




Review

# Optimization of Routing-Based Clustering Approaches in Wireless Sensor Network: Review and Open Research Issues

Asha Jerlin Manuel <sup>1</sup>, Ganesh Gopal Deverajan <sup>2</sup>, Rizwan Patan <sup>3</sup> and Amir H. Gandomi <sup>4,\*</sup>

<sup>1</sup> School of Information Technology and Engineering, Vellore Institute of Technology, Vellore 632014, India; ashajerlin.m@vit.ac.in

<sup>2</sup> School of Computing Science and Engineering, Galgotias University, Greater Noida 203201, India; dganeshgopal@gmail.com

<sup>3</sup> Department of Computer Science and Engineering, Velagapudi Ramakrishna Siddhartha Engineering College, Vijayawada 520007, India; prizwan5@gmail.com

<sup>4</sup> Faculty of Engineering & Information Technology, University of Technology Sydney, Ultimo 2007, Australia

\* Correspondence: gandomi@uts.edu.au; Tel.: +61-(02)-9514-5081

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**Abstract:** In today's sensor network research, numerous technologies are used for the enhancement of earlier studies that focused on cost-effectiveness in addition to time-saving and novel approaches. This survey presents complete details about those earlier models and their research gaps. In general, clustering is focused on managing the energy factors in wireless sensor networks (WSNs). In this study, we primarily concentrated on multihop routing in a clustering environment. Our study was classified according to cluster-related parameters and properties and is subdivided into three approach categories: (1) parameter-based, (2) optimization-based, and (3) methodology-based. In the entire category, several techniques were identified, and the concept, parameters, advantages, and disadvantages are elaborated. Based on this attempt, we provide useful information to the audience to be used while they investigate their research ideas and to develop a novel model in order to overcome the drawbacks that are present in the WSN-based clustering models.

**Keywords:** clustering; energy consumption; throughput; QoS

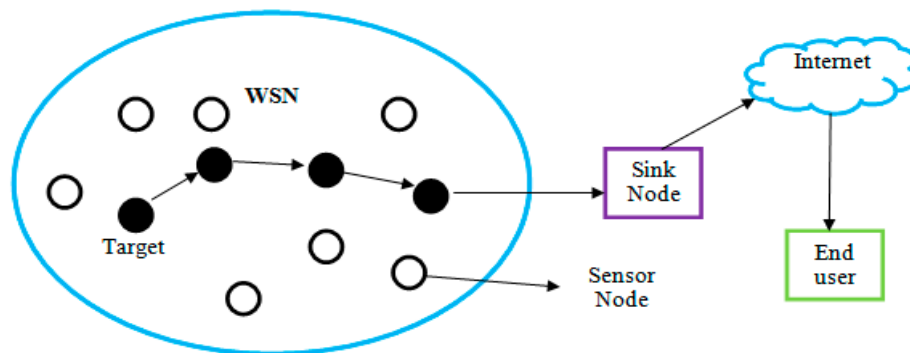
## 1. Introduction

### 1.1. Wireless Sensor Networks

A wireless sensor network (WSN) network is characterized as a small-scale gathering for sensor hubs, especially for sensing, monitoring, capturing, and processing the information concerning an application. Therefore, generally, these hubs completely rely on battery backup, storage, data size, computation, and bandwidth [1]. Nowadays, WSN has become unavoidable in daily life; hence, many studies tend to focus on specific application properties [2].

Real-time applications have attracted attention among technocrats and analysts because of the recent breakthroughs in the sensor field. To overcome the difficulties in the sensor field, scientists and technologists have found an answer in the utilization of real-time WSN applications. Real-time sensors have the ability to detect, record, and send feedback immediately to the end client for future processing of all the gathered data. In particular, a real-time application addresses the presentation of basic applications that need limited delay latency. For the current situation, the real-time application involves the extensive application of WSN, which has much potential for applications in different kinds of research. The main advantage of the real-time application is its capability of screening the

environment very quickly, providing an immediate response to the client, and easily controlling the outside environment. The outside environment is directly linked with the computer framework through multiple sensors, input and output gadgets, and actuators. WSN can empower the network limited delay guarantee, which is fundamental for an end-to-end packet delivery known as real-time WSN [3] as shown in Figure 1.



**Figure 1.** Wireless sensor network (WSN) architecture.

Events in real life can be changed into information, which can be saved, processed, and utilized for future purposes by sensor hubs in a WSN. Every sensor hub is changed in a particular manner as per their condition, for example, if the installation of a sensor node is underground, it should then have transceivers with high power transmission to block attenuation of noisy channels while on the off chance that the sensor is set in a marine situation [4]. At that point, a sensor's external shell/encasement needs to withstand the impact of salty and damp environments and being waterproof would be another significant and advantageous component. Each change in the environment can be monitored by sensors and that information can be sent to the main server in which decision-making processes can happen in real-time. Catastrophic failures can be reduced by the sensor networks via constant and solid monitoring of the environment [5]. Hence, WSN consists completely of sensor hubs and can communicate wirelessly. Sensor node architecture is explained in the next sections [6].

#### 1.1.1. Sensor Node Architecture

Advancements in the field of wireless communication have made improvements in WSN, such as gadgets known as sensor hubs, conceivable. Naturally in WSN, thousands of sensor nodes are utilized for the network because the lifetime of a sensor node basically relies on its battery, and these nodes are inclined to become damaged when they are circulated [7]. Sensors can be properly utilized in places in which it is difficult for a human to handle the environment. Small sensor hubs consist of three primary phases:

1. To receive the data;
2. Processing of data;
3. Data transfer through wireless communication.

Sensor hubs' main advantages are low power, small size, sensing capacity, data transmission through wireless communication, and computation which is shown in Figure 2.

#### 1.1.2. WSN Types

WSNs can be classified into five types depending on the situation for which the network is chosen.

##### Terrestrial WSN

This type of WSN has many minor hubs, which are randomly deployed in a particular region in which the communication is ad hoc.

Generally, two- or three-dimensional, grid, or optimal placement are utilized to organize these nodes. The main drawback of this type of WSN application is the impact that poor weather conditions, such as snow and rain, have on optical wireless communication interfaces.

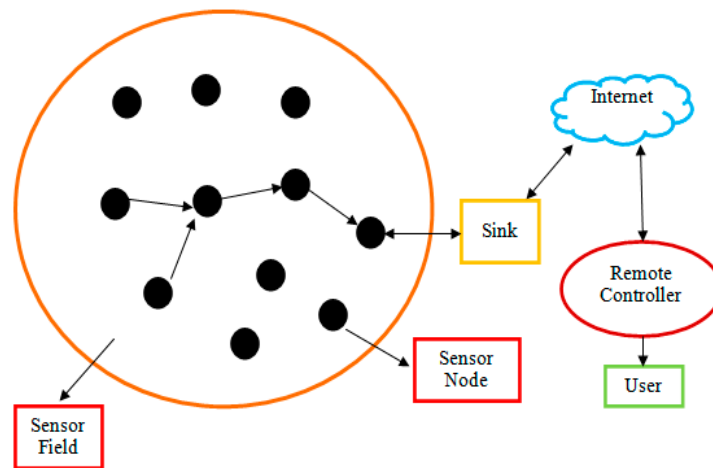


Figure 2. Sensor node architecture.

#### Underground WSN

In this type of WSN, sensor hubs are placed underground for gathering data about underground conditions. The downside of a WSN is the restricted battery power, since under these types of conditions, it is extremely hard to monitor energy or changes in the environment.

The main drawback of wireless communication is the loss of signal during high potential conditions. To improve WSN reliability, productive routing algorithms are required for explaining the confinement of the WSN's precision during the routing process [8].

#### Underwater WSN

Underwater WSNs (UWSNs) incorporate expensive sensor hubs for gathering data about underwater conditions; hence, these hubs can be placed directly underwater. Very poor network signals, limited bandwidths, and network delays are some of the restrictions in this type of network [9].

#### Mobile WSN

One of the main advantages of a mobile WSN is the automatic changing of the sensor hub's position when the power changes in response to the environment.

These types of hubs are generally attached to the computer for communication. This type of hub can collect data from a wide range of regions or data from other hubs in the network. The primary limitations of this type of WSNs are high maintenance, low navigation, poor coverage of zones, and high accessible status [10].

#### Multimedia WSN

Multimedia WSN applications have modest sensors, and they can detect, compute, actuate, and communicate. Use of the WSN incorporates home observation, traffic management frameworks, and environmental checking.

These types of WSN devices are interconnected in wireless communication and are capable of recovering video and sound transmissions and scalar sensor information from the earth [11].

### 1.1.3. WSN-Main Prerequisites

#### Power Efficiency

WSN utilizes a sensor that results in low power use. The response time is exceptionally quick in view of its constraints.

#### Reliability

Many techniques are used for power reduction in WSN hubs, which bring about an expansion in the system's lifetime and consistency.

