



# Cluster Head Election in Wireless Sensor Network: A Comprehensive Study and Future Directions

Rekha

Department of Computer Science and Applications, Maharishi Markandeshwar (Deemed to be University), Mullana (Ambala), India.

rekha\_dalia@yahoo.com

Rajeev Gupta

Department of Computer Science and Engineering, Maharishi Markandeshwar (Deemed to be University), Mullana (Ambala), India.

rajeev.gupta@mmumullana.org

Published online: 25 December 2020

**Abstract** – Due to the advancement of wireless communication interchanges, electronic technology, and micro-electro-mechanical devices, Wireless Sensor Network (WSN) has got advanced as a promising zone of research. WSN consists of a collection of sensor nodes having a little calculative capability, limited memory, and constrained energy assets. Clusters are formed from the collection of sensor nodes whose leader node (Cluster head) can send the sensed information from hubs to the BS. To condense the power consumption and boost group longevity, the cluster head executes data accumulation. This paper discusses many algorithms based on deterministic, probabilistic, adaptive, fuzzy logic, and Multi-attribute decision-making techniques for clustering and cluster head election. Existing algorithms enhance the network lifetime and energy efficiency but fail to provide a better quality of service and security. So many issues and challenges have been laid down and it is concluded that when computational intelligence is combined with network intelligence then QoS and security both can be provided along with the network longevity and energy efficiency in homogeneous as well as a heterogeneous environment.

**Index Terms** – Wireless Sensor Network (WSN), Deterministic Schemes, Adaptive, Schemes, Probabilistic Schemes, Multi-Attribute Decision Making Schemes (MADM), Fuzzy Based Cluster Head Election Schemes.

## 1. INTRODUCTION

The last few epochs have witnessed a tremendous progression in the field of wireless communications, embedded systems, and “Micro-Electro-Mechanical Systems(MEMS)” [1]. These systems have led to the development of small size objects having an on-board processor, limited memory, storage, battery, and multifunctional capabilities called sensor nodes. These hubs are sent in a topographical zone empowering them to impart and coordinate with each other to monitor the environment. A “Wireless Sensor Network (WSN)” is a communication framework that comprises several of these geographically scattered autonomous sensor nodes which are

densely deployed in a region to be checked [2]. They have the capability of sensing, gathering, analyzing, and detecting ambient conditions. The sensed information is additionally shipped off the base station (BS) or sink node for investigation and storage which also acts as a gateway to send data to the server [3]. Sensor nodes and wireless communication have helped in many application areas like military, hospitals, environment, home, Internet of things (IoT), and many other commercial applications[1, 2, 4].

### 1.1. Problem Statement

Sensor nodes have constrained energy resources, which can influence the stability and network longevity. Many energy-efficient procedures and methods have been lodged in the literature to boost the life of the network. One of the key methods to achieve network longevity and energy efficiency in WSNs is clustering [5, 6] in which nodes are gathered to shape a zone or group and one hub is assigned as bunch head or cluster head which can communicate with BS so that energy can be conserved as shown in Figure 1. There is always a requirement to select an efficient cluster head as to boost the network durability.

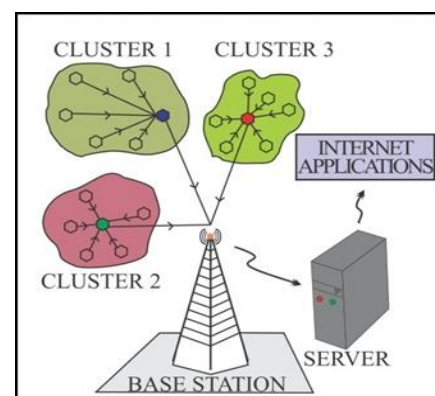


Figure 1 Wireless Sensor Network

**REVIEW ARTICLE**

1.2. Motivation

Phenomenal development in WSN in varied spheres which range from medical services to military applications and also assume a notable role in different areas viz. Safety, security, ecological, agriculture, engineering control, surveys, etc. [7] and further limitation imposed due to the power constraint of nodes has arisen the interest of many prospective researchers [8].

These expansions in WSNs have engrossed the attention of researchers to plan various algorithms/protocols considering safety, security, QoS, and energy constraints [9]. The profusion of exploration has reported the clustering aids in load balancing among the nodes so that the energy exploitation is accustomed between them [8].

Wireless Sensor Networks comprises small hubs called sensors which have the capability of sensing, analyzing, gathering, actuating, and identification to form a network that achieves some shared objectives [10]. This property of sensing has also led to many other real-life applications to make ambient intelligent [6]. The possibility to interact with the real physical world ubiquitously by using the underlying framework of middleware and communication protocols has led to constitute an innovative paradigm called an Internet of Things (IoT) [11] as shown in Figure 2. The IoT application domain can be classified into a centralized or distributed approach [12].

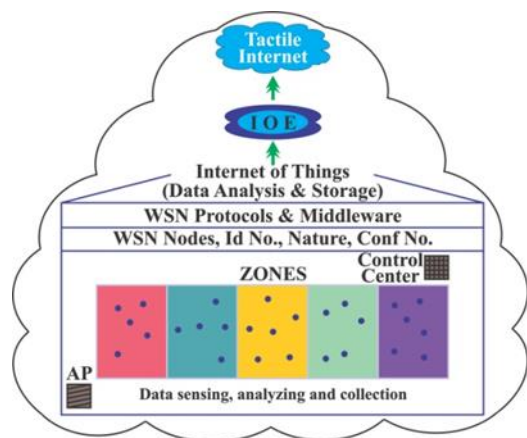


Figure 2 WSN as a Backbone for IoT

1.3. Objective

The fundamental objectives of this paper are to present an exhaustive survey on cluster head selection techniques in WSNs focusing on the basics of clustering and methods used to select cluster head being used. Current research has been critically reviewed to identify the issues in the existing literature and based on the same futuristic proposed model to consider random cluster head election and super cluster head election.

1.4. Clustering: Basic Concepts

Due to constrained energy resources in WSN, its performance may degrade and reduce the network lifetime. Clustering becomes important to ensure the reliability and scalability of performance in WSN. Depending upon the application requirements and characteristics of the network, nodes arranged in groups are called a cluster. Clusters consist of member nodes and a special node called cluster head. Member nodes can advance the gathered information to the CH.

Cluster formation consists of two steps:

- Network model
- CH election.

In the network model, the decision regarding the node type and network type is taken. Node type can be static or dynamic. Dynamic nodes keep on changing their position which further enhances the problem of cluster formation as it becomes difficult to maintain the cluster for a long time. Network type can be either centralized or distributed. In centralized, CH should have detailed information of network while in distributed, any node can become member or CH without the whole network information [6].

The next step involves cluster head election which can be performed using different approaches like deterministic, probabilistic, adaptive, fuzzy-based, MADM, etc.

Data is assembled by the cluster head from its cluster members using time-division multiplexing (TDMA) and then sends it to the sink over a secure channel [13]. The routing scheme can be multi-hop or single-hop or it can be designated as inter-cluster or intra-cluster routing. Cluster heads can be chosen arbitrarily from the positioned set of nodes or can be selected by following certain criteria [14]. In clustering, to reduce power consumption wake-up/sleep schedule can also help. All the nodes need not be in a wakeup state and consume energy. They can be set on snooze mode to preserve power [15].

Employing computational intelligence in clustering can enhance network efficiency by selecting stable nodes as Zonal or Cluster heads (CHs). Along with computational intelligence, recent research is incorporating network intelligence through soft computing techniques such as Genetic Algorithms [16 – 19], Neural Networks [20], Fuzzy logic [21 – 27], etc to aid in monitoring, surveillance and data gathering. In this process, a CH is heavily loaded with diverse responsibilities such as traffic analysis, data transmission, and aggregation, etc. In this manner, it devours more energy when contrasted with non-CH nodes. Either it is multi-hop or single-hop communication, CH's energy drains quickly because of the nature of its work or this uneven

**REVIEW ARTICLE**

communication load brings about an energy hole. Figure 3 illustrates the various strategies through which the cluster head can be selected.

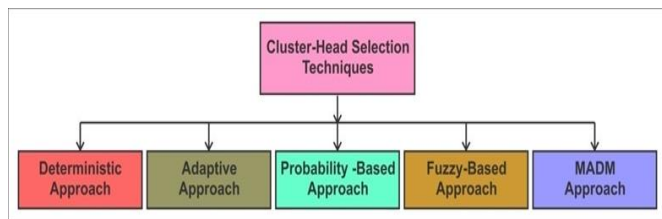


Figure 3 Cluster Head Election Techniques

They are:

- Deterministic Approaches
- Adaptive Approaches
- Probability-based Approaches
- Fuzzy based Approaches
- MADM Approaches

In the Deterministic approach, the special characteristics of sensor nodes like distance from the base station, node density, node centrality, etc. can be used for their election [28–34]. Resource information like residual energy, consumed energy in the previous round, etc. can be used in an adaptive approach. Probability-based clustering strategies assign a probability factor to each node based on its characteristics and determines the preliminary cluster heads [35–39]. In recent times, Researchers have started focusing on Fuzzy based techniques and the MADM approach for the election of optimal cluster head. In such clustering methods, many more capabilities and characteristics of the nodes are considered for cluster head election. Few strategies use an amalgamation of both the approaches are called the hybrid (Combine metric) approach.

