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Investigation of Energy Efficient Clustering Algorithms in WSNs: A Review

Iman Ameer Ahmad[1,2*], Muna Mohammed Jawad Al-Nayar[1], Ali M. Mahmood[1]

[1] Control and Systems Engineering Department, University of Technology-Iraq, Baghdad 10066, Iraq
[2] Department of Basic Science, College of Dentistry, University of Baghdad, Baghdad 1417, Iraq

Corresponding Author Email: cse.21.11@grad.uotechnology.edu.iq

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ABSTRACT

In recent years, Wireless Sensor Networks (WSNs) are attracting more attention in many fields as they are extensively used in a wide range of applications, such as environment monitoring, the Internet of Things, industrial operation control, electric distribution, and the oil industry. One of the major concerns in these networks is the limited energy sources. Clustering and routing algorithms represent one of the critical issues that directly contribute to power consumption in WSNs. Therefore, optimization techniques and routing protocols for such networks have to be studied and developed. This paper focuses on the most recent studies and algorithms that handle energy-efficiency clustering and routing in WSNs. In addition, the prime issues in these networks are discussed and summarized using comparison tables, including the main features, limitations, and the kind of simulation toolbox. Energy efficiency is compared between some techniques and showed that according to clustering mode “Distributed” and CH distribution “Uniform”, HEED and EECS are best, while in the non-uniform clustering, both DDAR and THC are efficient. According to clustering mode “Centralized” and CH distribution “Uniform”, the LEACH-C protocol is more effective.

1. INTRODUCTION

Wireless Sensor Networks (WSNs) are attracting increasing attention in many fields as their demands are increased in many scientific and industrial applications. The WSN is a network of close sensor nodes that are deployed in a geographical region of interest. The WSN usually contains a sensing unit, which measures the environmental parameters, a processing unit having memory, a transceiver that collects and transmits the sensed information to a central base station, and a power supply unit that supplies all other units. WSN has three main elements: nodes of the sensor, a tool to gather data (which consists of a base station and a Cluster Head (CH)), and an external system. Sensor nodes can be considered the basic units of WSN. They usually have constrained power supply sources, small storage capacity, low data-processing power, and limited transmission bandwidth.

Sensor nodes are deployed in random positions and their job is to monitor, sense, and explain a natural event or a physical phenomenon. They can supervise external conditions (such as temperature, humidity, wind … etc.) for alarm systems [1] or greenhouse applications [2] and periodically transmit the recorded data to the base station. The sensor nodes have batteries as the energy sources and their batteries usually cannot be replaced after a deployment. Therefore, energy utilization is a major concern and an open-research area in WSNs. Long communication distances between the sensor nodes and the sink base station will lead to rapid draining of the node’s remaining energy and will reduce the lifetime of the network. As a result, extending the network lifetime, balancing the load among all deployed sensor nodes, and increasing the scalability of the network are the main challenges when designing and implementing WSNs.

Several research studies of WSNs have been conducted in the field of WSNs. In 2005, Yoneki and Bacon [3] categorized WSNs and their technologies. They also described some existing research WSNs prototypes, as well as their future enhancements.

Yick et al. [4] 2008 compared different algorithms and proposals, in terms of their platform, operating system, communication protocol stack, and issues related to services and deployment. In 2010, Katiyar et al. [5] investigated the effect of heterogeneous structures of WSNs and compared many clustering algorithms in terms of objectives, characteristics, and complexity.

In 2013, Sara and Sridharan [6] discussed various issues related to mobile WSNs, related to energy efficiency and mobility. They also classified the routing protocols and highlighted their main features and possible enhancements. In 2014, Gupta and Sinha [7] conducted a literature survey on the WSN architecture and focused on network standards, protocol architecture of communication, and energy performance.

In 2015, Iqbal et al. [8] analyzed different optimization paradigms for WSNs alongside a set of different constraints.

Several surveys for WSN have been published. The authors presented a review of the available optimization techniques in WSN, they focused on existing clustering protocols in WSNs to solve all existing problems and make WSN as optimal as possible in general [9]. They analyzed the clustering's characteristics and parameters and looked at the goals, advantages, and significant characteristics of several clustering optimization techniques.

In another survey conducted by Merabtine et al. [10], the existing feature-based classifications of clustering protocols are reviewed and elaborated into a more generic and unified classification. They also analyzed and discussed the relevant design factors that may influence the energy efficiency of clustering protocols and proposed a new energy-oriented taxonomy.

This review, however, differs from the previous works in that it focuses on energy optimization clustering and routing algorithms in WSNs, which is a crucial issue when deploying and deploying such sensors. In addition, this survey analyzes the related works in terms of mobile nodes. This mobility has extra challenges to the clustering and routing protocols. Furthermore, the cluster head selection method of each recent proposal is discussed and its limitations are argued.