#### Scalability

WSNs can extend this system to include hubs as required. Its extensions should be easy to manage.

#### Mobility

Mobility is an essential component of WSN. Since WSN is a remote system, no wire is utilized for this system. This is the reason mobility is a key component of WSN.

### 1.1.4. WSN-Security Vulnerabilities

WSNs are widely used for intelligent monitoring of many parameters, including vehicular actions on streets, temperature, humidity, passages and structures, water level, pressure, criminal surveillance in streets and alleyways, remote checking on numerous patients, and numerous different other applications [12–14]. As previously described before, each WSN organization is subject to and must be adjusted by considering the nature of the establishment.

At any rate, the main research challenge is real-time communication, which completely relies on an application, such as event-driven, nonstop, and question-driven applications. In these applications, if the data packets are beyond the cut-off, it is viewed as influencing the framework execution and quality [5,15,16].

### 1.1.5. WSN-IoT

Since the establishment of the IoT model, WSNs have been found to be its critical enabler. In IoT, all the sensor nodes can connect to the internet for sharing and receiving information, whereas in WSNs, there is no direct connection to the internet for the nodes. All nodes in WSN require a mediator to connect to the internet. Significant research has been done in recent years on bridging WSN into IoT. When it comes to bridging IoT and WSN there are plenty of security breaches that need to be addressed and hence there is a great scope of research in this area which has been addressed by some of the notable researchers in their papers [17–19].

## 1.2. Clustering

WSN consists of a huge number of sensors but has limited battery power. Naturally, WSN hubs can work under harsh and hazardous environmental conditions; however, the battery cannot be recharged or replaced in these situations. Hence, energy conservation is essential for the network. Generally, routing protocols have an immense effect on energy utilization in which energy utilization is considered the main consideration while designing the routing protocol [20].

Cluster-based routing protocols are known to be best in the concept of energy savings for any type of sensor in order to increase the network's lifetime. A group of sensor hubs is generally eluded as clusters. In this group, an extraordinary hub called the cluster head (CH) and member hubs, known as ordinary nodes (ON), are used. The CH can select high energy and is utilized for data collection and transmission of other hubs to the base station (BS) [21]. In this type of protocol, the messages that pass through the system can be decreased [21,22] and the sensed data can be transmitted by sensor

hubs to the corresponding CH. The BS can collect data from all of the available CHs in the network via an intermediate CH, which purely relies on the type of WSN architecture that is selected [23]. The CH sensors information after accepting the information from the cluster member; this process is accomplished in order to dispose of repetitive information so that just the outright information is transmitted. This type of transmission is done to spare energy since energy utilization is considered one of the prime factors in WSN selection [24].

Clustering techniques generally increase scalability and significantly reduce radio transmissions [25–28]. A definitive goal of clustering is to offer an answer that maintains dependability among sensors throughout the system's activity [29].

### 1.2.1. Clustering—Design Challenges

In a large portion of the WSN open-air applications in some critical situations, such as those that are unattended, maintaining the battery is complicated. With this limitation, it is very difficult to extend the lifetime of the network.

Alongside the previously mentioned drawbacks, some different difficulties, which should be satisfactorily addressed while designing clustering algorithms exist, are listed below.

1. For clustering protocols, the number of clusters and formation processes are very essential. Balance among clusters is very important, and at the same time, message exchange during the formation of the clusters must be minimized.
2. The algorithm complexity increases linearly as the network develops.
3. CH selection is very important because it can directly affect the performance of the system.
4. The most ideal hub should be chosen with the goal that the system steadiness period and general network lifetime should be expanded.
5. In most of the strategies, CH choice depends on a few parameters, for example, energy level and hub location.
6. CH will receive the sensed data from the nodes on which the data aggregation process is performed. That process is the reason that these steps form the key structural challenge [27].
7. A clustering algorithm should handle all types of applications because WSNs are completely application dependent.
8. The clustering algorithm design must support defense applications in which data are highly confidential, for example, military applications and health monitoring [26]
9. Variable energy allocation becomes complicated in many of the researches.
10. While applying the clustering model in a larger network it becomes complicated and energy consumption will be gradually increased.
11. Clustering algorithms are combined with many hybrid models to improve the overall performance of the network. During that process interference of the network is also gradually increased.

### 1.2.2. Benefits of Clustering in WSN

1. Clustering can execute optimized management methodologies in the network.
2. From the sensor level, the topology of the network and communication overhead are managed by clusters because of hub associations with only the CHs.
3. Clustering can maintain the bandwidth for communication, and it can also prevent redundancy of exchange messages [30].

The section organization of this survey is divided into five parts. In Section 2, the earlier survey studies of clustering methodologies are discussed. In Section 3, an overview of routing protocol-based clustering models is discussed. In Section 4, a detailed discussion concerning clustering and clustering techniques in addition to the objectives, comparisons, pros and cons, and evaluation are discussed. In Section 5, the conclusion of the paper is presented.

## 2. Materials and Methods

There are numerous studies in WSNs addressing different subjects, for example, congestion control [31], quality-of-service (QoS) assurance [32], network lifetime maximization techniques, in-network aggregation techniques, and multiobjective optimization in addition to optimization algorithms.

A series of reviews that describe clustering, optimization, and clustering-based multihop routing protocols are presented in the following section.

### 2.1. Clustering-Based Routing Protocols

Rathi (2012) divided routing protocols into classical and swarm intelligence methods. At the beginning of this review, classification is described as dependent on a few factors, such as energy efficiency, path establishment, complexity in computation, and the structure of the network, among others. At that point, a grouping consisting of five general classes was introduced. For every one of the classic and swarm intelligence techniques, four classes were then introduced: (1) quality-of-service (QoS) awareness, (2) hierarchical, (3) data-centric, and (4) flow of network. At last, every classification was examined and discussed based on a few parameters, such as aggregation of data, location, and energy efficiency. Moreover, standard measurements were then introduced for the simulation [33].

Rostami (2018) contrasted different homogeneous and heterogeneous networks. This overview presented the difficulties of each analyzed protocol and contrasted them based on some clustering parameters, such as CH numbers, cluster counts and objects, complexity, and intercluster communication. When compared with homogeneous networks, the heterogeneous systems appear to provide better performance because they select the CH having high power, while in homogeneous systems, all hubs have an even operational and processing capability [34].

Abbasi (2007) presented the first overview and assessment of clustering protocols in WSNs. This overview contains two major categories, namely, convergence time and clustering attributes. Convergence time has variable and fixed parts, whereas clustering attributes have clustering-related properties and processes. After summing up the strategies and their significant objectives, as indicated by the proposed order, the techniques were assessed through parameters, such as cluster overlap and stability, rate of convergence, mobility of nodes, and location awareness [35].

Fanian (2016) introduced a study about techniques that were created according to the low-adaptive clustering hierarchy (LEACH) protocol. This survey depended solely on LEACH-based techniques, which were assessed in terms of balanced clustering, failure recovery, and the original LEACH. Comparisons were made with respect to clustering properties and processes and CH possibilities. At last, these factors were classified with respect to highlights, such as breakdown retrieval capabilities, multilevels, and configurations [36].

A review by Akkaya (2005) surveyed recent routing protocols and discovered classifications for different methods. Based on this survey, three main categorizations, namely location-based, hierarchical, and data-centric were defined. Every routing protocol was depicted and described under a suitable classification. In addition, protocols utilizing contemporary procedures, for example, QoS modeling and network flow, were additionally discussed [37].

Sha (2013) assigned a multipath routing protocol to WSNs, which are mainly infrastructure- and non-infrastructure-based networks. Each and every classification was studied and analyzed. At last, the methods in every classification were contrasted with respect to time for route setup, lifetime, efficiency, load balancing, and reliability [38].

In 2014, Afsar described an architectural perspective of survey clustering-based routing protocols. In the initial stage, clustering characteristics were explained, and after that, categorization of routing protocols was performed. Clustering techniques are generally classified into two categories, namely, equal and unequal sized clustering algorithms. Depending on their objectives, the clustering technique summary was then prepared and presented in this review. Finally, a comparison with respect to clustering features, such as algorithm complexity, cluster count and size, and mobility, is provided [39].



Riaz (2018) studied and presented an overview of clustering algorithms in which it is demonstrated that the major input parameters are initial energy, node degree, and density. During the CH selection process, the CH node should utilize minimum energy from the total energy consumption. Few of these protocols lead to the development of variable cluster sizes and counts, and sometimes, these protocols create a gap that is very close to the base station (BS) and consumes more energy during communication since the hubs take a longer path to arrive at the BS [40].

Pantazis (2013) focused on energy-efficient protocols and introduced a review of routing protocols that classifies the techniques into three general classes: (1) reliable routing, (2) communication model, and (3) topology model. Every technique presented in this overview is discussed based on advantages and disadvantages, robustness, route metric, scalability, periodic message, and mobility [41].