Paper is further structured into the following main sections: - part 2 reviews cluster head election approaches based upon deterministic, adaptive, probabilistic, fuzzy, and multiple attribute decision-making approach. Section 3 includes a review and limitations of existing work. This section also discusses the comparative analysis of various cluster head election schemes proposed by eminent researchers based on parameters used, tools, CH election, CH capabilities, and issues resolved. Section 4 focuses on open issues and challenges in WSN. Section 5 includes the futuristic proposed system model and Section 6 consists of the conclusion of this paper.

**2. CLUSTER HEAD ELECTION APPROACHES**

Extensive methods and algorithms have been proposed for clustering and zonal head election in IoT based Future Sensor Networks. Most of these procedures are based on node

configuration, node-weight, hierarchical routing, residual energy, probability, traffic heterogeneity, number of nodes, and many other related metrics [40, 41]. Heinzelman et al. in [2000][13] investigated a distributed clustering protocol called LEACH “Low-Energy Adaptive Clustering Hierarchy” protocol which minimized the energy utilization by allotting load to all the sensor nodes in a zone at different points of time. This aided in falling the power dissipation and improving the network longevity. Debroy et al. in [2011][3] have employed energy cost ratio as a significant metric for cluster head election. Nodes transfer the information of power and position to the sink node for cluster formation. It helps in the reduction of energy dissipation and increases the network lifetime.

**2.1. Cluster Head Election Using Deterministic Scheme**

Some approaches use very specific and reliable metrics to select the cluster head. Such metrics are definite as they depend upon the node condition e.g. node degree, node essentiality, the distance between a node and the base station, etc. Clusters formed by such schemes are more controllable that’s why such schemes are called deterministic schemes [42].

Izadi et al. [2013][28] recommended a cluster head election approach based upon distributed type2 which considers a cluster backup method for enhancing the network. Authors have claimed better results by comparing it with fuzzy and non-fuzzy methods in terms of balancing communication uncertainty.

Thenmozhi in [2016][29] proposed an efficient energy based cluster head election scheme employing metrics like leftover power, node’s degree, node’s ability, and connection density. Simulation results have been successfully concluded with high energy efficiency.

Jia et al. in [2016][30] investigated a cluster head election method for WSNs to resolve the overlapping coverage, unstable energy by using the Voronoi diagram. The author has successfully concluded results by balancing the network node energy and increasing the network lifetime.

Aggarwal et al. in [2018][31] proposed the “fuzzy-based unequal clustering (FUCA)” method which considers competition radius and a rank parameter. The radius and rank were calculated from the remaining power, density, and reachability of the node from the base station. FUCA methods perform well as compared to LEACH by balancing energy consumption its performance isn’t influenced by node thickness and its location.

Neamatollah et al. [2018][32] proposed a clustering procedure that lessens the hot spot problem by selecting nodes with maximum residual energy in each region as candidate cluster heads using fuzzy logic. Authors have successfully verified

**REVIEW ARTICLE**

that the proposed approach was improved as far as both organization lifetime and energy preservation.

Mehra et al. in [2018][33] proposed a “fuzzy-based CH election algorithm (FBECS)” which takes into deliberation the node’s density, remnant power, reachability of nodes from the sink as parameters to Fuzzy Inference System(FIS). Considering the network stability and balancing the network load authors have successfully concluded that the proposed system helps in enhancing the network span.

Selvaraj et al. in [2014][34] employed a new parameter called the rate of recurrent communication along with remaining power, neighboring nodes number, the distance between node and BS. The approach uses fuzzy logic to evaluate election

probability, depending upon the node’s past correspondence history fix on the Cluster Head and have provided significant results.

Considering the Grid-based network Manikanthan and Padmapriya in[2019][14] have proposed efficient route selection using cluster head. Multi-stage security is implemented for all nodes in advance. The proposed method has provided better results of energy enhancement and packet delivery ratio.

Table 1 shows the relative study of various cluster head election using deterministic schemes proposed by eminent researchers based on parameters used, tools, CH election, CH capabilities, and issues resolved.

Papers	Parameters Used	Tool Used	CH Election	CH Capabilities		Issues Resolved				Results
				Node Type	Mobility	N/w Longevity	Energy Efficiency	QoS Increased	Security	
Izadi et al. [28]	<ul style="list-style-type: none"> <li>Available energy</li> <li>Node density</li> <li>Node centrality</li> </ul>	MATLAB	Type-2 Fuzzy	Homogeneous	No	√	√	√	×	Backup cluster head helps in increasing network lifetime as well as a decrease in traffic.
Thenmozhi et al. [29]	<ul style="list-style-type: none"> <li>Remaining energy</li> <li>Node’s ability</li> <li>Connection density</li> <li>Node’s degree</li> </ul>	MATLAB	Fuzzy	Homogeneous	No	√	√	√	×	The average delay reduces by 23%. Packet loss rate reduces by 11%. Throughput improved by 18%. Residual energy is better than ECSHA.
Jia et al. [30]	<ul style="list-style-type: none"> <li>Coverage</li> <li>Life cycle</li> <li>Active nodes</li> <li>Average residual energy</li> </ul>	MATLAB	Fuzzy	Homogeneous	No	√	√	×	×	Network lifetime increased by 50% and 30% in comparison with LEACH, DEEC. Improvement in Residual energy.
Aggarwal et al.[31]	<ul style="list-style-type: none"> <li>Distance to the base station,</li> <li>Residual energy,</li> <li>Node density</li> </ul>	MATLAB	Fuzzy	Homogeneous	No	√	√	×	×	Remaining Energy enhanced by 185.88% and 35.75% as compared to LEACH and EAUCF.
Neamatollah et al.[32]	<ul style="list-style-type: none"> <li>Remaining Energy</li> <li>Degree of node</li> <li>Distance to BS</li> </ul>	MATLAB	Fuzzy	Homogeneous	Yes	√	√	×	×	Network lifetime improved by 30% Clustering overhead was reduced by 56%. Energy conservation by 12%.
Mehra et al.[33]	<ul style="list-style-type: none"> <li>Remnant Power</li> <li>Base station’s distance</li> <li>The density of the node</li> </ul>	MATLAB	Fuzzy	Homogeneous	No	√	×	×	×	Network lifetime increased by 13.47% in comparison with LEACH 11.38% with BCSCA, and 8.1% with CAFL.
Selvaraj et al.[34]	<ul style="list-style-type: none"> <li>Rate of recurrent Communication</li> <li>Outstanding Energy</li> <li>Neighbouring</li> </ul>	MATLAB	Fuzzy	Homogeneous	No	√	√	×	×	Network lifetime improved Energy efficiency increased



**REVIEW ARTICLE**

	Node's degree • Node and Base Station's distance									
Manikanthan and Padmapriya[14]	<ul style="list-style-type: none"> <li>• Packet transmission</li> <li>• Energy</li> <li>• Place</li> <li>• Transmission Power</li> </ul>	NS2	Fuzzy	Homogeneous	No	√	√	√	√	Increased packet delivery ratio, Energy level, Network lifetime

Table 1 Cluster Head Election Using Deterministic Scheme

2.2. Probability-based Cluster Head Election Scheme

Probabilistic algorithms help to enhance the network longevity to great extent. In these, the cluster head is selected randomly using the probability factor. Also overhead of clustering that includes time and message needs to be small. Overhead occurs due to the requirement of local information of cluster organization.

Kim et al. in [2008][35] have suggested a fuzzy-based method for electing cluster heads named CHEF (Cluster Head Election mechanism using Fuzzy) by considering two metrics i.e. distance and power of the nodes and has improved the network longevity in comparison with LEACH.

A et al. in [2017][36] have suggested two parameters such as distance between CH and neighbour node, Neighbour nodes' number for the selection of the cluster head. The model shows that the given approach has been proved to be better than the existing traditional LEACH method.

Mary and Gnanadurai in [2017][37] considered the 'used probability' for the CH election. Density, the distance between BS and nodes, and the power level of the node were considered as main input parameters to fuzzy logic. Simulation results proved the guaranteed growth in network lifetime.

Barani and Shantha in [2017][38] have tried to advance the LEACH protocol using Fuzzy logic (LEACH-FL) by considering node density, battery level, and distance as main parameters. Authors have proposed the concept of supercluster head and the election of supercluster head. In this cluster members are consistently distributed which further extends the network longevity.