This paper investigates the recent approaches in clustering and routing algorithms in WSNs. It focuses on energy-efficient techniques that extend the network lifetime and eliminates failure. This paper is organized as follows: in Section 2, WSN structure, mobility, energy, and clustering are discussed. Then, in Sections 3 and 4, energy-efficient clustering-related works are discussed, focusing on their main features, limitations, and simulation tools.

2. PRELIMINARIES OF THE WIRELESS SENSOR NETWORK

This section includes a concise explanation of the key components of WSN architecture.

2.1 Wireless sensor network architecture

The current state-of-the-art technology used in WSNs aims to build new types of wireless application-specific sensors. Traditional sensors have two types of nodes multi-purpose and bridge. The task of the general-purpose sensor node is periodically read measurements from its environment. It can be supplied with a variety of sensors that can measure various physical characteristics, such as temperature, light, humidity, velocity, acceleration, barometric pressure, magnetic field, etc. Gateway (bridge) nodes, on the other hand, gather the recorded data from nearby sensors and send it to the base station. Gateway nodes usually have higher processing capability, more battery power, and a longer radio transmission range. WSN is formed by joining both gateway and generic nodes.

To develop WSN applications, the sensing challenges can be organized into specific sets [4] as shown in Figure 1. The first set is the system with its details. Every node represents a separate system. It is needed to develop new systems with operating tools and memory for supporting various applications on a sensor system. The second task set is protocol communications that permit communication among the nodes of sensors and sensors and applications. The third set is the services. These tasks enhance the application performance and improve network efficiency.

It is worth mentioning that Set 2 is essential for communication with other sets and for exchanging data between the application and the sensor technology. Services are a bridge between communication aspects and the system. The system will manage the services with feedback to the system for the best performance of the application, and the system is also connected directly to the sensor technology. This structure is needed and basic for any development in WSN.

Considering the network management and requirements of the applications, sensor nodes must have the capability of self-organization. In other words, each group of nodes can organize sensors in a cluster and can control the communication among them efficiently [11]. Because of the limited processing capacity, storage, and power of sensor nodes, specific routing, and communication protocols are needed to fulfill these requirements. Not only mobile sensors are used, other sensors such RFID [12].

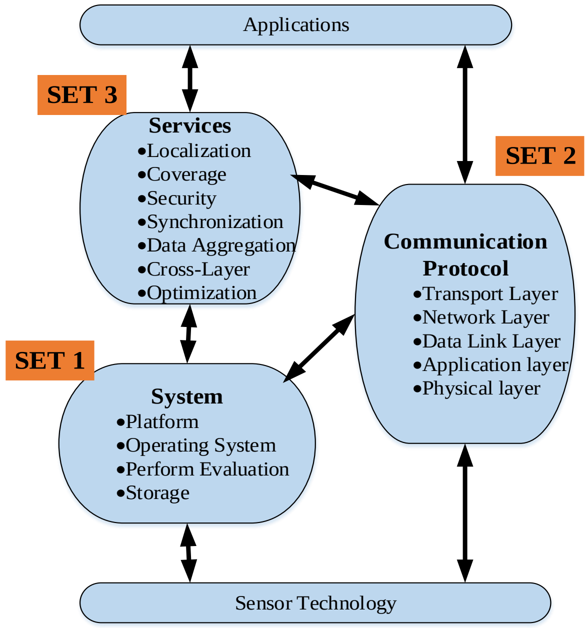

Figure 1. Application details in WSN [4]

Figure 1 above shows system details, some services, and some protocols in the communication set.

Designing WSN protocol techniques in any random layer can decrease energy and end-to-end delay [11]. Also, it can enhance system efficiency. This leads to the importance of optimizing the communication to make energy using minimum as possible. Traditional networking protocols, on the other side, have low performance in WSN because they are not built to meet specific requirements in WSN. To get desired specific requirements of WSN, new protocols for energy-efficient are used and developed; not in a specific layer but all different layers.

Since nodes of sensors work with limited power, optimization of using energy is a critical issue in a WSN. Many types of research are existed and focused on minimizing consumed energy. The sensor node will turn off when its power is run out and then disconnected from WSN. This might make the application perform badly. WSN Lifetime is determined based on how many nodes are active and work in the network. Therefore, power usage needs to be optimized and this will lead automatically to a rise in network lifetime.

2.2 Mobile wireless sensor networks

Recently, WSNs are deployed in many environments, such as land areas, metros (navigation applications [13]), and underwater vehicles. According to the nature of the environment, five kinds of WSNs have existed:

- Underground.

•Land Terrain.
•Multi-media such as cloud networks for different uses [14, 15].
•Mobile.
•Underwater.

The latter includes a set of different nodes, they are moved and interacted with their neighboring in the networks.

