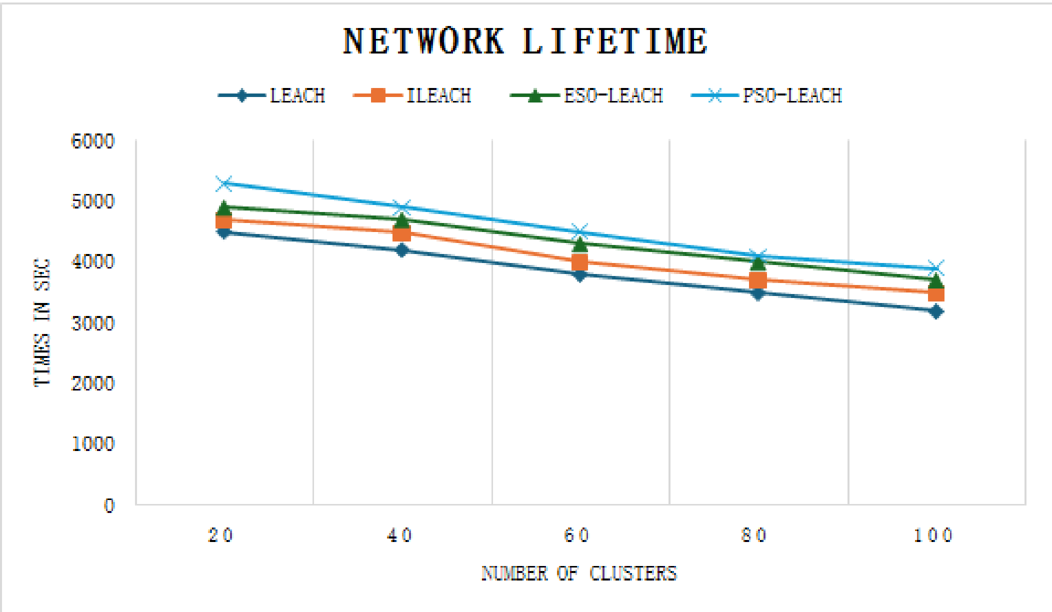

Figure 10: Number of Clusters vs. Evaluation of Network Lifetime

Graph 10above shows that the number of clusters vs. evaluation of network lifetime is a longer system lifetime (5300 rounds) than conventional methods.

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Table 6: Comparison of Time for Cluster Formation

Number of Clusters	LEACH	ILEACH	ESO-LEACH	PSO-LEACH
5	115	95	72	50
7	120	100	80	65
9	125	104	86	70
11	130	115	94	75
13	134	120	110	85

Table 6 represents the time analysis and It represents the overall amount of time spent on cluster creation and CH selection. The time will rise as the number of clusters increases. The PSO_LEACH strategy achieved a lower execution time (82 s) than other existing approaches in five clusters.

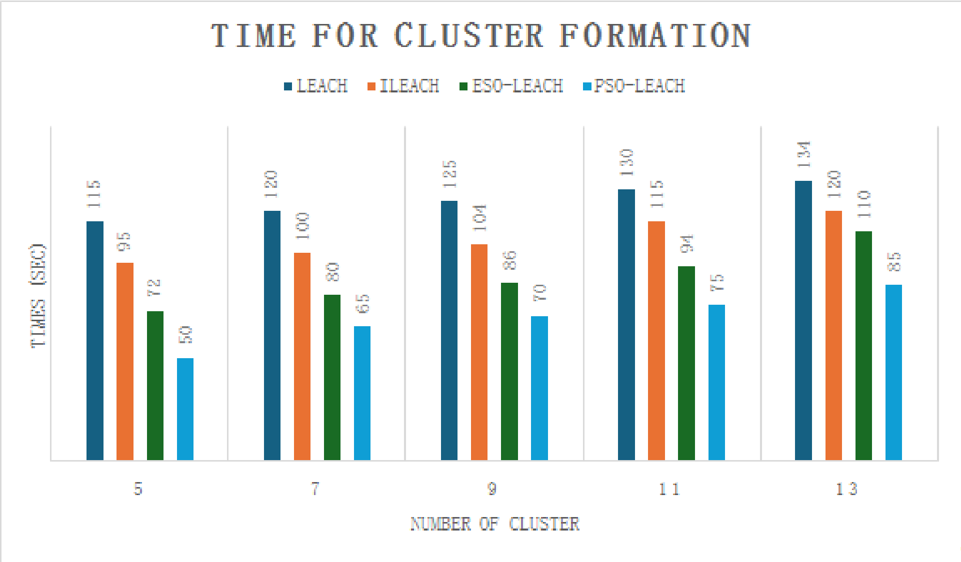

Figure 11: Number of clusters vs. time for cluster formation

Figure 11shows the cluster-building method's performance over time. In this article, the Hybrid method for cluster creation took less to execute than existing methods.