Baz and Sayadin [2017][43] have suggested two parameters distance between CH and neighbour node, the number of neighbour nodes to select the cluster head. Authors have considered these two parameters at a higher priority level in the traditional LEACH algorithm which elects the CH with the probability function. The threshold function and the above two parameters are used to select the CH. The simulation shows that the given approach has been proved to be better than the existing traditional LEACH method.

Behera et al. in [2019][2] have considered the parameters network diameter, total no. of nodes, total network energy, energy dissipation during receiving, aggregation during the simulation. The proposed R-LEACH model can improve network lifetime and transfer more packets to BS as compared to LEACH, CBDAS, GHND, and IGHND.

Table 2 shows the comparative analysis of various cluster head election using probability-based schemes proposed by eminent researchers based on parameters used, tools, CH election, CH capabilities, and issues resolved.

Papers	Parameters Used	Tool Used	CH Election	CH Capabilities		Issues Resolved				Results
				Node Type	Mobility	N/w Longevity	Energy Efficiency	QoS Increased	Security	
Kim et al. [35]	<ul style="list-style-type: none"> <li>• Concentration</li> <li>• Centrality</li> </ul>	MATLAB	Probability-Based	Homogeneous	No	√	√	×	×	22.7% improvement in power and local distance as compared to LEACH
A et al. [36]	<ul style="list-style-type: none"> <li>• Distance between nodes and CH</li> <li>• Neighbour nodes</li> </ul>	MATLAB	Probability-Based	Homogeneous	No	√	√	×	×	65% improvement in average left overpower and alive nodes  Overall 47% better than LEACH

**REVIEW ARTICLE**

Mary et al.[37]	<ul style="list-style-type: none"> <li>• Remaining node's energy</li> <li>• Density</li> <li>• Base station distance</li> </ul>	MATLAB	Probability-Based	Homogeneous and Heterogeneous	No	√	√	×	×	Network lifetime improved by 8% in comparison to ZSEP-E
Barani et al.[38]	<ul style="list-style-type: none"> <li>• The remaining power of the existing "LEACH" protocol</li> <li>• Holdback value</li> <li>• The distance of the node from nearest hop</li> </ul>	MATLAB	Probability-Based	Heterogeneous	Yes	√	√	×	×	Average delay, the delivery ratio improved in comparison with LEACH-FL
Baz et al. [43]	<ul style="list-style-type: none"> <li>• Distance between CH and neighbour node</li> <li>• Number of neighbour nodes</li> </ul>	NS2	Probability-Based	Homogeneous	No	√	√	×	×	Improvement in the average end to end delay, throughput, and packet release ratio
Behra et al.[2]	<ul style="list-style-type: none"> <li>• Network diameter</li> <li>• Total nodes</li> <li>• Whole network energy</li> <li>• Energy dissipation of receiving</li> <li>• Energy dissipation of aggregation</li> </ul>	MATLAB	Probability-Based	Homogeneous	No	√	√	√	×	Improvement in Throughput 60%, 66% life span enhancement 64% Residual energy

Table 2: Cluster Head Election Using Probability-Based Schemes

2.3. Cluster Head Election Using Adaptive Scheme

In adaptive schemes, resource data like remainder power, power dispersed during the previous round, introductory energy of the nodes, etc. are considered to choose their roles during various information gathering rounds in the cluster head selection method[42]. Based on adaptive schemes, some of the papers have been reviewed in this section.

Tamizharasi et al.in[2017][44] have suggested the heuristic decision-making approach which produces power-aware zones. Getting trapped at a local optimum solution is the major drawback of PSO (Particle Swarm Optimization) which is overcome by using the Bacterial Foraging algorithm. Simulation results indicate perfection in the network's span of the cluster.

Siqing et al. in [2018][45] recommended a multi-hop fuzzy-based clustering algorithm utilizing the Fibonacci sequence for improvement of the network life. It considers the leftover power of the nodes as well as the average of the lasting power of the neighbouring nodes to elect CH. The results when compared with LEACH and other related methods show perfection in terms of the network's span and hot spot issue.

Din et al. in [2016][46] proposed a cluster head election scheme for effectively using energy and dragging out the network's lifetime based upon fuzzy. For further study, the dependability of this calculation can be looked at against SEP and LEACH calculations.

Yan and Wang in[2017][47] have overcome the energy hole problem faced in classic hierarchical protocols like LEACH by suggesting a new distributed clustering scheme. Taking the node's power and the average energy of its one-hop neighbour

node as main parameters, results demonstrated that the proposed calculation performed better regarding network life and power burned-through per round.

Prasat and Shankar[2015][48] proposed the Ridge method to select efficient CH from the group. Framework performed better as far as alive and dead hubs, throughput, and remaining energy are concerned.

The et al. in [2018][49] considered fuzzy logic for the election of CH. Simulation results showed enhancement in a network lifetime, stability of the network, and data delivery as compared to LEACH and CHEF.

Table 3 shows the comparative analysis of various cluster head election using adaptive schemes proposed by eminent researchers based on parameters used, tools, CH election, CH capabilities, and issues resolved.

2.4. Fuzzy Based Cluster Head Election Scheme

Fuzzy logic is a decision-making approach and methodology which is adopted in circumstances where there are heaps of vulnerabilities related to the environment. The haphazard nature of real-life scenarios poses a lot of uncertainties with the decision due to which the conventional techniques of decision making based on a fixed criterion fail in providing the desired results. Hence, employing Fuzzy logic helps to deal with this uncertainty by not depending on the fixed values but the range of values and considering the linguistic variables in many applications.

Further integrating MADM approaches with Fuzzy logic add more efficiency to the results and the decision making process is improved across various overlapping metrics. Recently, researchers have been focusing on fuzzy-based schemes for

**REVIEW ARTICLE**

the election of cluster heads. Human experience and behaviour are considered major factors in these schemes to make decisions. But, the complexity level of such schemes is high because a lot of messages need to be exchanged. In this section, we survey a few methodologies in the territory of fuzzy-based CH election schemes.

Gupta et.al in [2005][23] have proposed an energy-efficient strategy for selecting the cluster head using fuzzy logic. The authors have concluded that the proposed system has helped in enhancing the network's lifetime.

Fawzy et al. in [2016][21] investigated an improved centralized clustering protocol (ICHS) in which the Cluster head is elected for the network operation time rather than periodic election at each round. ICHS helps in reducing the energy cost of the setup phase. Results show enhancement in the span of the network.

Considering the energy utilization of sensor nodes, Dongare and Mangrulkar in [2016][22] discussed two major attacks gray hole and black hole on some nodes so that compromised nodes can be selected and that node can be avoided to become CH. The authors used NS2 to compare the performance of WSN in the presence of attacked nodes. Parameters throughput, End to End delay, time, Packet delivery (PDR), average power consumption are used for the study.

Table 4 shows the relative investigation of various cluster head election through Fuzzy based schemes proposed by eminent researchers based on parameters used, tools, CH election, CH capabilities, and issues resolved.

Torghabeh et al. [2010][24] proposed a strategy to elect a cluster head based upon fuzzy. The selection criteria include parameters like the power of the nodes and the count of neighbours. Then, from the selected nodes, overall cooperation is evaluated using a fuzzy system, which is based on certainty, proximity, and distance in cluster heads. The authors have successfully concluded the results with less energy consumption and an efficient N/W lifetime of about 54% as compared to others.

Kavandi et al. in [2014][25] proposed a method using fuzzy logic for optimizing and increasing the effectiveness of the clustering method by using the lasting power, neighbours nodes, and other related parameters. The authors have concluded better results by extending network longevity and saving energy as compared to LEACH and CHEF protocols.

Taheri and Kavani in [2014][26] proposed a multihop clustering algorithm to enhance the network life. Four parameters remnant power, centrality, distance from BS, and concentration of nodes were considered as input to MATLAB. Comparative analysis of the proposed method was performed which proved that the algorithm helped in enhancing network lifetime. Gupta and Marriwala

in [2017][27] suggested a new approach which used improved distance energy-based LEACH and distance for heterogeneous and homogeneous WSN. The proposed system increased the stability and lifetime of the network.

Nayak and Devulapalli in [2016][50] have investigated an algorithm used for clustering in WSN which helps to increase the lifespan of the network. Authors have proposed three fuzzy parameters mobility, centrality, and remaining battery to select supercluster head (SCH) which is selected from various CHs of the cluster and has maximum energy. The simulation result has shown the enhancement in network lifetime and has verified to be superior to LEACH in terms of the last node and death of the first.

Nag et al. in [2016][53] recommended a hierarchical routing protocol for enhancing energy consumption for WSN. Election of cluster head is performed by using parameters like remnant energy, the distance between the base station and node, and how recently the node is designated as cluster head. Energy consumption is reduced by this method as compared to the earlier methods.

Patil and Sharma in [2016][54] proposed a cluster head election scheme based on radio signal strength and connectivity of nodes. The algorithm considers other parameters such as network size, number of base stations and sensor nodes, delay for study. The authors proved that the proposed scheme has a better lifetime of the network.

