DOI: https://doi.org/10.33103/uot.ijccce.23.2.2

# Analytical Study for Optimization Techniques to Prolong WSNs Life

Hayder I. Mutar[1], Muna M. Jawad[2]
[1,2]*Control and Systems Engineering Department, University of Technology, Baghdad, Iraq*
[1]*cse.19.12@grad.uotechnology.edu.iq*, [2]*muna.m.jawad@uotechnology.edu.iq*

***Abstract****— Wireless Sensor Networks (WSNs) have become the most cost-effective monitoring solution due to their low cost, despite their major drawback of limited power due to dependence on batteries. Each Sensor Node (SN) is clustered in a particular location and forms a network by self-organizing. They often operate in some of the world's most unusual or dangerous conditions. Networking errors, memory and processor limitations, and energy constraints all pose problems for WSN developers. Many problems in WSNs are expressed as multivariate optimization problems that are solved using biologically inspired techniques. Particle swarm optimization (PSO) is an easy, algorithmically sound, and robust optimization technique. It has been used to address problems like Clustering, data routing, Cluster Head (CH) collection, and data collecting in WSNs. This paper presents a brief analysis of WSN studies in which the PSO algorithm was used as the primary or secondary algorithm for enhancing lifespan of WSNs, focusing on results that show energy efficiency in the sensors, extending the network's life.*

***Index Term****— Cluster Head selection, Clustering, PSO, Routing, Wireless Sensor Networks.*

## I. INTRODUCTION

### A. Overview on WSNs and objectives

There is an evident increase in interest in Wireless Sensor Networks (WSNs) due to their wide application in various fields, including medical, military, civil and industrial, etc. A WSN is a network consisting of a set of tiny sensor nodes distributed randomly or uniformly (depending on the application) over a specific area and at least one sink or Base Station (BS) [1] . There are many types of sensor nodes in WSNs: source sensor nodes (normal nodes), intermediate sensor nodes (particularly Cluster Heads (CHs) in aggregate networks), and base station nodes (BSs). These nodes can monitor physical and environmental phenomena [2], [3].

This introduction provides an overview of WSNs in terms of the internal structure of the devices and the overall structure of the WSN, as well as a review of the most significant applications in which WSNs are currently used. Power consumption is the most significant problem facing WSNs because they operate with limited batteries. The problem was discussed with the most important protocols used to save and extend the life of the network, which are the clustering and routing protocols.

The main objectives of this paper are to provide a brief introduction to researchers on the WSNS and explicitly address the energy consumption problems of WSNs. Furthermore, our work is to review many techniques that depend on optimization in extending the life of WSNs, especially those that depend on the PSO algorithm because it is easy to converge

Received 04/May/2022; Accepted 25/May/2022
 ISSN (Print) 1811-9212 ISSN (Online) 2617-3352

DOI: https://doi.org/10.33103/uot.ijccce.23.2.2

and fast in giving results, in addition to the ease of linear programming in it and, on top of that, the availability of research on it. Recently, the PSO became a benchmark for performance measurement for the optimization methods used in energy consumption improvement in WSNs after the well-known LEACH protocol. The techniques are reviewed by clarifying the most important points they followed in their methods and highlighting the most critical obstacles facing the previous methods. The methods are classified in terms of the degree of complexity, contract type, simulation programs, and the metrics used to measure the performance. These analyses provide the researchers with a brief insight into how to start creating the new technologies that they want to build on swarm-based algorithms or other new technologies. Our contribution in this paper is summarized in analyzing previous methods and finding:

1. Strategies to conserve energy for WSNs.
2. Explain how algorithms and optimization methods are used in these strategies.
3. Shed light on the most critical obstacles facing the implementation of the proposed techniques.
4. Analyzing the essential points in the previous techniques, such as node type and the degree of complexity in deriving fitness functions, and the programs used to build and simulate these techniques.