Nodes in mobile nodes can sense, communicate and compute just like static nodes. But nodes in mobile nodes are characterized by their ability to organize and relocate themselves in the network. The mobile WSN can be started with some initial configuration and then the nodes can then be relocated within the network. Data that is acquired by a node of mobile nodes can be transmitted to another node in the same range of communication. There is another difference in the distribution of data. In static WSN nodes, information is distributed by a static-network routing protocol. On the other hand, mobile WSNs use dynamic routing to cope with network changes.

The mobile WSN architecture is similar to that of the static WSN. However, additional protocols and techniques are required for mobile sensors, such as localization and position estimators, mobilization mechanisms, and power harvesting. The architecture of a typical mobile sensor node is shown in Figure 2. The position finder unit is used to estimate the position of the sensor node within the global coordinates system and the mobilizer provides mobility. Due to the fact that finding accurate positions may be dependent on the GPS, which already consumes high power. Therefore, the position finder in the MWSN is consumed more power compared to the static sensor since the mobile node has to search for its new position by the GPS. The power generator unit generates the power to run all the required node services. One example of a power-generating unit is the solar cell [16].

There are many mobile WSN application examples, such as environment monitoring, search and rescue, animal and bird watching, and tracking targets. Sometimes, manual deployment of sensor nodes might not be possible, such as in disaster areas. Using mobile sensor nodes in these conditions ensures that the node will move to the area of interest after deployment, providing complete area coverage. In the military, applications such as tracking and monitoring require nodes that work in real-time to make decisions immediately. In addition to the features mentioned before, mobile sensors can not only relocate their positions but also avoid obstacles by applying obstacle detection and avoidance algorithms.

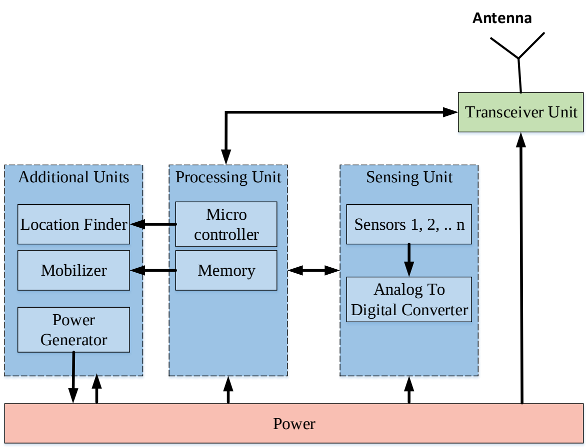

Figure 2. Mobile sensor node architecture [16]

2.3 Node mobility

Dynamic node positioning in WSNs is occurring due to the mobility of the nodes as well as the appearance of new nodes and the dying out of old nodes in the network. The network dynamics require frequent updates of the neighborhood information and the channel occupancies. Furthermore, due to the low data rate requirements of WSNs, a topology-based technique for assigning different channels to every part of the network becomes an impractical solution due to the high control information overhead. The update rate is highly dependent upon the degree of mobility of the network. The higher mobility in the network, the more frequent the nodes need to update the neighborhood channel information and vice versa [17].

2.4 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 in WSNs is to reduce energy depletion. The network design directly follows 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 collapsing 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 WSNs 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 [19]. 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 [20].

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 an important issue since nodes use batteries. WSNs usually use rechargeable or non-rechargeable batteries.

Some algorithms are suggested for Distributed Energy Saving Clustering (DEEC), the Development of Distributed Energy saving Clustering (DDEEC), Enhanced Distributed Energy Saving Clustering (EDEEC), and clustering in

Threshold Distributed power saving (TDEEC) clusters. All of them aim to save power and increase the lifetime of WSNs [21].

2.5 Clustering technique

In WSNs, there are many kinds of sensor nodes, those are [22]:

- Source sensor node (normal node).
- Intermediate sensor node (especially Cluster-Heads (CHs) in clustered networks).
- Base Station (BS).

Clustering, combined with data aggregation, is an efficient method to balance energy in WSNs. Clustering routing protocols are used in WSNs to increase energy efficiency because clustering reduces the size of data routed in the network. In WSNs, clustering has many advantages, such as increased scalability, reduced load, and energy consumption, data aggregation, collision avoidance, load balancing, latency reduction, fault-tolerance, higher robustness, increased connectivity, and maximizing the network lifetime [23, 24]. It is worth stating that robustness in general means how the system is resistive toward external perturbations such as noise, node failure, harsh environment and network scalability. Clustering is one of key factors that can maintain the robustness of WSN in achieving the desired functionality and prolong the life span of the network. Figure 3 summarizes the main attributes of the WSN clustering. This paper focuses on the role of clustering in energy reduction in WSNs. Therefore, in the next section, energy optimization based on clustering is discussed.