Sharma et.al in [2016][55] investigated a novel and an improved cluster head election mechanism based on traffic heterogeneity. The proposed strategy increases reliability by increasing the stability period for clustering in WSNs. Even the fuzzy-based cluster head election has been widely used in radar sensor networks as proposed by Hu et al. [56] in [2016].

Murugaanandam and Ganapath in [2019][51] have proposed a reliability-based methodology for the cluster head election. Residual energy, energy utilization rate, reliability index, the distance between adjacent nodes are the major parameters used for the election of CH. The proposed method helps in network longevity, energy conservation, and reduces the occurrence of CH election per cycle by 20% to 50%.

Ranganathan et.al in [2020][52] have recommended Residual energy, betweenness centrality, criticality as the factors used to control the power utilization and enhance the life of WSN. The base station constructs the topology and network life is enhanced by 10%.

### 2.5. Cluster Head Election Using the Multiple Attribute Decision-Making Approach (MADM)

Multiple criterion decision making (MCDM) is a decision-making process based on multiple, usually differing criteria. MCDM can be commonly characterized into two

**REVIEW ARTICLE**

classifications: multiple objective decision making (MODM) and multiple attribute decision making (MADM) . Employing MADM assists in providing solutions to problems relating to the election from among the restricted number of choices available. MADM approach is an upcoming technique used to select the optimal CH. Different criteria and alternatives are selected and the best alternative is used as the CH.

Azad et al. [2016][57] have used MADM (Fuzzy TOPSIS) by selecting the remnant energy, least distance from the base station, neighbouring nodes as the parameters which resulted in attaining substantial energy saving and lengthening network lifetime as compared to DHAC protocol. According to Hamzeloei and Dermany in [2016][58] network lifetime significantly increases. Four metrics are used for selecting CH and results prove that the proposed calculation is better regarding network lifetime when contrasted with LEACH and AHP (Analytical Hierarchical Protocol).

Farman et al. [2017] [59] purposed five significant parameters distance from the centroid, distance from nodes, remaining power level, merged node for the cluster head selection, and how many times the node has been selected as cluster head. ANP is preferred for the selection of an optimum cluster head.

Results have confirmed that the proposed technique utilizing the ANP approach broadens the network life expectancy.

Muhammad et al. in [2017] [60] purposed a Fuzzy-Topsis( Technique for the order of preference by similarity to ideal solution ) method based on Multiple criteria decision making(MCDM) to choose cluster head so that network lifetime can be enhanced. Parameters like residual energy, no. of neighbouring nodes, distance from the sink, the average distance between neighbouring nodes, energy consumption rates have been used to select the CH. Results have proved that energy is conserved by 80% and enhancement in network lifetime by 60%.

Authors Prince & Dwivedi [2019][61] have considered the eleven factors that influence the power intensity of the network. Performance analysis with the existing work is performed by using network-dead,first-gateway-dead, and first-dead-node. The purposed system proves to be better than the existing one.

Table 5 shows the comparative analysis of various cluster head election using MADM schemes proposed by eminent researchers based on parameters used, tools, CH election, CH capabilities, and issues resolved.

Papers	Parameters Used	Tool Used	CH Election	CH Capabilities		Issues Resolved				Results
				Node Type	Mobility	N/w Longevity	Energy Efficiency	QoS Increased	Security	
Tamizharasi et al.[44]	<ul style="list-style-type: none"> <li>Average Residual Energy</li> <li>No of the alive nodes</li> <li>Total elected cluster head</li> <li>Average Energy used</li> </ul>	NS2	BFA-PSO	Homogeneous	No	√	√	×	×	5% of the increase in energy consumption in comparison to 19% of LEACH Increase in the span of live nodes Intra-cluster distance improved
Siqing et al.[45]	<ul style="list-style-type: none"> <li>The lasting power of the nodes</li> <li>Neighbouring nodes</li> <li>Mean of the remaining energy of the neighbouring nodes</li> </ul>	MATLAB	Fuzzy	Homogeneous	No	√	√	×	×	Network lifetime extended
Din et al.[46]	<ul style="list-style-type: none"> <li>Residual Energy</li> <li>Communication cost</li> <li>Centrality</li> </ul>	MATLAB	Fuzzy	Homogeneous	No	√	√	×	×	The decrease in no. of dead node and average energy loss
Yan et al.[47]	<ul style="list-style-type: none"> <li>Size of Data packet</li> <li>Energy consumption</li> <li>Control packet size</li> </ul>	MATLAB	Random	Homogeneous	No	√	√	√	×	Lesser energy dissipation(0.0601J) than LEACH(0.2467J)



**REVIEW ARTICLE**

Prasat et al.[48]	<ul style="list-style-type: none"> <li>• leftover power</li> <li>• Network Throughput</li> <li>• Living nodes</li> <li>• Quiet nodes</li> </ul>	MATLAB	Ridge Method	Heterogeneous	No	√	√	×	×	Throughput and residual energy increased
The et al.[49]	<ul style="list-style-type: none"> <li>• Residual energy</li> <li>• A local distance of the node from the mobile sink</li> </ul>	MATLAB	Random	Homogeneous	Yes (BS)	√	√	√	×	Improvement in the network's life and average as compared to CHEF and LEACH

Table 3 Cluster Head Election Using Adaptive Scheme

Papers	Parameters Used	Tool Used	CH Election	CH Capabilities		Issues Resolved				Results
				Node Type	Mobility	N/w Longevity	Energy Efficiency	QoS Increased	Security	
Fawzy et al.[21]	<ul style="list-style-type: none"> <li>• The last node dies</li> <li>• The first node dies</li> <li>• Number of CHs per round</li> <li>• Throughput</li> <li>• Half node dies</li> </ul>	MATLAB	Base Station	Homogeneous	No	√	√	×	×	FND of ICHS improved by 62%, 63%, 68.3% in comparison with LEACH, COTS, LEACH-ACH HNA is 5% lesser than LEACH
Dongareet al. [22]	<ul style="list-style-type: none"> <li>• Packet release ratio</li> <li>• End to End delay</li> <li>• Throughput</li> <li>• Time</li> <li>• Average Power Consumption</li> </ul>	NS2	Fuzzy	Homogeneous	Yes	×	√	√	√	Improvement in Energy effectiveness, Packet conveyance proportion, and start to finish delay
Gupta et.al[23]	<ul style="list-style-type: none"> <li>• Energy</li> <li>• Concentration</li> <li>• Centrality</li> </ul>	(JESS) toolkit	Base Station	Homogeneous	No	√	√	×	×	Increase in N/w lifetime in comparison with LEACH
Torghabeh et al.[24]	<ul style="list-style-type: none"> <li>• Centrality</li> <li>• Distance b/w cluster heads</li> <li>• Closeness to the base station</li> </ul>	MATLAB	Base Station	Homogeneous	No	√	√	×	×	Less energy consumption and N/w lifetime prolongs by 54 %
Kavandi et al.[25]	<ul style="list-style-type: none"> <li>• Residual energy</li> <li>• Number of neighbours</li> <li>• Centrality</li> </ul>	MATLAB	Priority-based	Homogeneous	No	√	√	×	×	Better than LEACH and CHEF as far as expanding network lifetime and sparing energy
Taheri et al. [26]	<ul style="list-style-type: none"> <li>• Residual energy</li> <li>• Node proximity to neighbours</li> <li>• Distance to the base station</li> <li>• Node concentration</li> </ul>	MATLAB	Fuzzy	Homogeneous	No	√	√	×	×	Network lifetime improvement
Gupta et al. [27]	<ul style="list-style-type: none"> <li>• The preliminary power of the network</li> <li>• Data aggregation energy</li> <li>• Radio electronic power</li> <li>• Data packet size</li> </ul>	MATLAB	Fuzzy	Homogeneous & Heterogeneous	No	√	√	×	×	Perform in a way that is better than LEACH regarding FND, HND, LNA by 64%,18%,4% separately.
Nayak et al.[50]	<ul style="list-style-type: none"> <li>• Battery power</li> <li>• The centrality of the clusters</li> <li>• Mobility of Base</li> </ul>	NS-2	Fuzzy	Homogeneous	Yes Sink	√	√	×	×	More stable network and Network lifetime improved by 20% in comparison to LEACH

**REVIEW ARTICLE**

Murugaanandam et al.[51]	<ul style="list-style-type: none"> <li>Residual energy</li> <li>Energy utilization rate</li> <li>Reliability index</li> <li>Distance b/w adjacent nodes</li> </ul>	NS-2	Fuzzy	Homogeneous	No	√	√	√	×	20%-25% increase in network lifespan and energy efficiency and reduction in the frequency of CH election in every cycle as compared to LEACH and Fuzzy-TOPSIS
Ranganathan et.al[52]	<ul style="list-style-type: none"> <li>Betweenness centrality</li> <li>Residual energy</li> <li>Criticality</li> </ul>	NS-2.35	Fuzzy	Homogeneous	Yes	√	√	×	×	Network lifetime increased by 10%