Our paper is divided into two sections: the introduction and Methods of Energy Optimization in WSNs, which discussed numerous techniques presented by various studies for addressing the issues of energy consumption and extending the life of WSNs. As a result of the large number of studies concerned with extending the life of WSN, it was discussed the studies that use optimization methods to extend the life of WSN, especially those that use the PSO algorithm [4], due to their demonstrable results in extending the life of the network, speed of convergence, and their ease of application.

## B. Architecture of WSNs

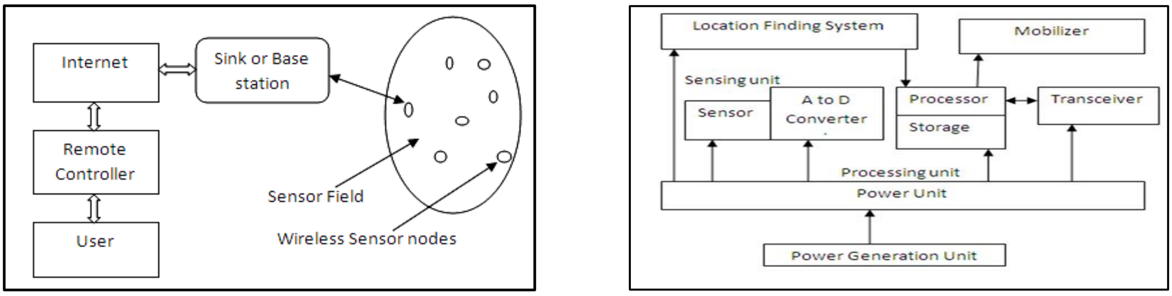
A WSN is a subset of a wireless network comprised of tiny (nodes), geographically dispersed autonomous devices capable of jointly sensing physical occurrences in their vicinity[5]. WSNs are composed of a single sink node and a large number of sensor nodes (SNs) distributed over a vast region (sensing field), as seen in *Fig. 1-a.* Data is transported between nodes and base stations through single-hop or multi-hop communication, and from the sink to the user over the internet[6].

A sensor node (SN) is composed of four fundamental components:1. Sensing unit consists of: Sensors and Analog-to-Digital Converter (ADC). 2. Unit of processing. 3. A unit of transceiver. 4. Power supply unit, as shown in the *Fig. 1-b.* The sensor creates an analog signal, which is transformed to a digital signal and then sent to the processor unit through the ADC. The processing unit is a tiny storage unit that manages the operation and allows the node to interface with other nodes in order to complete the sensing duties given to it. The transceiver unit is responsible for connecting the node to the network, whereas the sensor node's primary function is to detect events, perform data processing, and communicate information [6] .

Received 04/May/2022; Accepted 25/May/2022

ISSN (Print) 1811-9212 ISSN (Online) 2617-3352

DOI: https://doi.org/10.33103/uot.ijccce.23.2.2




A- COMPONENTS OF WSNS B- ARCHITECTURE OF WIRELESS SENSOR NODE

FIG. 1. COMPONENTS AND ARCHITECTURE OF WSNS [6].

## C. Applications of WSNs

WSN has recently gained prominence worldwide due to its diverse applications in various fields, including military surveillance, environment, industrial automation, home automation, medical management, and subsea exploration. *Fig. 2.* shows the classification of applications into five main parts [7].