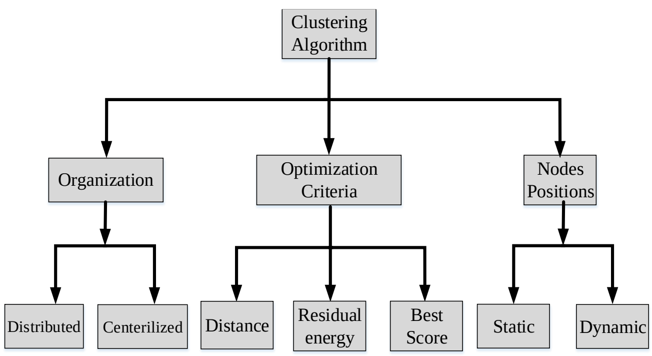

Figure 3. Main attributes of the WSN clustering algorithm

Zeng et al. [25] have addressed the problem of a lack of consideration for using the Low-Efficiency Adaptive Clustering Hierarchical (LEACH) protocol in heterogeneous energy network environments. They suggested the Energy-Coverage Ratio Clustering Protocol (ECRCP) to handle this issue, it depends on decreasing the consumption of system power. They designed an energy model. They choose the best clusters to count depending on the role of "minimum energy consumption". Each CH with the lowest residual energy from the previous cluster. The results showed that this method will increase the lifetime of WSN.

Jubair et al. [9] worked on optimization techniques for clustering in WSN to connect to the internet through a base station as shown in Figure 4. The authors made a useful survey and they studied all research and have resulted that hybrid optimization techniques are optimal solutions for all issues in WSNs. It is assumed that at least two algorithms have been used to achieve the same optimization. Hybrid optimizations therefore rely on current optimization techniques to accomplish the task of choosing the appropriate algorithm to employ in given case.

Table 1 shows a simple review of techniques respecting to cluster with summarized problems and solutions techniques to be used to solve these problems.

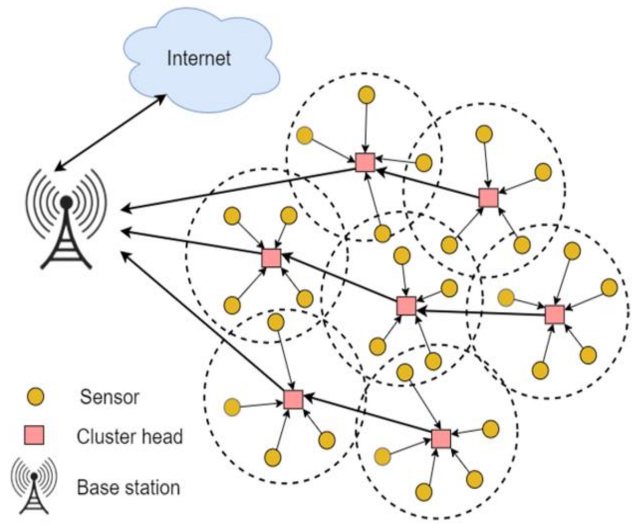

Figure 4. Clustering architecture in a WSN [9]

Table 1. Clustering algorithms comparing

REF	Problem	Solution
[25]	lack of consideration for using Low-Efficiency Adaptive Clustering Hierarchical (LEACH) protocol in heterogeneous energy network environments	Energy-Coverage Ratio Clustering Protocol (ECRCP)
[9]	Optimal coverage Reduce data redundancy Optimize the multi-objective function by determining the least number of sensors required	Genetic Algorithm and Ant Colony Optimization
[9]	Increasing WSN Energy Efficiency to Choose a Cluster Head and Assess Routing	Genetic Algorithm and ANFIS

3. ENERGY OPTIMIZATION METHODS IN WIRELESS SENSOR NETWORKS

To be able to make consumption of energy minimum of WSNs, small disjoint cluster groups of nodes are formed. These groups are formed by combining nodes depending on measures of similarity such as distance and Communication Range (CR). Clustering improves the robustness and scalability of the network. In general, sensor nodes have two basic tasks, namely:

- Sense and record the environmental parameters.
- Transmit the recorded information to the base station.

Compared with the sensing process performed by these nodes, data communication among these nodes usually consumes higher energy. Therefore, to maintain the operation of the nodes due to high-energy dissipation, a proper mechanism to optimize the node's energy dissipation is required. Moreover, other terms such as security and reliability have an important role to ensure reliable delivery of data and its accuracy at the base station node [26, 27].

4. ENERGY OPTIMIZATION-BASED CLUSTERING ALGORITHMS

One of the most used clustering routing protocols in WSN is Low-Energy Adaptive Clustering Hierarchy (LEACH) [28]. In LEACH, sensor nodes are split into groups of clusters. Each cluster uses an algorithm to select one node to become cluster-head and the rest of the nodes are working as the cluster members. Every cluster node collects its readings from the surrounding environment and then sends the readings to its CH. The CH aggregates the received data and compresses it, then transmits compressed data to the BS.