Table 4 Cluster Head Election Using Fuzzy Based Schemes

Papers	Parameters Used	Tool Used	CH Election	CH Capabilities		Issues Resolved				Results
				Node Type	Mobility	N/w Longevity	Energy Efficiency	QoS Increased	Security	
Azad et al.[57]	<ul style="list-style-type: none"> <li>Outstanding power</li> <li>No. of Neighbouring nodes</li> <li>The distance between nodes and base station</li> </ul>	MATLAB	MADM TOPSIS	Homogeneous	No	√	√	√	×	Network lifetime of TOPSIS is 117 % more than LEACH
Hamzeloei et al. [58]	<ul style="list-style-type: none"> <li>No. of neighbours</li> <li>Residual energy</li> <li>Distance to the base station</li> <li>Transmission range</li> </ul>	MATLAB	TOPSIS	Homogeneous	No	√	√	√	×	Improved the network lifetime as compared to LEACH and AHP
Farman et al.[59]	<ul style="list-style-type: none"> <li>Leftover power</li> <li>The distance between node and neighbouring node</li> <li>Distance between node and centre of the zone</li> <li>Frequency of node as CH</li> <li>The node which has been included in the group from the low-density zone.</li> </ul>	MATLAB	Base Station using MADM	Homogeneous	No	√	×	√	×	Network lifespan increases by 79.9%,61.3%,12.8% as compared to direct, LEACH, PEGA- SIS and CBDAS
Muhammad et al. [60]	<ul style="list-style-type: none"> <li>The energy consumption rate of node</li> <li>Neighbour node's Number</li> <li>Distance from the BS</li> <li>The Mean distance between the neighbouring node</li> <li>Leftover energy</li> </ul>	MATLAB	TOPSIS	Homogeneous	No	√	√	√	×	Network lifespan enhanced by 60% Energy conservation by 80% Reduction in occurrence of CH election in every round is 25% in comparison to the Fuzzy and LEACH
Prince & Dwivedi[61]	<ul style="list-style-type: none"> <li>Distance between CH and BS</li> <li>Higher leftover power</li> <li>Distance between node and CH</li> </ul>	MATLAB	TOPSIS	Homogeneous	No	√	√	√	×	Improved network lifetime as compared to LEACH, LEACH-C, EECS

Table 5 Cluster Head Election Using MADM Schemes

**REVIEW ARTICLE**

**3. REVIEW AND LIMITATIONS**

There has been a lot of exploration in the method of making these authoritative structures (or clusters). The clustering event plays a significant part in not simply the organization of the network, but can drastically influence network execution. There are a few key restrictions in the above investigation of WSNs, that cluster head election schemes must consider.

Deterministic-based approaches [28–34] perform well in enhancing network lifetime and energy efficiency but their performance is negligible in case of QoS improvement or security. No doubt authors in [28, 29] have tried to incorporate QoS and have tried to increase throughput while in [28] authors have tried to handle traffic efficiently. But from Table 1, it is clear that more work needs to be done in the case of the QoS and security field in cluster head selection in a real-time environment which is more prone to security attacks.

Probabilistic based approaches [35–39] failed to deal with QoS and security breaches during cluster head communication. No doubt, these schemes perform excellent for the longevity of network and power efficiency but in a heterogeneous environment, these metrics are not enough for secure communication. Adaptive schemes[44–49] have successfully improved the residual energy and network lifespan of the network. Authors have tried to improve QoS in [47, 49]. But security is still left out for future work.

Recently, fuzzy-based schemes [21–27, 50–52] are being employed for CH election but negligible work has been done in the field of QoS and secure communication[22] during cluster communication in single or multi-hop mode. Multi-attribute decision-making schemes [57–60, 61] perform very well as compared to deterministic, probabilistic, adaptive, and fuzzy-based schemes in providing QoS along with network longevity and energy efficiency. Table 6 shows the comparative analysis of various cluster head election techniques based on node mobility, real-time scenarios, security, and Quality of Service.

Criteria Type	Node Mobility	Real-Time Scenarios	Security	Quality of Service
Deterministic	No	No	No	No
Probabilistic	No	No	No	No
Adaptive	Few	Yes	No	Limited
Fuzzy	Few	Limited	No	Limited
MADM	Few	Yes	No	Yes

Table 6: Comparison between Various Techniques

**3.1. Comparative Analysis of Reviewed Papers Based Upon Results**

Considering the various approaches and parameters used in literature to elect the cluster head, a comparative analysis has been performed. In Figure 4, an attempt has been made to explain in %age, utilization, and improvement of each of the metrics in the deterministic based approach.

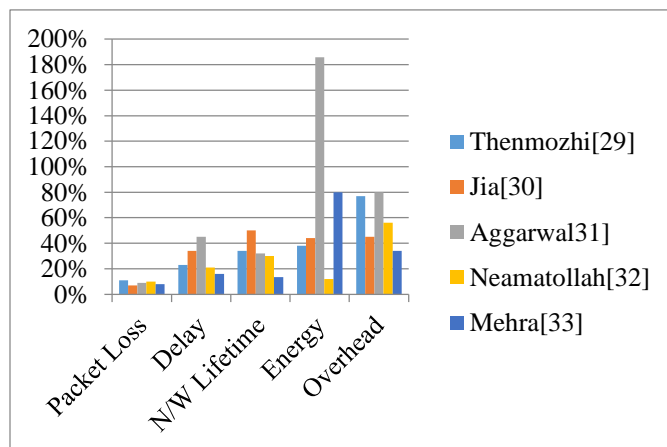


Figure 4 Comparative Analysis of Reviewed Papers

It is concluded that maximum energy consumption and overhead are being reduced by Aggarwal [31] and network lifetime is improved by Jia [30].

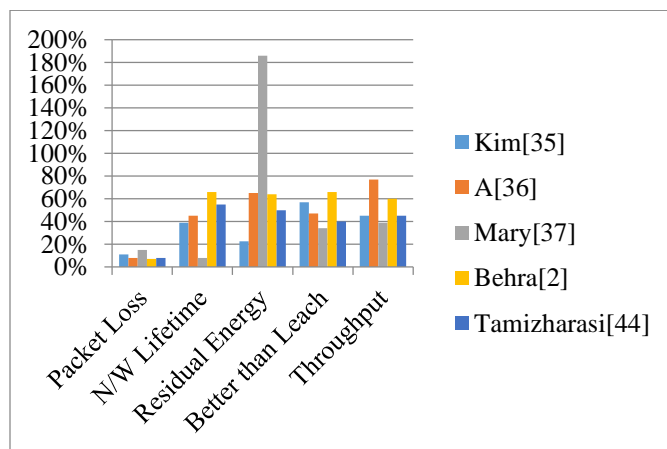


Figure 5 Comparative Analysis of Reviewed Papers

In Figure 5, an attempt has been made to explain in %age, utilization, and improvement of each of the metrics in probabilistic and adaptive based approach. It is concluded that maximum energy residual is by Mary [37] and throughput is improved by A et al. [36] and network lifetime is improved by Behra[2].

In Figure 6, an attempt has been made to explain in %age, utilization, and improvement of each of the metrics in Fuzzy

**REVIEW ARTICLE**

and MADM based approach. It is concluded that the maximum energy residual and network lifetime are improved by Azad [57]. Farman [59] and Muhamad [60] have performed well in the enhancement of network lifetime and saving of residual energy. From the above figures, it's very clear that researchers have successfully increased the network lifetime and remnant energy, but, security and QoS need to be improved.

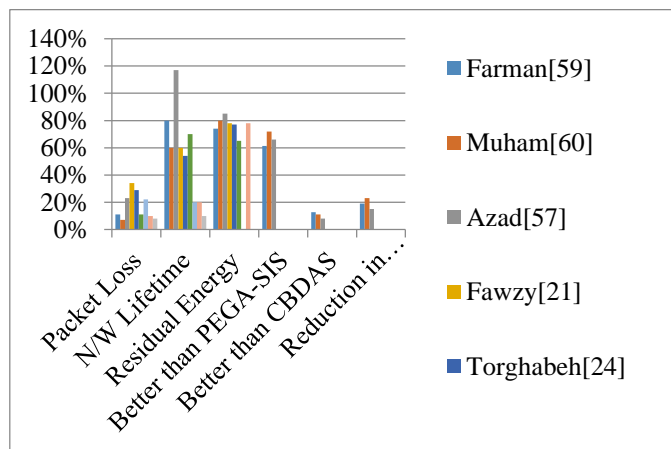


Figure 6 Comparative Analysis of Reviewed Papers

**4. OPEN ISSUES AND CHALLENGES**

After going through a deep analysis, there are several open issues and challenges in WSNs, that cluster head election schemes must consider.