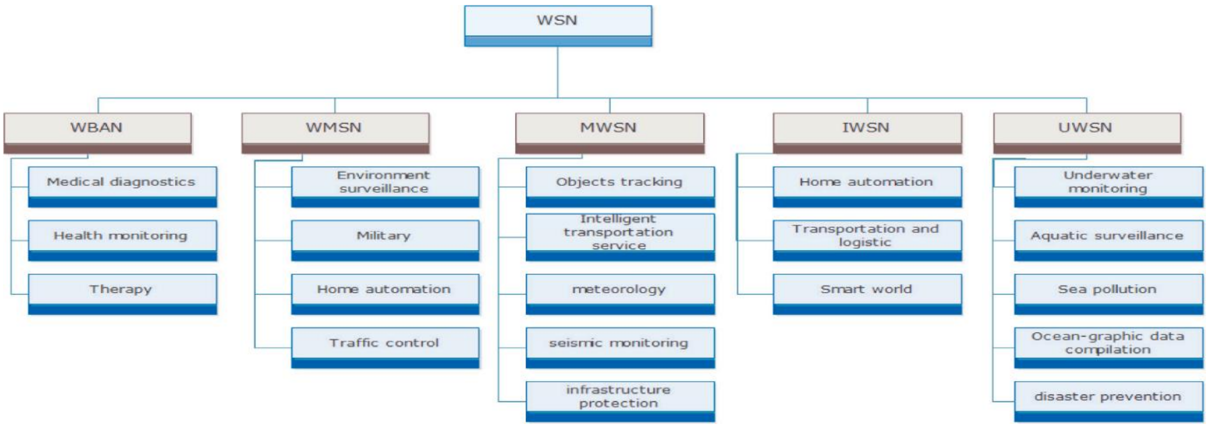



FIG. 2. WSN APPLICATIONS [7].

WBAN (Wireless Body Area Network), this term refers to sensor networks are employed in the medical and healthcare fields; (2) WMSN (Wireless Multimedia Sensor Network) is employed, when sensor nodes transport multimedia content like photos, audio, and video. (3) MWSN (Mobile WSNs) this refers to the applications that need the mobility of nodes, such as item tracking, seismic monitoring, meteorology, intelligent transportation services, and infrastructure security. (4) IWSN (Industrial WSN) refers to sensor nodes that are used across industrial societies or factories to control machinery. (5) UWSNs (Underwater WSNs) used the sensor nodes for underwater navigation, monitoring marine pollution, and disaster mitigation, among other functions [7].

## D. Power consumption of WSNs

WSNs face many limitations, the most important of which is limited power, as they depend on batteries to operate. Add to that the random deployment in remote areas and the limitation of the rest units, such as the processing unit, the sensor unit, and the type of communication that the sensor depends on within the network.

Received 04/May/2022; Accepted 25/May/2022
 ISSN (Print) 1811-9212 ISSN (Online) 2617-3352

DOI: https://doi.org/10.33103/uot.ijccce.23.2.2

WSN has restricted power source due to hardware limitations. Each node in a multi-hop ad-hoc sensor network performs two main functions: **(1)** ***Data aggregation***: The fundamental function of each sensor node is to acquire data from the environment through numerous sensors. The collected data through environmental sensing must be analyzed and delivered to neighboring sensor nodes from multi-hop delivery to the sink. **(2)** ***Data forwarding***: the SN is responsible for receiving data from its neighbors and passing it to one of its neighbors based on routing choices.

The primary goal of SN in sensing field is to detect events, process local data, and then broadcast the results. As a result, power consumption can be divided into three categories: ***sensing***, ***data processing***, and ***data transfer***, all handled by sensors, CPUs, and radios, respectively. The power consumption of a sensor node is depicted in *Fig. 3.* As can be seen, when compared to the other three, a sensor node uses the most energy for ***data transfer*** [8].