In a review by Ramesh (2011), various clustering methodologies were categorized and described and special attention to their CH selection procedures was emphasized. These methodologies were then contrasted with the necessity of clustering during each round for CH selection, appropriation of group heads over the system, cluster development required after every revolution of CH, balanced cluster creation, and parameters utilized and help highlight the importance of the CH determination technique on the presentation of these plans. The parameter utilization for this correlation was legitimized by thinking about the impacts of CH selection and its role in network energy efficiency [42].

Singh (2015) examined the advantages and impediments of cluster-based routing protocols using various methodologies. In this review, these techniques were classified based on block, grid, and chain. At last, methods were assessed in terms of cluster stability, scalability, energy efficiency, and delivery delay [43].

Arjunan (2019) introduced a study addressing unequal clustering techniques. These techniques were ordered into three main classes: (1) deterministic, (2) pre-set, and (3) probabilistic clustering algorithms. The presented protocols were described by characterization, targets, attributes, demerits, and merits. Deterministic algorithms were utilized for robust and reliable applications. A heuristic methodology was chosen in cases in which an optimal solution was needed for a specific environment. All mentioned protocols are contrasted with respect to cluster and CH properties [44].

Dehghani (2015) assessed clustering algorithms for energy saving. Every algorithm is described in detail and its advantages and disadvantages were thoroughly examined [45].

In a 2018 review by Sharma, heterogeneous routing algorithms were discussed. This survey describes four general heterogeneity-based classifications (1) computational, (2) energy, (3) link, and (4) different. Hub heterogeneity levels, CH selection, and sink position were the parameters selected for the comparative analysis of routing algorithms [46].

Liu (2012) introduced a study on network routing protocols and sketched out the advantages and goals of clustering techniques. This survey classified clustering attributes into four main classes: (1) cluster qualities, (2) CH attributes, (3) total proceedings of the protocol, and (4) clustering process. Regarding objectives and capabilities, the clustering method summary is presented. At last, the strategies dependent on the parameters that were adopted for every one of the four classifications and different parameters; for example, the stability of the cluster, scalability, and load balancing were compared [47].

Kaur (2017) examined a few clustering strategies that were previously investigated and referenced by considering in which circumstances these protocols would be suitable for use and in which cases productive outcomes would not be achieved. Some of these strategies were viewed based on distinctive clustering parameters, such as cluster development prerequisites, separation of detecting hubs from the BS, and threshold and residual energy in addition to computation of the ideal number of CHs [48].

In a review by Suhail (2017), general classification and scientific categorization of distributed clustering protocols were prepared. This overview additionally analyzed the bunching plans dependent on the stability and overlapping of the cluster, node location, and mobility [49].

Radha (2015) discussed different clustering techniques, for example, centralized, hybrid, and distributed techniques. This discussion could help researchers introduce a novel clustering algorithm that would be mainly focused on improving network lifetime and power factors [50].

Mitra (2012) analyzed the present condition of proposed clustering protocols with emphasis on their capacity and dependability necessities. In WSN, the energy constraints of hubs play a very crucial role in protocol design and implementation. Likewise, QoS measurements, for example, data loss tolerance, delay, and system lifetime uncover dependability issues when structuring recuperation components for clustering schemes. These significant attributes are frequently restricted as one regularly and negatively can affect the other [51].

Santhiya (2013) reviewed WSNs energy-efficient clustering algorithms. The “load-balanced clustering algorithm” was introduced for the balanced energy of clusters in both uniform and nonuniform distributions. Secure communication in clusters is very essential because if the clusters misbehave or are compromised, the entire network link then fails. To overcome this issue, cluster-based certificate disavowal for enrolling and evacuating hub authentications is recognized for dispatching attacks on the area. This process prevents the energy of sensor hubs from becoming exhausted in WSN and shields the sensor hubs from harmful attacks [52].

Dawood (2014) examined the scope of WSN clustering protocols. Moreover, this review subdivided the job of a clustering protocol to improve WSN exhibition. The review also examined the significance of improved QoS energy-based clustering protocols to maximize the battery power of WSN [53].

Kaur discussed different difficulties related to clustering and various strategies or procedures created to overcome these difficulties [54].

In 2014, Kumar reviewed various distinctive leveled clustering WSN algorithms from an energy efficiency perspective and furthermore, described the major ideas of clustering and its characteristics, focal points, impediments of clustering, and different clustering algorithms in its scientific categorization. This overview additionally presents relevant open issues and difficulties in progressive directing or clustering [55].

## 2.2. Optimization-Based Clustering Mechanisms

Several optimization-based clustering algorithms were developed in earlier days such as ant colony optimization (ACO), artificial bee colony optimization (ABCO), fuzzy logic (FL), genetic algorithm (GA), whale algorithm, particle swarm optimization (PSO), and so on.

Nayyar and Singh (2017) introduced an exhaustive review of ant colony optimization (ACO) for WSNs. This effort reviewed QoS parameters, such as energy utilization, bandwidth, delay, reliability, and data aggregation. Favorable circumstances and hindrances of ACO-based routing protocols for a WEN were further examined [56]. The major advantages of this process are that it can reduce energy consumption and will increase the bandwidth and message success ratio. The disadvantage is that it can increase the network delay.

Gambhir (2018) tried an “artificial bee colony optimization” (ABCO)-based LEACH algorithm with respect to assorted WSN situations by changing the number of rounds and corresponding number of sensor hubs. Many parameters, for example, dead and live hubs per round and packet to the BS per round were considered for execution assessment. Examination of every parameter starting with an ordinary LEACH was also introduced [57]. The major advantages of this process are that it can reduce energy consumption. The disadvantage is that it can increase the interference of the network.

In a review by Sambo (2019), a wide survey of the ongoing progressive methods dependent on computational intelligence (CI) or machine learning (ML) were examined. To accomplish this task, the calculations were grouped for different CL uses, which could be fuzzy logic (FL), genetic algorithm (GA), neural network (NN), reinforcement learning (RL), or swarm intelligence (SI). To assess and analyze these uses, several parameters, such as data aggregation, data delivery rate, and scalability, were selected [58]. The major advantages are that this method helps to increase the network lifetime



and the quality of service of the network. Due to the combination of the hybrid model, it can increase the interference of the network.

Wang proposed a whale algorithm-based optimization model for WSN. The mathematical model of hub inclusion in WSN was created to accomplish full inclusion for an area of interest. For the model, switch learning is brought into the first whale swarm streamlining calculation to upgrade the underlying appropriation of the population. This strategy leads to an upgrade in hub searchability and accelerates the global search. The outcome of this work showed that this algorithm could viably improve the inclusion of hubs in WSN and enhance system execution [59]. The major compensation of this process is that it increases the energy efficiency of the network. The disadvantage is that it can increase the network's end-to-end delay.

Hemalatha (2015) surveyed WSNs optimization techniques. This paper analyzed significant research issues regarding the optimization of energy and requirements for WSN optimization. This paper examined steering difficulties and requirements for WSN improvement. All the available optimization techniques are clearly discussed with their advantages and disadvantages [60]. All the available optimization techniques are clearly discussed with their advantages and disadvantages. The most common advantages and disadvantage of the network is that it increases the network lifetime and optimization-based models lead to an increase in the latency of the network.

In a review by Kaur (2015), a top to bottom investigation about power utilization was introduced. This work surveyed many significant methods for conserving power in WSNs. Emphasis was given to artificial intelligence (AI)-based power optimization methods including FL, NN, clustering, and network-based strategies [61]. The major advantage of the model is it can increase the accuracy of the network. The drawback is that it can reduce the precision of the network.

Parwekar's (2018) study addressed difficult issues, such as node maintenance and localization and clustering among others. The fundamental point of optimization strategies is to give the inside solution enough time and furthermore to limit energy utilization along these lines by drawing out the lifetime of the system. This study obviously depicts the utilization of distinctive distributed optimization methods in the field of WSN [62]. The major advantages are that this method helps to increase the network lifetime and the quality of service of the network. Due to the combination of the hybrid model, it can increase the interference of the network.

In 2016, more introduced an energy optimization design by optimizing the system hubs working mode to optimize the stages of WSN; this study stressed the use of the particle swarm optimization (PSO) technique. When compared to GA, PSO internally utilizes candidate answers to get a feasible answer to get reinforced molecules out of all multitude molecule change streamlined WSN. The PSO calculation is the most helpful strategy to advance the stages for example network coverage, hub position, grouping, and routing and data aggregation [63]. The major advantages of this process are that it can reduce energy consumption and will increase the bandwidth and message success ratio. The disadvantage is that it can increase the network delay.

A review by Sneha, Swathi (2016) examined various optimization methods, such as particle swarm optimization (PSO), artificial bee colony (ABC), ACO, and GA. These methods are used to improve the performances of various parameters, for example, reduced power consumption, optimal path, and target coverage. ACO and ABC yield high achievement rates and longer system lifetimes, especially for a fundamental system but for a thick system, they do not perform well [64,65]. The major advantages are that this method helps to increase the network lifetime and the quality of service of the network. Due to the combination of the hybrid model, it can increase the interference of the network.