**4.1. Dynamic Nature of Network**

Many researchers have considered sensor nodes to be stationary. But, it is essential to consider the dynamic nature of WSN due to varying network size, movements among sensor nodes, change in topology, and unpredicted operational flaws. Even the mobility due to node or sink can be challenging, forcing clusters to change with time.

**4.2. Network Longevity**

The network life depends on the alive sensors in the network. Due to the restricted processing capabilities of nodes, it is a cumbersome task to optimize communication cost, data collection, and load tolerance of nodes to increase their lifetime. Clustering optimization by choosing an optimal energy path for routing can help to increase the network lifetime.

**4.3. Secure Data Communication**

Data collection and aggregation is achieved at the CH. Since clustering in WSN collects very critical data of hostile environment which must be communicated without any malicious intent or attack or any kind of alteration. Therefore, it is essential to employ strict and strong authentication

algorithms to avoid malicious attacks in the network. WSNs are exposed to many attacks such as Denial of service, tampering which can disconnect nodes or CH, or part of the network.

**4.4. Secure Image Transmission Scheme for Clustered WSN**

Numerous Imaging Sensor nodes are also used in WSN for healthcare, environmental monitoring, traffic monitoring, etc. Due to limited bandwidth constraints, image compression techniques are used but to secure it from intruder's image encryption are also employed for transmission of images in WSN. But it is very challenging to secure sensor networks using existing security mechanisms. Therefore, an enhanced secure image transmission scheme for clustered WSN along with QoS is the need of the hour.

**4.5. The Requirement of Enhanced Quality of Services**

WSN is the backbone of very new technologies such as IoT and IoE which depend upon the prerequisite of Quality of Experience (QoE) and Quality of service (QoS). Many parameters such as bandwidth, latency, end-to-end delay, throughput, and reliability are almost ignored while electing CH in WSN. Hence there is a need to consider the requirements of these QoS parameters in cluster-based protocols for real-time IoT applications.

There are also certain limitations specifically related to the cluster head election. Few of them are as follows:

**4.6. The Distance of the Cluster Head From its Cluster Members and Other Cluster Members**

The position and the placement of CH in a zone determine the energy consumption of its members. The distance of CH from its cluster member is called intra-cluster distance and the distance of the CH from the members of the other clusters is called inter-cluster distance. The clusters having more intra-cluster distance consume more amount of energy as compared to the other clusters. According to Figure 7, a clustering algorithm must consider this fact and a cluster should be formed so that intra-cluster distance must be less than inter-cluster distance [62, 63].

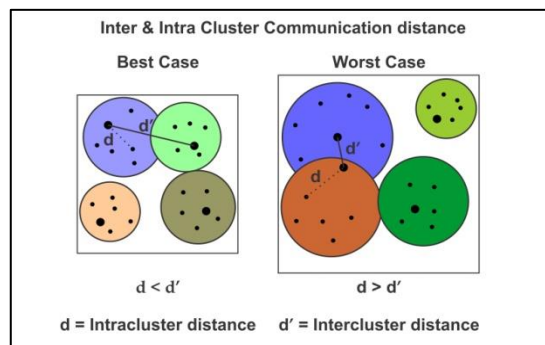


Figure 7 Inter & Intra Cluster Communication Distance



**REVIEW ARTICLE**

## 4.7. Cluster Head Rotation

Most existing algorithms do not consider the CH rotation which can be further imbibed in the latest researches by using appropriate parameters such as coverage rate and residual energy. The study of CH rotation may cost networks lifetime further which will be shortened [64, 65].

## 5. FUTURISTIC PROPOSED SYSTEM MODEL

Considering the above literature study, a hybrid method for cluster head election (HMCHS) can be proposed which will be both adaptive and dynamic and will make the use of network intelligence schemes ANP and PROMTHEE. We can further enhance the proposed method by the election of a cluster head in each zone based on parameters like primary energy, the distance of neighbouring nodes, residual Energy, etc.

The Cluster Head can use time-division multiplexing for giving equal slots to each of its node members to send the information. When the quanta will get over, either the cluster head will itself fuse the information and will send it to the base station or it will find the nearest cluster head to the BS to whom all the cluster heads will send information collected so far. Nearest CH can route the information regarding the whole environment to the BS.

Dissipation of energy will be huge during the transmission process, so HMCHS can optimize the process by incorporating three main features:

- Random Clustering.
- Dynamism in Cluster Head election.
- Role and Election of Super Head Cluster.

Once the cluster head is selected, it may send a message to all the nodes that whosoever wants to be a part of its zone by 'Request join'. Each sensor node is required to send a message to the CH to which it wants to join by sending a message 'ACK [0]' which is a positive acknowledgment. This process is repeated whenever CH reaches below its threshold. Superhead clusters can be selected from among the various cluster heads depending upon certain parameters like initial energy, residual energy, etc. All the cluster heads will be required to periodically share the information regarding themselves and their complete zone to the supercluster head. The objective of the supercluster head is to analyze the information shared and if any cluster head has the residual energy less than any of its nodes, then SCH can send a message to that particular CH and its members through selective flooding to re-elect the CH.

## 6. CONCLUSION

No doubt, very rigorous research is being done in the field of WSN, clustering, and cluster head election. An effort has been

made to study the existing literature and it has been concluded that due to the uncertainty and dynamic behaviour of sensor nodes in WSNs, a more intelligent and expert system for cluster head selection is required. Network Longevity and power efficiency have been mostly considered in the existing literature but now the research is more focusing on the mobility, the dynamic nature, and uncertain behaviour of the WSN environment. Existing techniques like deterministic, probabilistic, and adaptive methods need to be combined with hybrid methods such as Genetic algorithms, cuckoo method, Ant colony, and swarm intelligence to yield better results. Fuzzy and MADM methods may handle the real-time scenario and uncertain nature of the environment based on the appropriate selection of parameters. Metrics that have been left out in the traditional approaches such as quality, security, and scalability need to be considered in future work. Node Mobility should be considered in the future by focusing on random clustering and re-election of CH as and when the depletion of the energy of CH is huge.

## REFERENCES

- [1] Y. Al-obaisat and R. Braun, "On Wireless Sensor Networks : Architectures, Protocols, Applications , and Management Routing Protocols for WSNs," in Proceedings of the 2nd international conference on wireless broadband and ultra wideband communication (AusWireless), 2007, pp. 1–11.
- [2] T. M. Behera, S. K. Mohapatra, U. C. Samal, M. S. Khan, M. Daneshmand, and A. H. Gandomi, "Residual Energy Based Cluster-head Selection in WSNs for IoT Application," *IEEE Internet Things J.*, vol. 6, no. 3, pp. 5132–5139, 2019.
- [3] B. K. Debroy, M. S. Sadi, and M. Al Imran, "An efficient approach to select cluster head in Wireless Sensor Networks," *J. Commun.*, vol. 6, no. 7, pp. 529–539, 2011, doi: 10.4304/jcm.6.7.529-539.
- [4] P. K. Batra and K. Kant, "LEACH-MAC: a new cluster head selection algorithm for Wireless Sensor Networks," *J. Wirel. Networks*, vol. 22, no. 1, pp. 49–60, 2016, doi: 10.1007/s11276-015-0951-y.
- [5] A. Abed, A. Alkhatib, and G. S. Baicher, "Wireless Sensor Network Architecture," in International Conference on Computer Networks and Communication Systems, 2012, vol. 35, no. Cncs2012, pp. 11–15.
- [6] A. Zeb et al., "Clustering Analysis in Wireless Sensor Networks: The Ambit of Performance Metrics and Schemes Taxonomy," *Int. J. Distrib. Sens. Networks*, vol. 12, no. 7, pp. 1–24, 2016, doi: 10.1177/155014774979142.
- [7] S. R. Jino Ramson and D. Jackuline Moni, "Applications of Wireless Sensor Networks - A survey," *Proc. IEEE Int. Conf. Innov. Electr. Electron. Instrum. Media Technol. ICIEEIMT 2017*, vol. 2017-Janua, no. July, pp. 325–329, 2017, doi: 10.1109/2005.1467103.
- [8] A. A. Abbasi and M. Younis, "A survey on clustering algorithms for wireless sensor networks," *Comput. Commun.*, vol. 30, no. 14–15, pp. 2826–2841, 2007, doi: 10.1016/j.comcom.2007.05.024.
- [9] S. Verma, N. Sood, and A. K. Sharma, "Genetic Algorithm-based Optimized Cluster Head selection for single and multiple data sinks in Heterogeneous Wireless Sensor Network," *Appl. Soft Comput. J.*, vol. 85, p. 105788, 2019, doi: 10.1016/j.asoc.2019.105788.
- [10] L. Xu, R. Collier, and G. M. P. O'Hare, "A Survey of Clustering Techniques in WSNs and Consideration of the Challenges of Applying Such to 5G IoT Scenarios," *IEEE Internet Things J.*, vol. 4, no. 5, pp. 1229–1249, 2017, doi: 10.1109/JIOT.2017.2726014.
- [11] S. Aslam, N. U. Hasan, J. W. Jang, and K. G. Lee, "Optimized energy