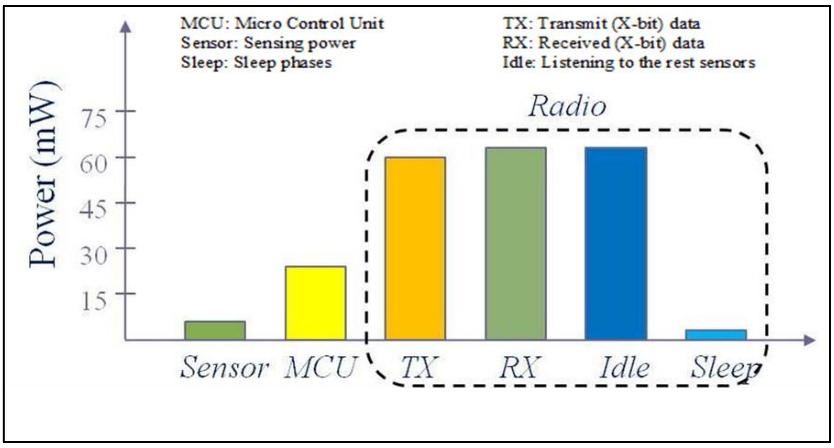



FIG. 3. POWER CONSUMPTION OF SN [8].

### E. Clustering Protocols in WSNs

Clustering refers to the division of SNs in field sensing into numerous groups referred to as clusters, each with its leader referred to as the CH. Each SN senses data and transmits it to its associated CH [9]. After that, CHs send the data to a BS either directly (single-hop) or in a multi-hop manner [10].

Clustering is used in WSNs to accomplish many goals. The main goal is to increase the network's lifespan and performance. Clustering methods use a variety of different approaches to accomplish their goals. Several advantages of clustering methods include the following[11]: Maximize network longevity, Decreasing energy consumption, Reduce redundant data, Load balancing in the network, Maximum network coverage, Avoidance of collisions, and Enhancing the network's stability.

Many protocols, techniques, and approaches have been used in clustering protocols based on WSNs. Clustering protocols have been classified according to their methodology and processes for managing clustering activities [9], [10], [12]–[15]. *Rawat and Chauhan in 2021* [11] classified clustering protocols into ***four types*** according to their methodology and processes for managing clustering activities as follows: Homogeneous, Heterogeneous, Fuzzy and Heuristic protocols.

Received 04/May/2022; Accepted 25/May/2022

DOI: https://doi.org/10.33103/uot.ijccce.23.2.2

### F. Routing Protocols in WSNs

Routing is how nodes are transmitted and routed to transfer their data to the sink; Routing has a significant effect on decreasing energy usage and improving network life. However, designing routing protocols in a WSN is challenging because it involves limitations for network energy efficiency. The most critical challenges facing the design of an appropriate routing protocol in WSNs are power consumption limits, node deployment, data aggregation, node capability, fault tolerance, and network dynamics [16]. Other routing challenges in WSNs include quality service, scalability, connectivity and coverage, transmission media, limited hardware resources, and more[17].

## II. TECHNIQUES OF ENERGY OPTIMIZATION IN WSNs

Optimization techniques have recently been extensively applied to address several WSN-related issues, particularly the issue of WSN lifetime, where selecting CHs from other nodes in the surveillance field is an NP-hard problem. As a result, the optimization algorithms generate optimum or near-optimal solutions for the chosen CHs and the optimal path for data routing.

PSO is a pillar or the foundational basis of these scientific papers on ground-breaking algorithms and developing WSNs to increase network existence and optimize energy consumption. The following studies demonstrate the PSO algorithm's superiority over many previously used protocols (such as the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol, which is considered a benchmark for measuring energy consumption in WSNs) and other algorithms for reducing energy consumption.

### A. Targets of Studies

This section summarizes the most significant proposals and protocols presented by researchers aimed at extending the life of WSNs and demonstrating how they used the PSO algorithm to accomplish their objectives of enhancing the overall performance of WSNs, as well as highlighting the most significant disadvantages of their proposals. Concerning the advantages, they have been shown in the majority of studies to significantly improve the life of WSNs by saving the sensors' energy for the longest feasible amount of time, among other things.

Table I highlights the essential objectives of each study, the names of the researchers, the study's history and the most significant disadvantages of each study. We avoided explaining the advantages of each technology because they all contributed to the longevity of WSNs. In addition, all the techniques analyzed made progress over their predecessors, with which their performance was compared.