LEACH-centralized (LEACH-C) is an enhancement of LEACH. In this routing protocol, sensor parameters such as residual energy and their locations are sent to BS before CH is selected. The BS calculates the residual energy of nodes and eliminates the weak sensors list of CHs. The basic limitation of LEACH-C is that the built topology is not the best and power consumption is too high [29].

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [30] is a clustering algorithm depending on chain topology. All nearby sensors in the network that lies within one region are gathered via connection to form several chains, and then the leader of every chain is elected dynamically. Chains are designed and built by a greedy algorithm and every node has a role to serve as a leader. In addition, every node needs only to connect with the nearest neighbor. However, there is a constraint with the algorithm, because of chain construction.

Hybrid Energy-Efficient Distributed (HEED) Clustering [31] is yet a different proposed hierarchical routing algorithm. It explains a smart approach of CH choosing by tournament among nodes. The residual power of sensor nodes is considered for choosing CHs. Every sensor node computes its Average Minimum Reachability Power (AMRP) to find which CHs can join the cluster next.

Numerous studies have shown that HEED has four main goals: (1) extending network lifetime by distributing energy consumption; (2) terminating the clustering process within a fixed number of iterations; (3) minimizing control overhead (to be linear in the number of nodes); and (4) producing well-distributed cluster heads. Dasgupta and Dutta [32] suggested a new method for CH choosing depending on Fuzzy C-Means Clustering (FCM) algorithm. The optimization was performed based on minimum distance criteria and maximum node residual power. Razzaq et al. [33] suggested a k-mean based on the clustering technique, that can determine if a sensor node could become a CH using two-weight functions. They also consider the best packet size to ensure flexibility.

Arumugam and Ponnuchamy [34] suggested a power routing technique that calculates a term to select the best CH. However, the proposed routing protocol can only select nodes with the most remaining energy and does not take any other factor into optimization. Shokrollahi and Mazloom-Nezhad Maybodi [35] introduced a clustering algorithm that can save energy. This algorithm combines both FCM with ECAFG algorithms to optimize choosing of CH based on these factors:

- Residual power.
- Distance between node and center of the cluster.
- BS.

Murali and Gupta [36] presented a smart sensor clustering algorithm, based on the relation of communication and the degree of cooperation between nearby nodes. The results showed less energy, compared to the case where no cooperation is done among nodes.

Jung et al. [37] suggested the CH method that is depending on the fuzzy logic technique. The proposed algorithm used some parameters as optimization parameters:

- The density of nodes.
- Rate of data exchange.
- System power.

Rahimi and Chrysostomou [38] suggested a load-balancing method that can optimize the distribution of energy consumption among nodes. The proposed algorithm used a fuzzy logic controller to form a priority queue depending on optimization parameters to allocate CH among nodes within a cluster.

Shaikh et al. [39] introduced Group based Trust Management Scheme (GTMS) for cluster formation in WSNs. They proposed to compute the trust level of each node in one cluster rather than for each member node. As a result, the trust is evaluated by listening to the transmission of each packet sent, resulting in decreased energy consumption for all the nodes.

Shao et al. [40] proposed the Dependable and Lightweight Trust System which is a trust system for clustered WSNs. The researchers evaluated the trust level of the nodes based on both direct and indirect trust. However, the downside of this algorithm is that the evaluations are sampled via the communication of node-to-node, which affects the node's energy.

Ci et al. [41] proposed an algorithm for clustering that can both save power and extend the lifetime of the network. It considers the factors related to power, the density of node, and communication for choosing CH. For the phase of cluster-joining, both the distance factor and the residual energy are used to make the non-uniform distributed cluster set of the network. The results show good performance to reduce and balance energy consumption.

Hasan and Mohammed [13] proposed a new effective trust-based energy clustering protocol based on the Whale Optimization Algorithm (WOATCA). This algorithm selects trusted nodes to represent cluster heads with five parameters:

- The residual energy of each node.
- The number of packets each node forwards.
- The average cluster distance.
- Transmission delay.
- The density of the nodes.

After simulating the network, results showed that WOATCA outperformed the existing protocols by decreasing the selection of compromised, unsecured nodes that lose their energy faster than secure nodes. As a result, only secure nodes will be selected as cluster heads. Therefore, the results outperform other existing trust-based algorithms [42].

Wang et al. [43] introduced an Affinity Propagation-based Self-Adaptive (APSA) clustering algorithm. They combined the benefits of K-medoids with the Affinity Propagation (AP) algorithm, achieving higher clustering performance. The proposed AP is first used to estimate how many CHs are existed and to optimize the initial cluster centers for K-medoids. Afterward, the modified K-medoids are used to iteratively build network topology. The proposed algorithm successfully overcomes the drawbacks of the typical K-medoids in terms of both the homogeneity of clustering and the rate of convergence.