## REVIEW ARTICLE

- harvesting, cluster-head selection and channel allocation for IoTs in smart cities,” *Sensors (Switzerland)*, vol. 16, no. 12, 2016, doi: 10.3390/s16122046.
- [12] P. Porambage, C. Schmitt, P. Kumar, A. Gurtov, and M. Ylianttila, “PAAuthKey: A Pervasive Authentication Protocol and Key Establishment Scheme for Wireless Sensor Networks in Distributed IoT Applications,” *Int. J. Distrib. Sens. Networks*, vol. 2014, 2014, doi: 10.1155/2014/357430.
- [13] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, “Energy-efficient communication protocol for wireless microsensor networks,” *Proc. 33rd Annu. Hawaii Int. Conf. Syst. Sci.*, vol. 1, pp. 1–10, 2000, doi: 10.1109/HICSS.2000.926982.
- [14] S. V. Manikanthan and T. Padmapriya, “An efficient cluster head selection and routing in mobile WSN,” *Int. J. Interact. Mob. Technol.*, vol. 13, no. 10, pp. 56–70, 2019, doi: 10.3991/ijim.v13i10.11303.
- [15] A. A. Baradaran and K. Navi, “HQCA-WSN: High-quality clustering algorithm and optimal cluster head selection using fuzzy logic in wireless sensor networks,” *Fuzzy Sets Syst.*, vol. 389, pp. 114–144, 2020, doi: 10.1016/j.fss.2019.11.015.
- [16] X. Yuan, M. Elhoseny, H. K. El-Minir, and A. M. Riad, “A Genetic Algorithm-Based, Dynamic Clustering Method Towards Improved WSN Longevity,” *J. Netw. Syst. Manag.*, vol. 25, no. 1, pp. 21–46, 2017, doi: 10.1007/s10922-016-9379-7.
- [17] M. Elhoseny, X. Yuan, Z. Yu, C. Mao, H. K. El-Minir, and A. M. Riad, “Balancing energy consumption in heterogeneous wireless sensor networks using genetic algorithm,” *IEEE Commun. Lett.*, vol. 19, no. 12, pp. 2194–2197, 2015, doi: 10.1109/LCOMM.2014.2381226.
- [18] M. Wu, H. Liu, and Q. Min, “Lifetime enhancement by cluster head evolutionary energy efficient routing model for WSN,” in *6th International Conference on Instrumentation and Measurement, Computer, Communication and Control, IMCCC 2016*, 2016, pp. 545–548, doi: 10.1109/IMCCC.2016.86.
- [19] K. N. Dattatraya and K. R. Rao, “Hybrid based cluster head selection for maximizing network lifetime and energy efficiency in WSN,” *J. King Saud Univ. - Comput. Inf. Sci.*, no. xxxx, 2019, doi: 10.1016/j.jksuci.2019.04.003.
- [20] P. L. Rajarajeswari and N. K. Karthikeyan, “Hyper-geometric energy factor based semi-Markov prediction mechanism for effective cluster head election in WSNs,” *J. Intell. Fuzzy Syst.*, vol. 32, no. 4, pp. 3111–3120, 2017, doi: 10.3233/JIFS-169254.
- [21] A. E. Fawzy, A. Amer, M. Shokair, and W. Saad, “Proposed intermittent Cluster Head selection scheme for efficient energy consumption in WSNs,” in *34th National Radio Science Conference (NRSC)*, 2017, no. NRSC, pp. 275–283, doi: 10.1109/NRSC.2017.7893486.
- [22] S. P. Dongare and R. S. Mangrulkar, “Optimal Cluster Head Selection Based Energy Efficient Technique for Defending against Gray Hole and Black Hole Attacks in Wireless Sensor Networks,” *Phys. Procedia*, vol. 78, no. December 2015, pp. 423–430, 2016, doi: 10.1016/j.procs.2016.02.084.
- [23] G. Indranil, D. Riordan, and S. Srinivas, “Cluster-head election using fuzzy logic for wireless sensor networks,” in *Proceedings of Annual Communication Networks and Services Research Conference*, 2005, pp. 255–260, doi: 10.1109/CNSR.2005.27.
- [24] N. A. Torghabeh, M. R. A. Totonchi, and M. H. Y. Moghaddam, “Cluster head selection using a two-level fuzzy logic in wireless sensor networks,” in *CCET 2010 - 2010 International Conference on Computer Engineering and Technology, Proceedings I*, 2010, vol. 2, pp. 357–361, doi: 10.1109/ICCET.2010.5485483.
- [25] H. Kavandi, M. Meghdadi, and M. Bayat, “A Method for Optimizing of the Energy Consumption in Wireless Sensor Networks By Dynamic Selection of Cluster Head Using Fuzzy Logic,” *Indian J. Sci. Res.*, vol. 7, no. 1, pp. 1018–1025, 2014.
- [26] M. Taheri and Y. S. Kavian, “Energy Efficient Algorithm for Wireless Sensor Networks using Fuzzy Logic,” *Int. J. Comput. Appl.*, vol. 89, no. 14, pp. 1–5, 2014, doi: 10.5120/15696-4055.
- [27] S. Gupta and N. Marriwala, “Improved distance energy based LEACH protocol for cluster head election in wireless sensor networks,” in *4th IEEE International Conference on Signal Processing, Computing and Control, ISPCC 2017*, 2017, pp. 91–96, doi: 10.1109/ISPCC.2017.8269656.
- [28] D. Izadi, J. Abawajy, and S. Ghanavati, “A new energy efficient cluster-head and backup selection scheme in WSN,” in *Proceedings of the 2013 IEEE 14th International Conference on Information Reuse and Integration*, 2013, pp. 408–415, doi: 10.1109/IRI.2013.6642500.
- [29] E. Thenmozhi and S. Audithan, “Energy Efficient Cluster Head Selection and Data Convening in Wireless Sensor Networks,” *Indian J. Sci. Technol.*, vol. 9, no. 15, pp. 1–6, 2016, doi: 10.17485/ijst/2016/v9i15/77749.
- [30] D. Jia, H. Zhu, S. Zou, and P. Hu, “Dynamic Cluster Head Selection Method for Wireless Sensor Network,” *IEEE Sens. J.*, vol. 16, no. 8, pp. 2746–2754, 2016, doi: 10.1109/JSEN.2015.2512322.
- [31] D. Agrawal and S. Pandey, “FUCA: Fuzzy-based unequal clustering algorithm to prolong the lifetime of wireless sensor networks,” *Int. J. Commun. Syst.*, vol. 31, no. 2, pp. 1–18, 2018, doi: 10.1002/dac.3448.
- [32] P. Neamatollahi and M. Naghibzadeh, “Distributed unequal clustering algorithm in large-scale wireless sensor networks using fuzzy logic,” *J. Supercomput.*, vol. 74, no. 6, pp. 1–24, 2018, doi: 10.1007/s11227-018-2261-5.
- [33] P. S. Mehra, M. N. Doja, and B. Alam, “Fuzzy based enhanced cluster head selection (FBECS) for WSN,” *J. King Saud Univ. - Sci.*, vol. 32, no. 1, pp. 390–401, 2018, doi: 10.1016/j.jksus.2018.04.031.
- [34] H. Natarajan and S. Selvaraj, “A Fuzzy Based Predictive Cluster Head Selection Scheme for Wireless Sensor Networks,” *Proc. 8th Int. Conf. Sens. Technol. Liverpool, UK A*, pp. 560–566, 2014.
- [35] J. Kim, S. Park, Y.-J. Han, and T. Chung, “CHEF: cluster head election mechanism using fuzzy logic in wireless sensor networks,” in *10th international conference on Advance Communication Technology*, 2008, vol. 1, pp. 654–659, doi: 10.1109/ICACT.2008.4493846.
- [36] A. Krishnakumar and V. Anuratha, “An Energy-Efficient Cluster Head Selection of LEACH Protocol for Wireless Sensor Networks,” in *InNextgen Electronic Technologies: Silicon to Software (ICNETS2)*, 2017 International Conference on, IEEE., 2017, pp. 57–61.
- [37] S. A. Sahaaya Arul Mary and J. B. Gnanadurai, “Enhanced Zone Stable Election Protocol based on Fuzzy Logic for Cluster Head Election in Wireless Sensor Networks,” *Int. J. Fuzzy Syst.*, vol. 19, no. 3, pp. 799–812, 2017, doi: 10.1007/s40815-016-0181-1.
- [38] S. B. S and S. V. U, “Super Cluster Head Selection and Energy Efficient Round Robin Load Balancing Technique in Wireless Sensor Networks,” *Int. J. Eng. Sci. Comput.*, vol. 7, no. 4, pp. 10065–10072, 2017.
- [39] A. Al-Baz and A. El-Sayed, “A new algorithm for cluster head selection in LEACH protocol for wireless sensor networks,” *Int. J. Commun. Syst.*, vol. 31, no. 1, pp. 57–61, 2017, doi: 10.1002/dac.3407.
- [40] K. Ramesh, “Improved Fair-Zone Technique Using Mobility Prediction In WSN,” *Int. J. Adv. Smart Sens. Netw. Syst.*, vol. 2, no. 2, pp. 23–32, 2012, doi: 10.5121/ijassn.2012.2203.
- [41] K. Somasundaram, S. Saritha, and K. Ramesh, “Enhancement of network lifetime by improving the leach protocol for large scale WSN,” *Indian J. Sci. Technol.*, vol. 9, no. 16, 2016, doi: 10.17485/ijst/2016/v9i16/92242.