Mangat (2012) presented a review on a PSO-based clustering investigation. The fundamental purpose behind picking the PSO technique for clustering is the small number of parameters that should be modified. Single form, with slight varieties, functions admirably in a wide assortment of uses. PSO has been utilized for approaches that can be utilized over a wide scope of uses, for example, image segmentation, design of the system, clustering of web usage data, signal processing, pattern recognition, classification, and multiobjective optimization. The hybridization of PSO with

other transformative calculations, such as GA and differential evolution (DE) has been a powerful tool for improving PSO proficiency and precision [66]. The major advantage of the model is it can increase the accuracy of the network. The drawback is that it can reduce the precision of the network.

### 3. Cluster-Based Routing Protocol Classification—Overview

In this section, clustering is subdivided into three different categories: (1) parameter-based, (2) optimization-based, and (3) methodology-based clustering. First, parameter-based clustering is subdivided into two major classifications, including clustering-based both on primary and secondary parameters. Second, optimization-based clustering is subdivided into classical and hybrid optimization approaches. Finally, methodology-based clustering is subdivided into fuzzy-based and metaheuristic methods as given in Figure 3. All these classifications are thoroughly explained in Section 4.

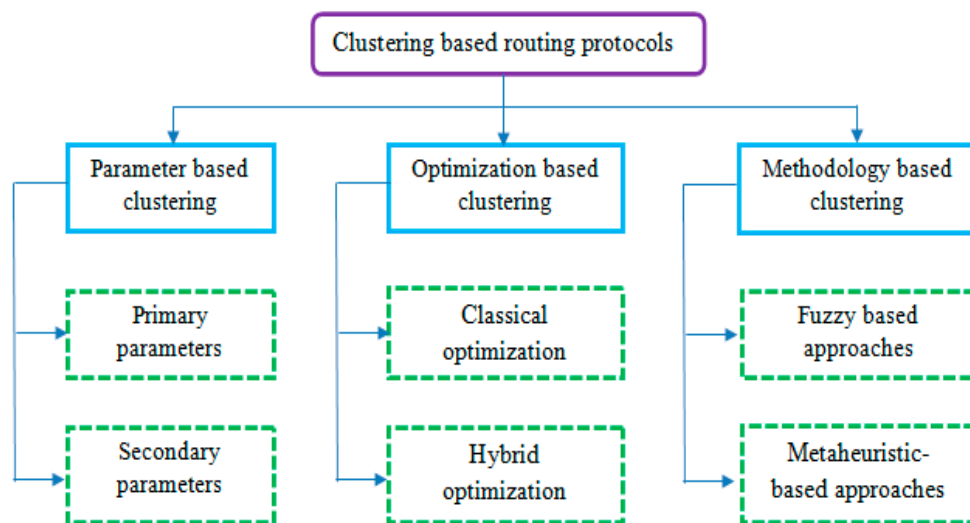


Figure 3. Classification of clustering-based routing protocols.

#### 3.1. Parameter-Based Clustering

##### 3.1.1. Clustering Based on Primary Parameters

The major primary parameters consist of general objectives and clustering strategies for head selection. The major subsections consist of objectives.

##### Strategy for CH Selection

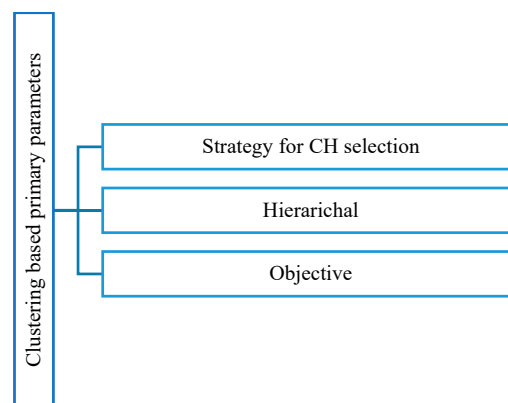
A short description is given to illustrate the general method for choosing a cluster head based on various strategies, such as those that benefit the crowd. This segment presents noteworthy ways to address the CH choice from the previously mentioned strategies. It is depicted in Figure 4.

##### Objective

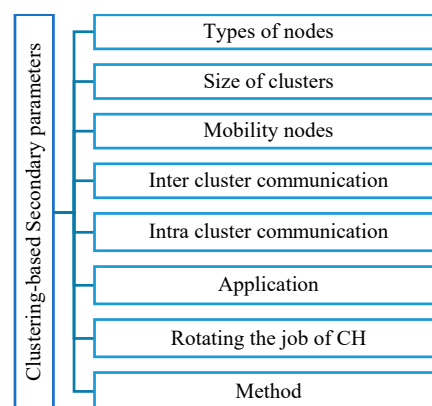
Calculated different directing in addition to techniques containing numerous goals, for example, data aggregation, fault tolerance, scalability, network stability, node connectivity, load balancing, collision avoidance, network coverage, and network lifetime among others are some of the primary goals of calculated different directing. The remainder of the goals are considered optional and are set to help accomplish the principal targets. Optional destinations are of less significance [36].

##### 3.1.2. Clustering Based on Secondary Parameters

In this section, secondary parameters are discussed briefly. The developed clustering model has several features and characteristics. The Figure 5 shows the details about those clustering methods.



**Figure 4.** Clustering-based primary parameters.



**Figure 5.** Clustering-based secondary parameters.

### Types of Node

Homogeneous and heterogeneous nodes are available for algorithms. CHs are generally chosen from heterogeneous sensor hubs if calculations utilize such hubs.

### Cluster Size

Cluster size can be controlled or uncontrolled. This model is used to examine a technique to determine whether the creators focused on controlling cluster size. In general, the coverage area of the cluster is fixed according to the distance from the BS. Clustering algorithm density decides the cluster size for the determination of a range of clusters [41].

### Mobility of Nodes

CH and normal nodes may have motion or be motionless. If a motion is available, it would be over a limited range.

### Intercluster Communication

CHs and BS can be directly connected by either a one-hop or also by a multihop connection.

### Intracluster Communication

Generally, in intracluster communication multihop transmission is employed. That choice is the smarter one for using multihop intracultural communication in which there are few CHs when part hubs are a long way from CHs or when there are more limitations on sensors. Consequently,

the parameters were viewed as having the possibility that a single-hop or multinumber of hops could be used for assessment measures [40].

### Rotating of the CH

This rule decides if a technique to utilize a system will supplant the hubs and assume the job of a CH. In specific techniques, CHs are occasionally supplanted. In some different techniques, they are supplanted after a predetermined timeframe or when the CH energy level reaches the predetermined limit. With the help of the energy threshold system, this technique, for the most part, attempts to bring system energy utilization together.

### Methods

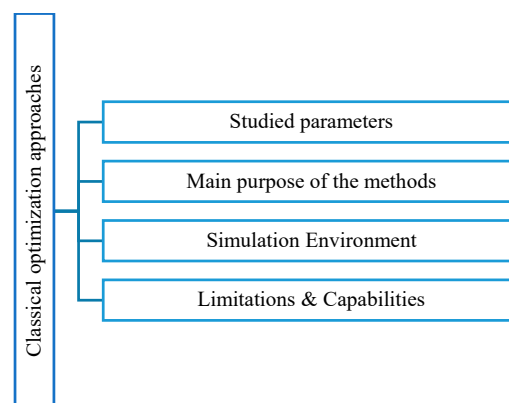
The clustering technique may be centralized or distributed but involves a centralized or hybrid distribution in some strategies.

### 3.2. Optimization-Based Clustering

Optimization-based clustering is classified into classical and hybrid optimization approaches.

#### 3.2.1. Classical Optimization Approaches

The essential factors for classical optimization approaches are parameters from earlier developed models, including their limitations, utilizations, capabilities, and simulation environments are shown in Figure 6.



**Figure 6.** Classical optimization approaches.

#### 3.2.2. Hybrid Optimization Approaches

Fuzzy- and metaheuristic-based methods which is shown in Figure 7 are the major segments of hybrid optimization approaches. The considered elements introduced for attribute inspection of the two strategies consist of capabilities, drawbacks, input and output factors of fuzzy logic, rule evaluation, and setting method, defuzzification, and fuzzy logic utility.

### 3.3. Methodology-Based Clustering

In this section, methodology-based clustering consists of two sections, namely, fuzzy- and metaheuristic-based approaches. The figure provides the factors for both the fuzzy and metaheuristic algorithms.

#### 3.3.1. Fuzzy-Based Approaches

This section provides factors that are used by the fuzzy-based approaches and it is shown in Figure 8. To portray each attribute of a fuzzy system, a few factors are considered in reviewed protocols,

such as the principle of FL, capacities, fuzzy input and output factors, rule evaluation, capabilities, and limitations.