Cuevas-Martinez et al. [44] introduced a centralized, smart, unequal clustering approach for WSNs. This algorithm guarantee that the network will be more reliable and longer life while the data transmission is kept uncompromised. The basic idea is that BS decides which node becomes the cluster head, based on the evaluated best scores obtained from a Type-2 Fuzzy system. The input parameters to that system are calculated by the base station or gathered from the network nodes while reducing the control message exchange. The base station controls all of the sensor nodes in the network in a round-based scheduling scheme that alternates rounds when the base station selects cluster heads, with other rounds in which the cluster heads were previously elected, collects data from their surrounding nodes, and forwards them to the base station. The simulation results showed major improvement in performance that is done to the suggested algorithm when compared to other current clustering protocols.

Sujith et al. [45] proposed a zone-based clustering algorithm that is energy-efficient and performs efficiently in large-area WSNs. In this algorithm, the sensing field is clustered into zones of equal size, and a single zone is chosen per each zone to monitor all other zones. The cluster heads are selected based on their uniform distribution inside each zone, which ultimately leads to conserving their energy. Simulation results showed that the suggested clustering algorithm performs better than other methods.

Meena and Singh [46] proposed a Hierarchical Clustering Algorithm in WSNs based on firefly optimization. The Cluster formation and the selection of CH are applied using the firefly optimization algorithm with the constraint to minimize the power consumption. This optimization can escape from local optima, provide high-performance solutions and improve the network lifetime. It also can reduce energy utilization. The results showed that the proposed algorithm gives better results compared to other methods.

Yao et al. [47] proposed Energy Balanced Clustering Routing (EBCR). In the first step, a lightweight cluster head selection and a distributed clustering technique are introduced by using dynamic cluster radius and intersection region node division schemes with new parameters. Then the cluster cooperative routing algorithm is optimized, and the optimization enhances the efficiency of transmission between cluster heads. The simulation results show that the EBCR algorithm has increased performance in terms of less network energy consumption, and an increased number of surviving nodes in the scenario where no energy-harvesting is used. The results give the EBCR algorithm higher performance under various energy harvesting conditions, which is beneficial in energy utilization ability compared with the DCEM method.

Rawat and Chauhan [48] proposed a Particle Swarm Optimization-based Energy Efficient Clustering protocol (PSO-EEC) to increase both the network lifetime and performance. The proposed algorithm uses the PSO algorithm to select the CH and the relay nodes in the sensor network. The PSO fitness function accounts for the energy ratio of each node, the distance between CH and nodes, and the degree of the node for selecting the best node for the CH. The performance of the proposed algorithm is compared with the many existing algorithms in terms of energy expenditure, network lifetime, and throughput. The suggested scheme has improved the lifetime of the network. The period when the network is stable is better than the existing protocols.

Enhancing network lifetime and performance is one of the main research directions in WSN. The PSO algorithm is used in the proposed strategy to choose the best CH for the clusters and relay nodes for data transfer to the base station. The CH selection procedure employs the fitness function to select the best CH for overseeing cluster activities by taking into account the energy ratio of nodes, the distance between nodes and the cluster head, and node degree [48]. In addition to the previously mentioned routing protocols, there exist many clustering algorithms, such as the Threshold-sensitive Energy-Efficient Sensor network protocol (TEEN), the Saving Energy Clustering Algorithm (SECA), Energy Aware Unequal Clustering (EAUC), the Energy-Efficient Unequal Clustering (EEUC) and Unequal Cluster-based Routing scheme for multi-level Heterogeneous WSN (UCR-H) [43]. Bavaghar et al. [49] proposed a clustering algorithm for WSN that has a two-phase clustering model. That is CH selection and CH optimization.

Wei et al. [50] proposed a cluster head energy-based algorithm that constructs energy density function and assigns the node with higher remaining energy as CH. Hence, no random CH selection is done. Singla et al. [51] proposed a CH selection algorithm for mobile sensor nodes with RF energy harvesting, using a K-means clustering algorithm. Dhanusha [52] proposed a Weighted Rendezvous Planning (WRP) algorithm to control the movement of mobile sink in WSN to reduce consumed energy. Gharaei et al. [53] proposed a two-stage genetic algorithm for cluster head election and determining the optimal cluster size.

Ren et al. [54] presented an artificial bee colony optimization for cluster head selection and path optimization of data transmission with a mobile sink. Aydin et al. [55] proposed a greedy approach and neural network algorithm for CH selection and a genetic algorithm for optimal route selection to the mobile sink. Gharaei et al [56] described a novel routing protocol for heterogeneous consumer home networks. This protocol uses a Robotic Vacuum as a mobile sensor to enhance the energy consumption of consumer devices.