TABLE I. TARGETS OF STUDIES

| AUTHORS | SUMMARY OF RELATED WORK | Disadvantages |
|---|---|---|
| 1. Rejinaparvin and et al. (2015) [18] | They suggested two algorithms: PSO for the clustering stage for eliminating individual nodes; and Gravitational Search Algorithm (GSA) for routing, which determines the optimal route from nodes to the BS for hopping to transmit sensing data. Along with the CH node, a Cluster-Assistant node was suggested. | Combining two optimization techniques for CH selection and routing consumes considerable resources; add an additional CH selection. |

Received 04/May/2022; Accepted 25/May/2022

ISSN (Print) 1811-9212 ISSN (Online) 2617-3352

DOI: https://doi.org/10.33103/uot.ijccce.23.2.2

| | | | |
|---|---|---|---|
| 2. | Solaiman and et al. (2016) [19] | They combined two algorithms, the first K-mean algorithm for the purpose of grouping the nodes into a set of clusters and the second is PSO algorithm to choose the best CH for each cluster. | The CH is elected twice per iteration, once through the K-mean and once through the PSO. |
| 3. | Vimalarani and et al. (2016) [20] | The PSO was suggested for two purposes: clustering and CH selection. They offered two modes of communication based on the distance to the BS: direct-hop, or multi-hop. | A high degree of complexity by adopting a fitness function for clustering and another for selecting CH, and each function depends on three determinants, which increases the degree of complexity. |
| 4. | Rao and et al. (2017) [21] | They used optimization and hierarchical methods for clustering, where PSO for CHs selection, and (CH-Weight) for clusters formation. | The selection of CHs prior to clustering results in an imbalanced distribution of CHs in the field. |
| 5. | Xiang, and et al. (2017) [22] | They used PSO to identify CHs based on a fitness function, and then clusters are formed based on the signal strength received from CHs. | It is possible to lose nodes during the clustering process, or there may be irregularity in the connection of the nodes with two of the CHs, resulting in a connection conflict. |
| 6. | Yadav and et al. (2018) [23] | They incorporated PSO into the LEACH to find the optimal CHs, based on fitness function in PSO. | Ignore the clustering process and the method for nodes to be connected to CHs. |
| 7. | Kanchan and et al. (2018) [24] | They proposed a Quantum-inspired PSO-based network life extension algorithm consisting of three steps: Position updating, CH selection, and Formation of clusters. For each step, there is a fitness function ( i.e. three fitness functions). | Three fitness functions, each with its own set of constraints that need a significant amount of hardware resources. |
| 8. | Asha and et al. (2018) [25] | They used three algorithms for clustering and routing; the PSO and K-means for clustering and selected the optimal CHs. The Glowworm Swarm Optimization (GSO) algorithm for routing and finding optimal paths within a cluster and between clusters in WSN. | A combination of algorithms based on fitness functions requires a lot of processing, power consumption and delay. |
| 9. | Vijayalakshmi and et al. (2018) [26] | They combined two metaheuristic algorithms, PSO and Tabu Search (TS), in order to select the best CHs and find the best path to route data to the BS. | TS consumes more energy compared to PSO and uses less processing time than PSO. |
| 10. | Tabibi and et al. (2018) [27] | They used PSO to define the set of nodes representing as Rendezvous Points (RP) with the mobile sink, i.e. selecting CHs from among the nodes by PSO, and finding the shorten path for mobile sink to discover the CHs. | Reducing of clusters to a minimum resulting increases the multiplicity of hops or increase the distance between Rendezvous Points (RP) and nodes. |
| 11. | Shanthi and et al. (2019) [28] | They suggested the PSO and Fish Swarm Optimization (FSO), built on a multi-hop clustering algorithm, to reduce power utilization in WSN. | The combination of two metaheuristic algorithms, each based on two fitness functions, with many parameters, results in a high degree of complexity in resource consumption and delay in data transmission. |
| 12. | Wang and et al. (2019) [29] | They used PSO in the heterogeneous phase of the network to select CHs based on a specific fitness function. | Maybe a conflict in motion of mobile sink in the event more than one CHs transmits their information. |
| 13. | Jothikumar and et al. (2019) [30] | They combined PSO and a Heuristic Algorithm for Clustering Hierarchy (HACH), where the clustering procedure is determined by the hierarchy algorithm and the CH-selection process by PSO. | They overlooked the issue of hot spots in CHs located near the sink. |