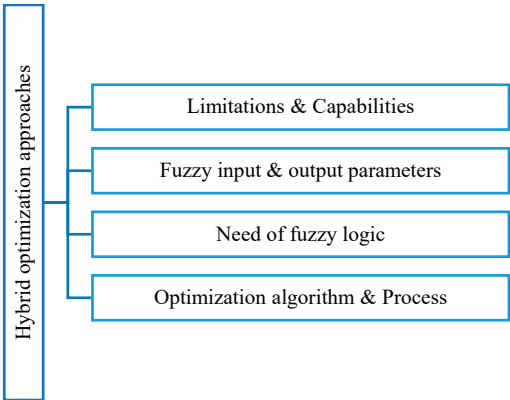


Figure 7. Hybrid optimization approaches.

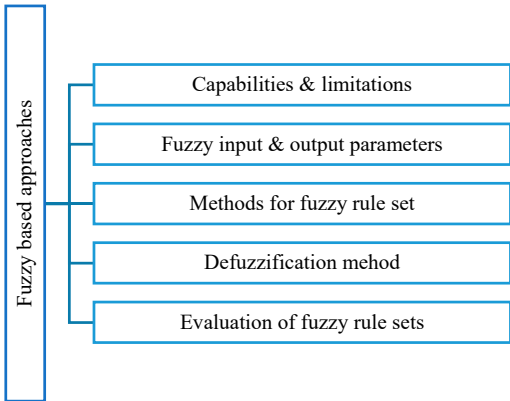


Figure 8. Fuzzy-based approaches.

3.3.2. Metaheuristic-Based Approaches

This section examines the elements measured in metaheuristic-based methodologies that are introduced in this section and shown in Figure 9 for explaining the procedures, such as capabilities, constraints, factors concentrated in the protocols addressing ways to develop optimization algorithms, processes, reasons, and simulation environment, used in the earlier developed works.

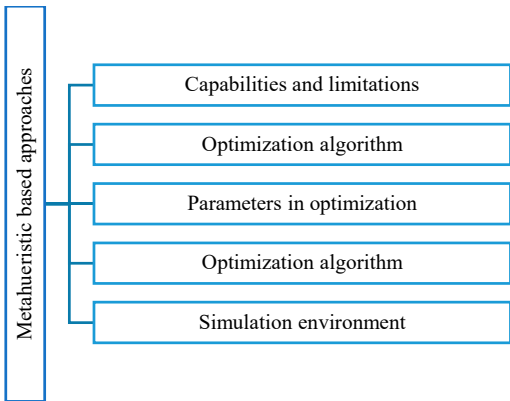


Figure 9. Metaheuristic-based approaches.

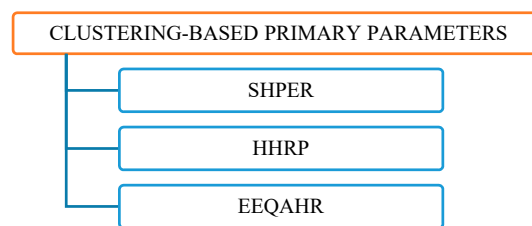
#### 4. Classification of Cluster-Based Routing Protocols

The choice of clustering method is very important for the WSN in order to fulfill its requirements, such as power utilization and reduction in energy consumption. Numerous strategies and calculations have been introduced for this reason in different classifications as mentioned in previous sections.

This section explains all the described classifications in Section 3.

##### 4.1. Parameter-Based Clustering

This section is divided into the primary parameter- and secondary parameter-based clustering, which is explained in the next sections and is shown in Figure 10.



**Figure 10.** Clustering protocols based on primary parameters.

##### 4.1.1. Clustering-Based Primary Parameters

###### SHPER: Scalable Hierarchical Power-Efficient Routing

Kandris (2011) introduced a new routing methodology known as scalable hierarchical power-efficient routing (SHPER), and perceived QoS-aware video routing (PEMuR) is a combination of video scheduling and energy-aware hierarchical routing mechanisms. Generally, based on the residual energy, CH is selected during the initial phases. There are two levels of CH, namely, lower- and upper-level CHs. Lower-level CH is far away from the BS, whereas upper-level CHs are close to the BS. From the residual and required energy, the routing index can be derived to transmit the information among sequential CHs [67].

###### HHRP: Heterogeneous Hierarchical Routing Protocol

Kim (2011) proposed a heterogeneous hierarchical structure that utilizes control and delivery paths between the BS and sensing hub. Multimedia data are generally transmitted via a delivery path between the sensing hub and BS with the help of a relay hub. Relay hubs are generally dependent on bandwidth, distance, and residual energy. A single relay hub for the delivery path can prevent congestion in the network. However, command paths can easily overlap with the relay hubs due to small data when compared with the actual data. Security keys are also used in this protocol to fight against attackers. While establishing the delivery path, recovery steps and isolation influences affect existing delivery paths, which basically increment intricacy and time [68].

###### EEQHR: Energy-Efficient QoS Assurance Hierarchical Routing

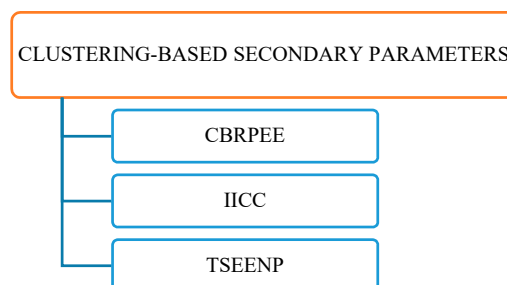
In 2011, Lin introduced energy-efficient QoS assurance hierarchical routing (EEQHR) for WMSNs. In this method, the relay hub is chosen based on the data correlation coefficient, residual energy, trust value, and hop count of a hub neighboring CH. The above-mentioned factors are stored by every node for the optimization factor table. A data correlation coefficient is used for combining information in order to diminish the measure of information transmission. The idea of a trust value metric can be obtained from an informal community investigation in which trust esteem is evaluated by checking legitimacy or by the implication of present and past conduct of neighboring hubs. After each round, the cluster structure is changed by offering portability to the CH, which maintains a strategic distance from producing system gaps and equalizing energy utilization. The proposed method prolongs the



network lifetime; however, its reliance on high transmission power level may cause an obstruction in the nearby hubs [69].

#### 4.1.2. Clustering-Based Secondary Parameters

This section describes secondary parameters and it's shown in Figure 11.



**Figure 11.** Clustering protocols based on secondary parameters.

##### Cluster-Based Routing Protocols for Energy Efficiency (CBRPEE)

Maimour (2014) presented another characteristic of a clustering procedure from the perspective of the data routing procedure. Node energy consumption management is very essential for maximizing the overall network lifetime. Load balancing techniques and global management systems are needed for prolonging the lifetime of the WSN. Clustering methodologies need to provide optimal traffic distribution in addition to low overhead CH rotation among all CHs, and the selected method should maintain network coverage and connectivity. Unequal clustering, in which intra- and intercluster communications (IICC) are known to be exceptionally encouraging, can occur. Be that as it may, viable methods should be created to manufacture such clusters without information on global network topology. For significant clustering, estimation of optimal parameters is highly essential; however, it is not a simple task in WSN because of its constraints [70].

##### IICC: Intra- and Intercluster Communication IICC

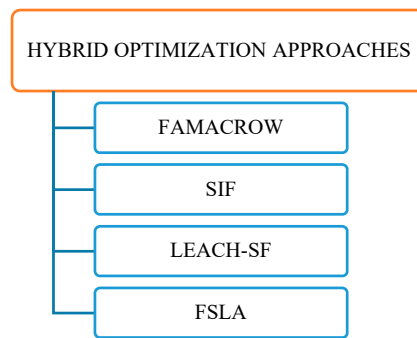
In a study by Goyal (2016), the use of IICC for underwater WSN (UWSN) to aggregate the data was proposed. This framework provides an ideal choice for CH in which optimal IICC depends on multipath and energy. The proposed work efficiently increases the system performance by improving the results of the following parameters, such as packet delivery ratio, energy efficiency, and delay; hence, the method is adaptive for many systems [71].

##### TSEENP: Threshold Sensitive Energy-Efficient Network Protocol

Samant (2017) presented a cluster reactive protocol known as the threshold sensitive energy-efficient network protocol (TSEENP), which is especially intended for critical application of time. As various hubs are required for cooperative communication, this protocol could be utilized for cluster formation. To examine the low-energy path for the clusters and hubs, vector quantization (VQ) is used. For primary issues of intra- and interclass communication, the TSEENP and TSEEN Vector Quantization Protocol (VQP) can be used, respectively [72].

#### 4.2. Optimization-Based Clustering

This section is divided into classical and hybrid optimization approaches, which are explained below and shown in Figure 12.



**Figure 12.** Hybrid optimization-based routing protocols.

#### 4.2.1. Classical Approaches

Classical approaches mainly concentrate on CH selection. Some of the methods are discussed and analyzed and it's given in Table 1.