Gautam et al. [57] explained dynamic clustering and distance aware routing protocol (DDAR). DDAR considers distances for CH choosing with the super cluster head (SCH) technique depending on how the node is close to the BS. This algorithm explains the role of SCH in saving the power of CHs when nodes are too far from the BS. It consumes about 15.5% less energy than the conventional LEACH protocol, 15.4% less energy than LEACH-C. Moreover, the simulation showed that the number of alive nodes for the proposed DDAR protocol is 96 nodes after 450 seconds of simulation time, while in LEACH and LEACH-C, the number of nodes is less than 7 at the same time of the simulation.

Sirsikar and Wankhede [58] compared many techniques and results in using Two Hop Clustering (THC) because it is a protocol that employs a 2-hop clustering method, this will decrease the needed power of nodes in the network to exchange data with CH nodes. Two-hop member nodes send data to the CH nodes through one-hop nodes; this will save power. CH selection in THC is based on remaining energy and node degree. THC working is divided into three phases initial, distributed node clustering, and actual data transmission.

Sirsikar and Wankhede [58] also explained Energy Efficient Clustering Scheme (EECS) and its clustering algorithm in which cluster head candidates compete to get the ability to elevate to cluster head for a specific round. This competition contains candidates that broadcast their residual energy to neighboring nodes. By dynamically scaling clusters based on cluster distance from the base station, EECS created the core of the LEACH algorithm. The approach is an algorithm that clarifies the issue that clusters farther from the base station demand more energy for transmission than clusters that are nearby. In the end, this results in better energy distribution throughout the network and better resource utilization. Other studies were related to our research that can be used for more information [59-63].

Table 2 shows a comprehensive review of each of the related works. The review summarizes each study with the cluster head selection method, constraints, simulator, and mobility support.

Table 2. Comprehensive review of each of the related works

Ref.	CH Selection method	Mobility support	Constraints	Simulator
[28]	Random rotation, distributed	Static nodes and sink	All sensors observe the environment at a fixed rate and do not work as event-driven.	MATLAB
[29]	In centralized selection, all nodes are within communication range of each other, and the BS, centralized.	Static nodes and sink	Clustering infrastructure is assumed, where data aggregation is used to reduce the data sent from the cluster to the sink.	NS
[30]	Each node only communicates with neighbors, the greedy-chain protocol.	Static nodes and sink	Since the nodes are organized into chains, nodes must have global knowledge of the network.	NS2
[31]	Cluster selection is according to the node residual energy and node proximity to its neighbors.	Static nodes and sink	The network model does not specify the homogeneity of nodes, network density, and diameter, node synchronization, or energy consumption	Not specified
[32]	Based on the Fuzzy c-means algorithm with minimum distance and maximum residual energy criteria satisfied.	Static nodes and sink	Non-realistic assumptions: fixed number of clusters and same initial energy	C language
[33]	K-means with clustering- routing protocol.	Static nodes and sink	Simple assumptions are made: all sensors are homogenous and both delay and retransmissions are not considered.	MATLAB
[34]	Cluster head with maximum residual energy is elected.	Static nodes and sink	The concentration of nodes is required in CH selection. Besides, the work does not consider confidentiality and integrity of data.	Not specified
[35]	Fuzzy c-means algorithm and genetic fuzzy system.	Static nodes and sink	Strict assumptions: all nodes have the same sensing and processing capability. Also, all nodes can communicate directly with BS.	MATLAB
[36]	Cooperative communication among nodes, TDMA-based CH selection.	Static nodes and sink	A cooperative network is assumed.	Not specified
[37]	CH based on fuzzy inference system.	Static nodes and sink	Fuzzy is limited in terms of multi-objective optimization.	MATLAB
[38]	Load-balance for selecting CH using fuzzy logic, and TDMA scheduling to reduce intra-cluster communication.	Static nodes and sink	Sensor nodes must be aware of network topology.	MATLAB
[39]	Lightweight Group-based Trust Management Scheme for CH selection, distributed scheme.	Static nodes and sink	Nodes are assumed to be clustered at the startup using other clustering algorithms.	Sensor Network Simulator and Emulator (SENSE)
[40]	Uses node identities (roles) to reduce networking consumption while malicious, selfish, and faulty CHs.	Static nodes and sink	Clustering nodes when a program is started into a specific number of clusters.	The NetLogo-based trust simulation engine
[41]	Based on the energy threshold, node's residual energy, sensor nodes density distribution, and the communication factor.	Static nodes and sink	Node density must be calculated, and network topology must be known.	MATLAB
[43]	K-medoids combined with affinity propagation	Static nodes and sink	Each node must be aware of all other nodes and their positions.	MATLAB
[44]	The base station selects the CHs according to the best scores factor calculated using a Type-2 Fuzzy system.	Static nodes and sink	Careful network design is required to reduce message exchange.	MATLAB
[45]	The network is split into zones of equal size, and a single zone is chosen per zone to monitor all other zones. The CHs are selected based on their uniform distribution inside each zone to conserve their energy.	Static nodes and sink	The sensing field is divided into zones, and each zone is to be monitored by a zone monitor.	MATLAB
[46]	The clustering and CH selection are performed using a firefly optimization algorithm, considering minimum power consumption in WSN.	Static nodes and sink	The algorithm is a population-based meta-heuristic, which is complex to run on sensor nodes.	MATLAB
[47]	The cluster head is selected using dynamic cluster radius and intersected-region node division schemes.	Static nodes and sink	The energy of the sink node is assumed unlimited and the communication range covers all networks.	Not specified