*Received 04/May/2022; Accepted 25/May/2022*

*ISSN (Print) 1811-9212*  *ISSN (Online) 2617-3352*

DOI: https://doi.org/10.33103/uot.ijccce.23.2.2

| | | | |
|---|---|---|---|
| 14. | Battar and et al. (2019) [31] | They suggested using PSO and Firefly algorithms to find the shortest path to route the aggregation data to the sink node. | They conducted no simulations of their idea and did not establish an equation for their algorithm's fitness function. |
| 15. | Preethiya and et al. (2019) [32] | They suggested constructing a hybrid WSN consisting of sink nodes "females" and normal nodes "Children." The female nodes would select the CHs from their clusters-Children's based on PSO. | There is complexity as a result of four fitness function constraints and two stages for each clustering and routing phase. |
| 16. | Mahima and et al. (2019) [33] | They used PSO to improve the LEACH protocol in the CHs selection process and other meta-heuristic algorithms to route data to BS. | Using several algorithms increases complexity and uses a large amount of hardware resources. |
| 17. | Shinde and et al. (2020) [34] | They use PSO to select the CHs, and then the network is formed based on the signal strength received from the nodes. | They did not specify the mathematical formula for their fitness function. |
| 18. | Zhang and et al. (2020)[35] | They used the "Dynamic Adaptive Classification PSO" (DAC-PSO) protocol to select the CH-central and CH-aid to route data to the sink. | Two fitness functions for clustering with three limitations and one fitness function for routing data and election two cluster heads. |
| 19. | Sahoo and et al. (2020) [36] | They suggested PSO for selecting CH by a fitness function based on five factors: residual energy, distance, node degree, average energy, and energy consumption rate. | Fitness function for clustering with a lot of limitations. |
| 20. | Moorthi and et al. (2020) [37] | they suggested integrating PSO in LEACH protocol for clustering, selecting CHs, and routing data based on the shortest distance to receiving nodes. | Without any mathematical fitness function for clustering. |
| 21. | Loganathan and et al. (2021) [38] | They proposed a new energy-efficient CH-selection method based on PSO to solve disparity clustering and routing issues by assumed a Super CH between the SN and the CH and sink nodes. | Not helpful in homogeneous network. |

## B. Studies Analysis

This section analyzes studies based on the experiment's field, the homogeneity of the nodes, the simulation programs, and the degree of complexity of studies. We mean by "complexity degree" the number of algorithms and fitness functions combined to create a unique technology for each study; combining multiple algorithms, numerous constraints, and numerous fitness functions in a single study results in an increased complexity degree; therefore, it requires additional processing and time delay, consequently, additional hardware resources. The node type has a direct impact on the lifespan of WSNS as well as the implementation of the technique, where heterogeneous nodes are always considered to have infinite energy, unlike the rest of the nodes, which are homogeneous. Routing techniques often use heterogeneous nodes to avoid the problems caused by hot spot points near the BS. Table II, illustrate studies analysis. Chart in *Fig. 4* shows the percentage of proposed node types in studies. Chart in *Fig. 5* shows the percentage of the used simulation programs in studies. *Fig. 6* shows the percentage of complexity degrees in studies. These charts provide a quick analysis of the percentages of the most significant programs and the types of nodes employed, etc., to provide researchers with an early indication of the direction of previous methods. The performance metrics are collected from the 21 research papers and are displayed in *Fig. 7* as a pie chart. Energy consumption, residual energy, network lifetime, number of living nodes, number of dead nodes, network throughput, number of packets sent and received, and network stability duration have been used to evaluate these studies.