**Table 1.** Classical optimization-based routing protocols.

| S. No. | Names of Algorithms | Energy Consumed | Energy Efficiency | Network Delay | Network Throughput | Network Loss | Overall QoS |
|--------|---------------------|-----------------|-------------------|---------------|--------------------|--------------|-------------|
| 1      | LEACH [28]          | Moderate        | Moderate          | Moderate      | Moderate           | High         | Moderate    |
| 2      | TL-LEACH [73]       | Low             | High              | Moderate      | High               | Moderate     | Moderate    |
| 3      | T-LEACH [74]        | Low             | High              | Moderate      | High               | Moderate     | High        |
| 4      | DS-LEACH [75]       | Low             | High              | Moderate      | High               | Low          | High        |
| 5      | LEACH-EP [76]       | Low             | High              | Moderate      | High               | Moderate     | Moderate    |
| 6      | LEACH-DT [77]       | Low             | High              | Moderate      | High               | Moderate     | Moderate    |
| 7      | LEACHSWDN [78]      | Low             | High              | Moderate      | High               | Low          | Moderate    |
| 8      | MODLEACH [79]       | Moderate        | Moderate          | Moderate      | Low                | Low          | High        |
| 9      | MECH [80]           | Low             | High              | Moderate      | High               | Moderate     | Moderate    |
| 10     | PECRP [81]          | Low             | High              | Moderate      | High               | Low          | High        |
| 11     | EEHC [82]           | Low             | High              | Moderate      | High               | Low          | High        |
| 12     | FBR [83]            | High            | Low               | Moderate      | Low                | Low          | High        |
| 13     | EERA [84]           | High            | Low               | Moderate      | Low                | Low          | High        |
| 14     | LCRPOCH [85]        | Low             | High              | Moderate      | Low                | Moderate     | Moderate    |
| 15     | LEFCA [86]          | Low             | High              | Moderate      | Low                | Moderate     | Moderate    |
| 16     | HEER [87]           | Low             | High              | Moderate      | Low                | Low          | Moderate    |
| 17     | HDMC [88]           | Moderate        | Moderate          | Moderate      | Low                | Low          | Moderate    |
| 18     | EAMR [89]           | Low             | High              | Moderate      | Low                | Low          | Moderate    |

#### LEACH: Low-Energy Adaptive Clustering Hierarchy

LEACH is known to be the first dynamic protocol and considers WSN requirements. This method generally utilizes randomly distributed motionless sensor nodes and is known to be a basic protocol for other advanced clustering protocols. LEACH is a distributed, hierarchical, one-hop, probabilistic protocol. In 2007, Zhixiang presented a protocol called TL-LEACH that consists of three useful stages namely, cluster head selection, settings, and data transfer. In the CH determination stage, the main level CHs are chosen randomly based on the threshold value,

$$R(i) = \begin{cases} (q+1) \times \text{mod}\left(\frac{1}{s}\right) \times s & \text{if } i \in G \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

In which

$s$  → Expected percentage of CH nodes in the population of sensors;

$q$  → Current round number;

$G$  → Group of hubs which never transform into CHs in the last  $1/s$  adjusts (turns).

At that point, the second-level CHs are chosen from the principal level CHs depending on energy. Initially, non-CH hubs become individuals from the principal level CHs. Next, the main level CHs become individuals from the second-level CHs in a process that is dependent on a brief separation. At long last, non-CH hubs transmit data to the principal level CHs during the data transfer phase. At that point, the principal level CHs transmit the aggregated information to the second-level CHs, which generally transmit the information to a BS [73].

In 2008, Hong introduced the concept of T-LEACH which is mainly based on the threshold values for cluster head selection and reallocation of the CH. T-LEACH aims to reduce the CH replacement count by using the residual energy of the network. The results improved energy efficiency when compared with earlier models. This protocol performs better than the general LEACH protocol [74].

Bagherzadeh (2009) introduced a density of sensor (DS)-LEACH protocol, which has setup and steady-state phases. The main functions of the setup phase are to introduce CH based on the density of hubs, scheduling based on time-division multiple access (TDMA), set-up the cluster, and show advertisements. This protocol mainly calculates the probability of becoming a CH. In the second phase, each hub that is not transformed into a cluster head chooses which cluster it should join and relies upon most received signal power. If the node is selected as a cluster head, the membership message is then sent to that cluster head. The remaining steps are like the LEACH protocol [75].

Jia (2010) presented the low-energy adaptive clustering hierarchy energy protocol (LEACH-EP). In this method, which is based on node energy, the CH can be selected for every node as done in the LEACH protocol. The main difference between the LEACH and LEACH-EP protocols is the threshold energy, which can be calculated with the help of residual energy in the current round, whereas average energy can be calculated in the previous round [76].

A study by Kang (2012) presented the low-energy adaptive clustering hierarchy with distance-based threshold (LEACH-DT) protocols for CH selection. In this protocol, the distance among CH and BS can decide the probability of the hub to become a CH or not. The LEACH-DT is like the LEACH protocol, but the distinction lies in the great level of the number of CHs(pi) as determined by the formula shown below:

$$R(i, q) = \begin{cases} \frac{s}{1-s \times (q \bmod (\frac{1}{p_1}))} & G_i(q) = 0 \\ 0 & G_i(q) = 1 \end{cases} \quad (2)$$

In which

$G_i(q) \rightarrow$  Binary to confirm CH only once for all  $\frac{1}{s_i}$  of the rounds.

Equation (2) shows that CHs are selected by a distributed randomized function. Time is divided into rounds denoted as  $q$ . In every round  $q$ , the node  $i$  elects itself to become CH using the probability function given in Equation (2).

$$S_i = k(\varepsilon_i / (\sum_{i=1}^N \varepsilon_i)) \quad (0 \leq s_i) \leq 1 \quad (3)$$

$$\varepsilon_i = \left( \frac{1}{E_{CH}} \right) \times (d_i) - E_{non-CH} \quad (4)$$

In which

$d_i \rightarrow$  Distance among hubs and BS;

$E_{CH}$  and  $E_{non-CH} \rightarrow$  Residual energy of CH and non-CH nodes.

Equations (3) and (4) explain the energy consumption and  $S_i$  provides balanced energy consumption, respectively. The balanced equation for the expected energy expense can be constructed using Equations (3) and (4).

This protocol uses direct and multihop transfers to send a message from the CH to the BS [77].

Wang (2012) presented a protocol called LEACH with a sliding window dynamic number (LEACH-SWDN) consisting of setup and steady-state phases. Initially, in the setup phase, each hub starts its current round in order to select the random number before the process from the sliding window is refreshed. This number cannot be chosen between 0 and 1 as it is expected to be dynamic. With respect to the performance of the network, the number may change. In the second phase, this protocol works as the same found in the LEACH protocol. Once the data is collected by the BS, the average energy calculation of each node is performed by the BS. This process is also used to increase energy efficiency in a significant way [78].

Amodu (2018) improved the LEACH protocol to produce an effective CH replacement method, which uses dual transmission power levels in order to amplify the transmitted signals. In this situation, when a hub turns into a CH, it uses high force enhancement, and when it is a non-CH hub, it uses low force intensification. This method utilizes the CH exchanging component that is dependent on the limit with the goal that the CH will continue to work well and not vary when the CH energy is higher than the threshold value. In any case, another CH is chosen, and the bunches are reshaped [79].

#### Maximum Energy Cluster Head (MECH)

Chang proposed a routing protocol called the maximum energy cluster head (MECH). This protocol has properties of a hierarchical tree and self-configuration. It improves the LEACH protocol from a few perspectives. MECH generally forms clusters that are dependent on the node count of the cluster child and coverage area. This protocol has a randomly distributed topology in addition to a hierarchical routing model for reducing the distance between the BS and CH [80].

#### Power-Efficient Clustering Routing Protocol (PECRP)

The author Liu proposed the power-efficient clustering routing (PECRP) protocol, which is utilized for significant distances and complicated data transfer for static hub-based networks. This protocol is the improved version of the LEACH protocol and is mainly used for CH selection. The system is based on multihop transmission with a combination of the circle domino effect. The major advantage of this model is the reduction in network delay that results in the maximization of the network's lifetime [81].

#### Energy-Efficient Heterogeneous Clustering (EEHC)

Kumar (2009) presented the energy-efficient heterogeneous clustering (EEHC) protocol, which is subdivided into three hub forms: (1) ordinary, (2) propelled, and (3) super hubs. This convention incorporates two stages. In the setup stage, each progression looks precisely like those of the LEACH protocol. The main distinction is the use of three hub forms with three diverse energy levels. For CH selection, a weighted probability is used for the underlying energy of the hubs in contrast to the other protocols. This weight should be equivalent to the proportion of each hub's initial energy to the underlying energy of ordinary hubs. The threshold value is also used for CH selection [82].