[48]	Thus, distributed clustering will balance the load of cluster heads and eliminate the hot zone problem. The cluster head is selected by applying the PSO fitness function, accounting for the energy ratio of nodes, the distance between nodes and CH, and node degree to select the best node for the cluster head role.	Static nodes and sink	PSO requires more calculation power.	MATLAB
[49]	Two phases: CH selection and optimization	Static nodes and sink	Considers static nodes only.	C Language
[50]	Selection is based on energy density function and LEACH.	Static nodes and mobile sink	No errors in transmission power, fixed sensor nodes, and a single mobile sink is assumed.	MATLAB
[51]	K-means algorithm to cluster mobile nodes.	Mobile nodes and mobile sink	Nodes with RF energy harvesting are assumed.	MATLAB
[52]	Weighted rendezvous planning algorithm to control the motion of mobile sinks.	Static nodes and mobile sink	Only a single sink node is assumed and no cluster head is implemented.	Not specified.
[53]	Genetic algorithm with two stages to control cluster size.	Static nodes and mobile sink	Complex to run on a simple-resource sensor node and only a static network is considered.	MATLAB
[54]	Bee colony optimization for CH selection and data routing to mobile sink.	Static nodes and mobile sink	Complex bee algorithm relative to moderate node resources, only static nodes are assumed.	MATLAB
[55]	Greedy approach and neural network algorithm for CH selection and genetic algorithm for optimal route selection to the mobile sink.	Static nodes and mobile sink	Complex to be run on sensor node with moderate calculation power.	MATLAB
[56]	The energy depletion time of consumer devices (used in home network environments) is balanced, leading to increased coverage time and better network performance.	Static nodes and mobile sink	Static nodes are assumed.	OMNET++
[63]	Enhanced approach for decreasing power consumption in WSNs, TDMA scheduled.	Static nodes and sink	Homogeneous nodes are assumed, and no data privacy nor security is considered.	MATLAB

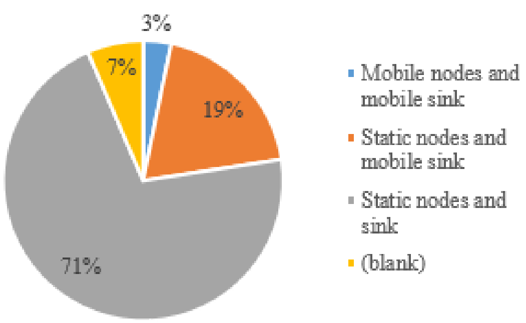

Figure 5. The most mobility support

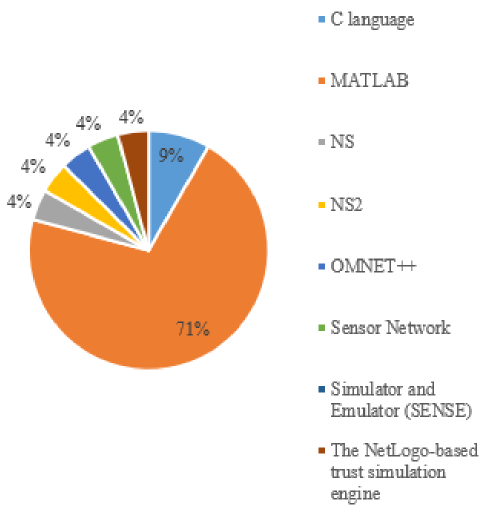

Figure 6. The most used simulator

Figure 5 and Figure 6 below summarize the most studies with the most used simulator and most mobility support.

Table 3 introduces a comparison of the energy efficiency of the most common clustering techniques in WSN. In Table 3, it can be noticed that there are many effective energy algorithms, so according to these parameters (clustering mode, distribution channel and residual selection and Energy efficient), it can be used as a criterion for choosing the best clustering technique.

Table 3. Energy efficient clustering scheme (EECS)

Algorithms	Clustering mode	CH Distribution	CH Residual Selection	Energy efficient
LEACH	Distributed	Non Uniform	No	No
LEACH-C	Centralized	Uniform	Yes	Yes
TL-LEACH	Distributed	Non Uniform	No	Yes
HEED	Distributed	Uniform	Yes	Yes
EECS	Distributed	Uniform	Yes	Yes
DDAR	Distributed	Non Uniform	Yes	Yes
THC	Distributed	Non Uniform	Yes	Yes

5. CONCLUSIONS

This paper 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.

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