## REVIEW ARTICLE

- [42] K.Ramesh and K.Somasundaram, "a Comparative Study of Clusterhead Selection Algorithms in Wireless Sensor Networks," *Int. J. Comput. Sci. Eng. Surv.*, vol. 2, no. 4, pp. 153–164, 2011, doi: 10.1002/fut.
- [43] A. Al-Baz and A. El-Sayed, "A new algorithm for cluster head selection in LEACH protocol for wireless sensor networks," *Int. J. Commun. Syst.*, vol. 31, no. 1, pp. 1–13, 2018, doi: 10.1002/dac.3407.
- [44] A. M. E. Tamizharasi, J. J. S. M. E, A. K. Priya, and R. Maarlin, "Energy Aware Heuristic Approach for Cluster Head Selection in Wireless Sensor Networks," *Bull. Electr. Eng. Informatics*, vol. 6, no. 1, pp. 70–75, 2017, doi: 10.11591/eei.v6i1.598.
- [45] Z. Siqing, T. Yang, and Y. Feiyue, "ScienceDirect ScienceDirect Fuzzy Logic-Based Clustering Algorithm for Multi-hop Wireless Fuzzy Logic-Based Clustering Algorithm for Multi-hop Wireless Sensor Networks Sensor Networks," *Procedia Comput. Sci.*, vol. 131, pp. 1095–1103, 2018, doi: 10.1016/j.procs.2018.04.270.
- [46] W. I. S. W. Din, S. Yahya, R. Jailani, M. N. Taib, A. I. M. Yassin, and R. Razali, "Fuzzy logic for cluster head selection in wireless sensor network," in *AIP Conference Proceedings*, 2016, vol. 1774, p. 050006, doi: 10.1063/1.4965093.
- [47] A. Yan and B. Wang, "An adaptive WSN clustering scheme based on neighborhood energy level," in *2017 IEEE 3rd Information Technology and Mechatronics Engineering Conference (ITOEC)*, 2017, pp. 1170–1173.
- [48] K. A. Prasath and T. Shankar, "RMCHS: Ridge method based cluster head selection for energy efficient clustering hierarchy protocol in WSN," *2015 Int. Conf. Smart Technol. Manag. Comput. Commun. Control. Energy Mater. ICSTM 2015 - Proc.*, no. May, pp. 64–70, 2015, doi: 10.1109/ICSTM.2015.7225391.
- [49] The, P. T., Manh, V. N., & Hung, T. C. (2018, February). Improving network lifetime in wireless sensor network using fuzzy logic based clustering combined with mobile sink. In *2018 20th International Conference on Advanced Communication Technology (ICACT)* (pp. 113-119). IEEE.
- [50] P. Nayak and A. Devulapalli, "A Fuzzy Logic-Based Clustering Algorithm for WSN to Extend the Network Lifetime," *IEEE Sens. J.*, vol. 16, no. 1, pp. 137–144, 2016, doi: 10.1109/JSEN.2015.2472970.
- [51] S. Murugaanandam and V. Ganapathy, "Reliability-based cluster head selection methodology using fuzzy logic for performance improvement in wsns," *IEEE Access*, vol. 7, pp. 87357–87368, 2019, doi: 10.1109/ACCESS.2019.2923924.
- [52] R. Ranganathan, B. Somanathan, and K. Kannan, "Fuzzy-Based Cluster Head Amendment (FCHA) Approach to Prolong the Lifetime of Sensor Networks," *Wirel. Pers. Commun.*, vol. 110, no. 3, pp. 1533–1549, 2020, doi: 10.1007/s11277-019-06800-5.
- [53] S. Biswas, J. Saha, T. Nag, C. Chowdhury, and S. Neogy, "A Novel Cluster Head Selection Algorithm for Energy-Efficient Routing in Wireless Sensor Network," *2016 IEEE 6th Int. Conf. Adv. Comput.*, pp. 588–593, 2016, doi: 10.1109/IACC.2016.114.
- [54] M. Patil and C. Sharma, "Energy efficient cluster head selection to enhance network connectivity for wireless sensor network," in *Recent Trends in Electronics, Information & Communication Technology (RTEICT)*, *IEEE International Conference on*, 2016, pp. 175–179.
- [55] D. Sharma, S. Verma, and K. Sharma, "Network Topologies in Wireless Sensor Networks: A Review," *Int. J. Electron. Commun. Technol.*, vol. 4, pp. 93–97, 2013, doi: 2230-7109.
- [56] Y. Hu, H. Liu, and J. Liang, "Cluster-Head Election Using Fuzzy Logic Systems in Radar Sensor Networks," in *Proceedings of the 2015 International Conference on Communications, Signal Processing, and Systems*, 2016, pp. 171–179.
- [57] P. Azad and V. Sharma, "Clusterhead selection using multiple attribute decision making (MADM) approach in wireless sensor networks," *Lect. Notes Inst. Comput. Sci. Soc. Telecommun. Eng. LNICST*, vol. 115, pp. 141–142, 2013.
- [58] F. Hamzeloee and M. K. Dermay, "A TOPSIS Based Cluster Head Selection for Wireless Sensor Network," *Procedia Comput. Sci.*, vol. 58, pp. 8–15, 2016, doi: 10.1016/j.procs.2016.09.005.
- [59] H. Farman et al., "Analytical network process based optimum cluster head selection in wireless sensor network," *PLoS One*, vol. 12, no. 7, pp. 1–28, 2017.
- [60] B. Muhammad, R. Bilal, and R. Young, "Fuzzy-TOPSIS based Cluster Head selection in mobile wireless sensor networks," *J. Electr. Syst. Inf. Technol.*, pp. 1–16, 2017, doi: 10.1016/j.jesit.2016.12.004.
- [61] P. Rajpoot and P. Dwivedi, "Multiple Parameter Based Energy Balanced and Optimized Clustering for WSN to Enhance the Lifetime Using MADM," *Wirel. Pers. Commun.*, vol. 106, no. 2, pp. 829–877, 2019, doi: 10.1007/s11277-019-06192-6.
- [62] P. T. Karthick and C. Palanisamy, "Optimized cluster head selection using krill herd algorithm for wireless sensor network," *Automatika*, vol. 60, no. 3, pp. 340–348, 2019, doi: 10.1080/00051144.2019.1637174.
- [63] V. Pal, G. Singh, and R. P. Yadav, "SCHS: Smart Cluster Head Selection Scheme for Clustering Algorithms in Wireless Sensor Networks," *Wirel. Sens. Netw.*, vol. 04, no. 11, pp. 273–280, 2012, doi: 10.4236/wsn.2012.411039.
- [64] X. Kuang, L. Liu, Q. Liu, and L. Xiang, "A clustering approach based on convergence degree chain for wireless sensor networks," *Secur. Commun. Networks*, vol. 5, no. June 2011, pp. 422–437, 2015, doi: 10.1002/sec.
- [65] A. Lipare, D. R. Edla, and R. Dharavath, "Energy Efficient Routing Structure to Avoid Energy Hole Problem in Multi-Layer Network Model," *Wirel. Pers. Commun.*, vol. 112, no. 4, pp. 2575–2596, 2020, doi: 10.1007/s11277-020-07165-w.

## Authors



**Rekha** is working as an Assistant Professor of Computer Science and IT in Apeejay College of Fine Arts, Jalandhar, Punjab, India. She received her MCA degree from Guru Nanak Dev University, Amritsar, Punjab in 1998. Currently, she is working and pursuing her Ph.D. degree from the Department of Computer Science and Engineering, Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala. Her research interests include wireless sensor networks and information security and image processing. She published several papers in journals and conferences.



**Rajeev Gupta** has 15+ years of teaching, research, and software development experience. He is currently working in the Department of Computer Science and Engineering, Maharishi Markandeshwar (Deemed to be University), Mullana, Ambala. His areas of research specialization are Image processing, Internet of Things, WSN, and Mobile Ad-hoc networks. He is an Associate Life Member of Computer Society of India (CSI), Member of International Association of Engineers (IAENG), and Middle East Association of Computer Science and Engineering (MEACSE).