Table 7: Comparison of Time for Cluster Head Selection

Number of Clusters	LEACH	ILEACH	ESO-LEACH	PSO-LEACH
5	84	75	65	55
7	99	85	78	68
9	100	95	85	79
11	124	110	99	88
13	145	131	118	97

The time will be extended if the number of CHs is increased. In comparison to other current techniques, the Hybrid scheme achieved a short execution time (55 s) in five CHs, as given in Table 7.

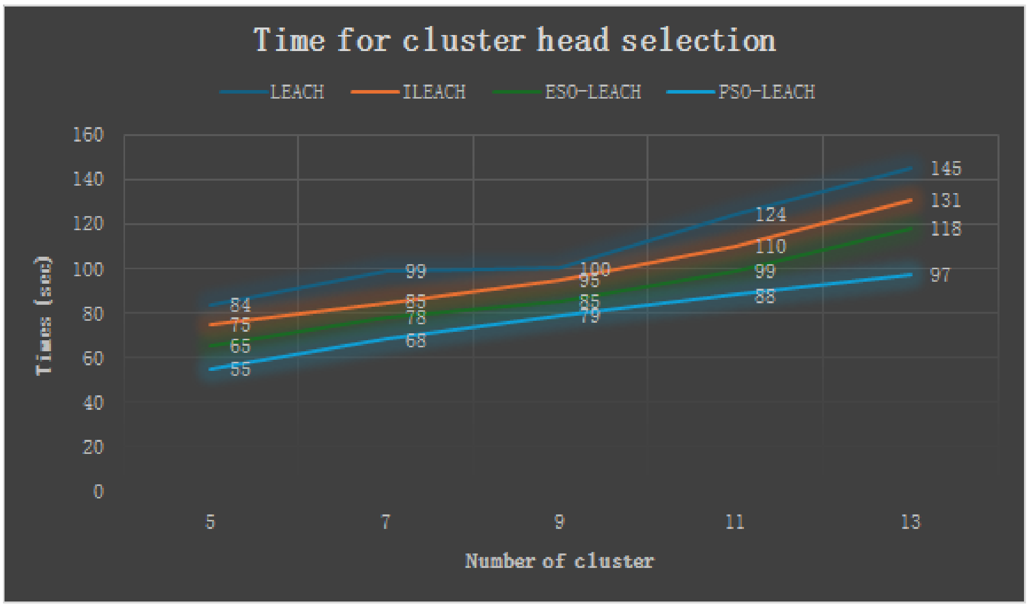

Figure 12: Time for Cluster Head Selection

Figure 12 shows the CH selection method's performance over time. In comparison to existing strategies for CH selection, the proposed method took less time to execute in this analysis.

5. CONCLUSION

This work presented the theory and details of WSN. It analyzed many research studies and discussed the main characteristics and structural elements of WSN networks. Then, it discussed the main limitations and constraints of such networks, which is limited energy. Several research studies have been conducted in this area. This paper listed the most recent works that are related to energy optimization in WSN. It highlighted the main features and limitations of each related work. The main subject that is almost missing from those works is sensor node mobility. This issue is very important, particularly in cases where mobile nodes are to be implemented rather than static nodes and a single mobile sink node. Hence, it is essential to conduct more research in this area and to present suitable clustering and routing algorithms that can handle both mobility and energy efficiency. The study results by which best techniques in power saving according to clustering mode or distribution type. Out of these energy-efficient schemes, cluster-based schemes have received relatively great interest due to the significant gains in overall network lifetime. In most of the existing techniques, various attempts have been made to achieve energy efficiency through hierarchical clustering where nodes are grouped into clusters, and data is forwarded by the cluster head to the Base Station (BS). In this work, state-of-the-art energy-efficient cluster-based and grid-based techniques in WSN have been critically evaluated considering different parameters like metrics for cluster formation, energy consumption, and network lifetime. Moreover, the design issues and research challenges of hierarchical approaches have been discussed. Based on the evaluation metrics, a comparative analysis is presented that can help in the selection of appropriate techniques for specific requirements. The significance of both clustering and grid-based techniques and their limitations have been identified giving the notion about the applicability of a particular scheme in a certain operating environment.

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