#### Flow-Balanced Routing (FBR)

A study by Tao (2013) introduced the flow-balanced routing (FBR) protocol to accomplish both coverage preservation and power efficiency for multihop WSNs. These protocols use four main algorithms: (1) rerouting, (2) multihop backbone construction, (3) network clustering, and (4) flow-balanced transmission. Sensors hubs are chosen to form clusters without any sensor overlap in the available network with the help of clustering algorithms. Multilevel backbone construction is done via a backbone clustering algorithm using sinks and CH although it may not be a tree. To normalize energy consumption, data are transferred via the multipath hop from the sensor hub to the sink using the FBR algorithm. Finally, this protocol is assessed by two matrices, known as network and coverage lifetime. The FBR protocol outperforms in both matrices when compared with other protocols [83].

### Energy-Efficient Routing Algorithm (EERA)

Yin presented a novel approach, namely, the energy-efficient routing algorithm (EERA) that mainly focuses on expanding the network lifetime. The protocol has several subsections: (1) greedy algorithm for packet forwarding, (2) intracluster, and (3) an intracluster algorithm. These concepts are extremely applicable to high-density-based networks. By using this model consumption of energy during the data transfer between the source to the destination, energy consumption is greatly reduced, and the network's overall performance is improved [84].

### Layered Clustering Routing Protocol with Overlapping Cluster Heads (LCRPOCH)

In a study by Agrawal, a novel method called layered clustering routing protocol with overlapping cluster heads (LCRPOCH) with five stages was developed. In the first stage, sensors with a unique identification (ID) are distributed. In the second stage, the whole network can be split into constant cluster sizes. CH evaluation is done, and it forms layers in the third stage. The CH node can be selected based on the density and proximity of hubs. The next stage assesses and allocates CH overlapping. In the last stage, information is transferred to BS via CH in addition to CH overlap [85].

### Low-Energy Fixed Clustering Algorithm (LEFCA)

Cengiz (2015) introduced a protocol called the low-energy fixed clustering algorithm (LEFCA). In this protocol, the clusters are constructed in the setup phase itself. Sensor hubs in the cluster will remain the same for the entire transmission. This protocol generally uses the clustering methodology by apportioning the hubs into fixed clusters. CH gathers all the information from the child node, which will then transmit to the BS. The main point to be noted in this protocol is to decide whether the CH will remain as a CH after completion of data transfer; this process is decided by the CH residual energy [86].

### Hamilton Energy-Efficient Routing Protocol (HEER)

A study by Yi (2016) introduced the Hamilton energy-efficient routing (HEER) protocol with the idea of a Hamiltonian path. This protocol uses data aggregation that can be sent through a Hamiltonian path formed by whole CHs, and the protocol controls the size of the cluster by choosing CH hubs. For the first round only, the cluster can be created. For different rounds, CH cannot be changed; instead, the CH roles may change based on energy in the Hamiltonian path after a predetermined time period [87].

### Hierarchical Distributed Management Clustering (HDMC)

In 2016, Shahraki presented the Hierarchical Distributed Management Clustering (HDMC) protocol for energy efficiency enhancement, coverage area lengthening, and fair distribution of energy consumption between nodes. Previous node records and current resources are used for CH selection. Bethatasit may, since a hub does not recognize neighboring hubs and their aim is to turn into a CH, a novel authority section is appointed for CH selection. This section helps the network select the CH based on earlier rounds and hubs in its degree to transmit its inclination data [88].

### Energy-Aware Multihop Routing (EAMR)

Cengiz (2017) introduced a protocol called the Energy-Aware Multihop Routing (EAMR) protocol. In the setup phase of this protocol the CHs, their individuals, and there-distributor hubs are allotted so that from the outset every hub can randomly pick itself as a CH. Those distributor hubs are selected by the CH hub, so basically it will select the neighbor CH hub as its redistributor hub. This stage is performed just a single time toward the start of the EAMR. In the steady-state phase, the major processes are the transmission of the gathered information, CH reallocation, and redistributor hub selection [89].

#### 4.2.2. Hybrid Optimization Methodologies

Hybrid optimization methodologies are a combination of fuzzy logic and metaheuristic algorithms. Recently developed approaches for these hybrid optimization techniques are described below and shown in Figure 12.

##### Fuzzy and Ant Colony Optimization-Based Combined MAC, Routing, and Unequal Clustering Cross-Layer Protocol for WSNs (FAMACROW)

Gajjar introduced a protocol, called the fuzzy ant-colony-optimization-based combined media access control (MAC), routing, and unequal cross-layer protocol for WSNs (FAMACROW), for layering network nodes. This protocol has CH selection, clustering, and intercluster routing. CH inputs are residual energy, quality of communication, and neighboring hub count. As needed, each hub executes a feature info service (FIS) and calculates fuzzy yield by the name of Proficiency. The hub with the most noteworthy capability will turn into a CH in the assigned space. To prevent hot spot problems, unequal clustering is utilized in this protocol. This convention profits from ACO for data directing among groups and transmission to the BS [90].

##### Swarm-Intelligence-Based Fuzzy Routing Protocol (SIF)

Zahedi introduced a sensor intelligence routing (SIR) protocol based on the fuzzy-c-mean (FCM) protocol. FIS is used to select CH based on fuzzy parameters, such as distance from the BS, residual energy, and distance from the center of gravity in addition to the fuzzy outputs. In this convention, Mamdani's standards FIS table is advanced before beginning the system tasks by consolidating the Firefly Algorithm (FA) and the SA calculations dependent on a target work that has been characterized for application [91].

##### Centralized Cluster-Based Routing Protocol Based on Sugeno Fuzzy Inference System (LEACH-SF)

Shokouhifar provided a centralized cluster-based routing protocol based on Sugeno Fuzzy Inference System (LEACH-SF) protocol for WSN. FCM is utilized for balanced cluster formation in order to select an appropriate cluster Sugeno fuzzy system. Sugeno fuzzy systems use local sensor information. Since tuning the fuzzy standards inside the framework is the most significant issue, it has a key role in the activity of LEACH-SF. ACO is used to upgrade the Sugeno fuzzy principles. The improvement method should be performed once before the LEACH-SF is put into action. Reproduction results showed that LEACH-SF can proficiently frame balance groups and augment organized lifetime. The proposed clustering method was intended for the systems with fixed sensor hubs. The main distinction is that LEACH-SF profits by the Sugeno-type FIS rather than Mamdani's derivation strategy in SIF. What is more, the artificial bee colony (ABC) calculation was used to advance the Sugeno-type fuzzy principles table [92].

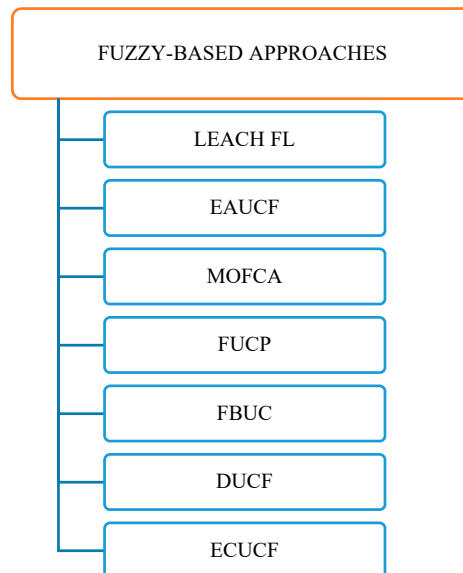
##### Fuzzy Shuffled Frog-Leaping Algorithm (FSFLA)

Fanian presented a fuzzy shuffled frog-leaping (FSFLA) algorithm, which uses a shuffled frog-leaping algorithm (SFLA) to streamline the Mamdani fuzzy standard-dependent application. This protocol uses four inputs for the fuzzy frameworks: (1) node histories, (2) neighboring node count, (3) remaining energy, and (4) distance from BS. The capacity of hubs to be selected as CHs is resolved after considering a trade-off between the significant parameters about hub conditions and their upgraded fuzzy standards. This protocol uses two specified thresholds to choose an applicant hub as a CH. The convention can be balanced by the application as a result of having two decided thresholds for turning up-and-comer hubs to the last CHs [93].



### 4.3. Methodology-Based Clustering

This section is divided into fuzzy- and metaheuristic-based methodologies, which are explained below and are shown in Figure 13.



**Figure 13.** Fuzzy-based approaches.

#### 4.3.1. Fuzzy-Based Approaches

Due to uncertain incidents occurring in the WSN environments and overlapping parameters affecting the roles of CHs, many protocols use fuzzy logic for clustering and selecting appropriate CHs. A number of these algorithms are discussed here.

##### LEACH Protocol Using Fuzzy Logic (LEACH-FL)

Ran (2010) presented the LEACH protocol using FL (LEACH-FL). In this protocol, CH selection is done with the help of fuzzy logic. This protocol is known to be an improved adaptation of the LEACH protocol with respect to info factors of the fuzzy BS distance, residual energy, and node probability to become CH. This convention uses a dispersed clustering procedure, and choosing CHs depends on fuzzy yields similar to LEACH. One-hop communication is used to transfer the data from CH to BS [94].

##### Energy-Aware Unequal Clustering Algorithm with Fuzzy (EAUCF)

In 2013, Bagci introduced an energy-aware unequal clustering algorithm with fuzzy (EAUCF), which addresses the hot spot issue. The EAUCF protocol diminishes the intragroup work of the CH that is either near the BS or has low residual battery power. A fuzzy logic approach was adopted to deal with vulnerabilities in CH range estimation. Results show that EAUCF performs better than different calculations with respect to the first hub biting the dust, half of the hubs being alive, and energy productivity measurements in all situations. Hence, EAUCF is a stable and energy proficient clustering algorithm to be used in any WSN application [95].

##### Multiobjective Fuzzy Clustering Algorithm (MOFCA)

Sert (2015) proposed the multiobjective fuzzy clustering algorithm (MOFCA) which is not just for energy proficient but is also conveyance-free for WSNs. This algorithm considers remaining vitality levels, separation to the sink, and density parameters in the computation of the CH rivalry range while using fuzzy logic for overcoming WSN vulnerabilities. As for assessments, this algorithm is more

energy efficient. As expressed in the framework model, MOFCA incorporates fixed or portable hubs. In any case, this portability is reproduced by the change in the area of hubs without causing energy utilization. According to the assessment, MOFCA is much better than the existing calculations during the analyses done during this investigation [96].

#### Fuzzy-Based Unequal Clustering Protocol (FUCP)

In 2015, Gajjar 2015 presented the fuzzy-based unequal clustering protocol (FUCP) for remote sensor systems. In this protocol, the cluster selection uses fuzzy logic and is performed based on residual energy, quality of communication, and is centerless with respect to its neighbor. This protocol uses an unequal clustering approach mainly to remove the hot spot problem. Comparative analysis done with existing protocols and results shows that the FUCP is 40% more energy-efficient, ends 57% more packets to the BS, and extends network lifetime by 31% [97].

#### FL-Based Unequal Clustering (FBUC)

Logambigai (2016) presented a fuzzy logic-based unequal clustering algorithm. Here, the regular CHs of each hub are first decided randomly. Second, the regular CH uses fuzzy logic based on three parameters (distance to BS, leftover energy, and hub degree) to decide the span of the series. At that point, the last CHs would be the hubs with the most extreme fuzzy yield in their space. From that point on, the hubs use the logic and sources of info to compute the opportunities. In the final stage, the CH selection is done with the largest fuzzy yields [98].

#### Distributed Unequal Clustering Using FL (DUCF)

Baranidharan (2016) contributed another clustering algorithm called the distributed unequal clustering using fuzzy logic (DUCF). Unequal clustering is used for load balancing of nodes. The fuzzy inference FIS structure in DUCF uses the leftover energy, hub degree, and separation from the base station as information for the processing of CH selection. Load adjustment forms the core idea of this protocol, which is processed by the fluctuations in the group size of the CH hubs. This protocol also uses the Mamdani technique for fuzzy deduction and centroid strategy for defuzzification. The major advantages of this protocol are an improved network lifetime and load balancing capacity [99].

#### Energy Conserved Unequal Clusters with Fuzzy Logic (ECUCF)

A study by Sundaran (2017) proposed a protocol (energy conserved unequal clusters with fuzzy logic (ECUCF)) aimed at reducing hot spot problems and enhancing energy efficiency. To expand the lifetime of the system and increment energy proficiency of the WSNs, areas are framed relying upon the hubs' adequate separation from the BS. Node proximity, residual energy, and distance from the BS are considered for CH selection. The major advantages of this protocol are improvements in the number of clusters, expansion of the coverage area, and enhancement of the hub's energy efficiency [100].

### 4.3.2. Metaheuristic Methodologies

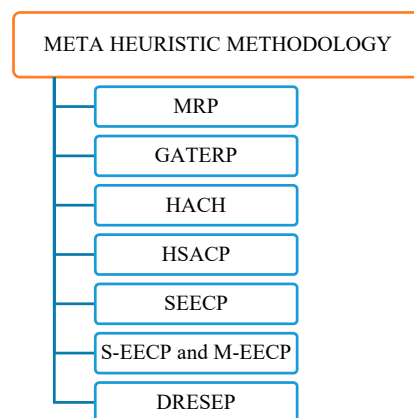
Figure 14 discusses about the different Metaheuristic methodologies available and each methodology is discussed in detail below.

#### Multipath Routing Protocol (MRP)

In this study, the author proposed an ACO-based multipath routing protocol (MRP) for reactive WSNs. While designing this algorithm, WSN characteristics are considered, such as limited energy sources. Based on the residual energy MRP selects CH. The ACO algorithm is applied for multipath routing among CHs and sink nodes. These algorithms outperform other networking protocols in terms of prolonging network lifetime and energy efficiency [101].

### Genetic Algorithm-Based Threshold Sensitive Energy-Efficient Routing Protocol (GATERP)

Mittal (2018) proposed the genetic algorithm-based threshold sensitive energy-efficient routing protocol (GATERP) for basic time applications. In this protocol, CH is chosen based on genetic algorithm-based parameters, such as cluster division and cohesion. The protocol utilizes an intercluster data transmission algorithm for the lifetime network increment. In order to improve load balancing capabilities, GA-based multihop communication is presented as it reduces energy consumption. Network performances have been measured in terms of energy consumption and energy efficiency [102].



**Figure 14.** Metaheuristic methodologies.

### Heuristic Algorithm for Clustering Hierarchy (HACH)

In 2017, Oladimeji proposed the heuristic algorithm for clustering the hierarchy (HACH). For every round, the selection is based on both CH and active hubs. Inactive hub selection uses a stochastic sleep scheduling system to decide the choice of hubs that can be placed into rest mode without unfavorably influencing system inclusion.

A clustering algorithm can use the novel heuristic hybrid operator to combine two unique answers to accomplish an improved arrangement that upgrades the appropriation of CH hubs and coordinates energy use in WSNs. This protocol improves network performance in terms of an extended lifetime under various energy heterogeneity settings [103].

### HSA Cluster-Based Protocol (HSACP)

Hoang (2014) introduced the harmony search algorithm (HSA) algorithm. This algorithm can significantly minimize the distance among cluster members and CHs for the purpose of energy optimization. This protocol is utilized in a real-time environment. Comparative analyses have been made with known cluster protocols, such as the LEACH and Fuzzy C Means protocols. The HSA protocol outcome shows that it can be used for centralized cluster-based WSN, especially in emergency environments [104].

### S-EECP: Stable Energy-Efficient Clustering Protocol

In 2016, Mittal proposed the stable energy-efficient clustering protocol (S-EECP) in which residual energy is used for CH selection. This protocol generally reduces inappropriate load balancing. The dissipation of energy in CH can be reduced with the help of an intercluster data transmission algorithm. The dual-hop communication concept is used to reduce energy consumption. This protocol outperforms other existing algorithms in terms of stability period, energy values, and load balancing. Node mobility is a significant point for WSN, which is not considered in this protocol [105].

### Single-Hop Energy-Efficient Clustering and Multihop Energy-Efficient Clustering Protocols (S-EECP and M-EECP)

Kumar (2013) proposed the single-hop and multihop energy-efficient clustering protocols (S-EECP and M-EECP, respectively). For S-EECP, the weighted probability is used for CH selection. This probability relies upon the proportion among the network's average and hub's residual energies. Energy is the primary factor for CH selection. In this situation, the hub, which has more residual energy than the network, is chosen as the CH. In the case of M-EECP, collected data can be sent to the BS via multihop communication [106]. Three types of sensors with various battery levels are used to assess network lifetime. This method has been compared with many earlier methods, and the results prove that it performs better than those methods in terms of energy efficiency and load balancing [106].

### Distance-Based Residual Energy-Efficient Stable Election Protocol (DRESEP)

Mittal (2015) proposed a distance-based residual energy-efficient stable election protocol (DRESEP) protocol for an event-based data collection model. The aim of these algorithms is to send collected data from sensor nodes to the CH, which rely on perceived changes [107]. In order to accomplish energy minimization, dual-hop communication is used. It surpasses the other existing protocols in terms of network lifetime and optimization [108–110].

## 5. Conclusions

A major powerful solution for maintaining the energy efficiency of a sensor network is via energy constraints of sensor hubs and the functionalities of the clustering model. In this review, the current protocols and algorithms are analyzed. Those protocols are classified into parameter-, optimization-, and methodology-based clustering. Primary and secondary parameters in terms of clustering features are considered. At this point, every class of techniques was assessed and examined by the introduced parameters. With the end goal of providing valuable data and motivating researchers, this appraisal expects to present another viewpoint and a beginning stage for investigative techniques by considering classified approaches for easy comprehension of inadequacies in the procedures. In the future, we plan to extend this work into different fields of WSN, for example, body area network, battery-powered sensor systems, and mobile sink planning.

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