Received 04/May/2022; Accepted 25/May/2022
 

DOI: https://doi.org/10.33103/uot.ijccce.23.2.2

TABLE II. TECHNIQUES ANALYSIS

| Ref. | FIELD OF RESEARCH | Nodes type | Simulation program | Complexity degree |
|---|---|---|---|---|
| [18] | Clustering nodes and Routing data | Homogeneous | NS-2 | Complex |
| [19] | Clustering and CH selection | **Heterogeneous** | MATLAB | Complex |
| [20] | Clustering and CH selection | Homogeneous | NS-2 | Simple |
| [21] | Clustering and CH selection | Homogeneous | MATLAB | Simple |
| [22] | Routing and Clustering | Homogeneous | MATLAB | Simple |
| [23] | CH selection | Homogeneous | MATLAB | Simple |
| [24] | CH selection | Homogeneous | C++ | Complex |
| [25] | CH selection and Routing | Homogeneous | MATLAB | Complex |
| [26] | CH selection and Routing | Homogeneous | MATLAB | Simple |
| [27] | Mobile Sink and Routing | Homogeneous | MATLAB | Simple |
| [28] | Clustering algorithm | Homogeneous | MATLAB | Complex |
| [29] | Clustering, CH selection and Routing | Homogeneous | MATLAB | Complex |
| [30] | Clustering, CH-selection, and Routing | Homogeneous | MATLAB | Complex |
| [31] | Routing | Homogeneous | Suggest MATLAB | Complex |
| [32] | CH selection and Routing | Heterogeneous | NS-2 | Complex |
| [33] | CH selection and Routing | Homogeneous | NS-2 | Complex |
| [34] | Clustering and CH selection | Homogeneous | MATLAB | Simple |
| [35] | CH selection | Homogeneous | MATLAB | Complex |
| [36] | Mobile Sink and CH selection | **Heterogeneous** | MATLAB | Complex |
| [37] | Clustering algorithm | Homogeneous | NS-2 | Simple |
| [38] | Clustering, CH selection and Routing | **Heterogeneous** | MATLAB | Complex |

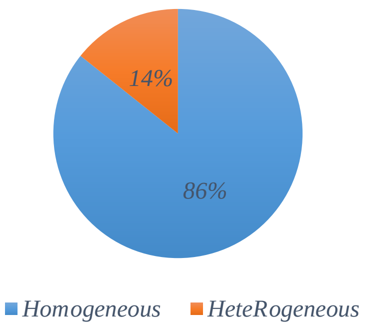



FIG. 4. PROPOSED NODE TYPES IN ALGORITHMS.

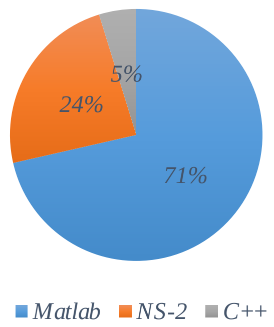



FIG.5. SIMULATION PROGRAMS IN TECHNIQUES.

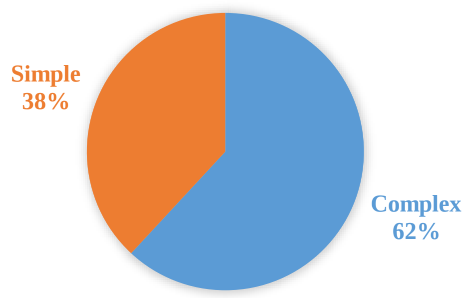



FIG. 6. COMPLEXITY DEGREES IN METHODS.

Received 04/May/2022; Accepted 25/May/2022

ISSN (Print) 1811-9212 ISSN (Online) 2617-3352

DOI: https://doi.org/10.33103/uot.ijccce.23.2.2

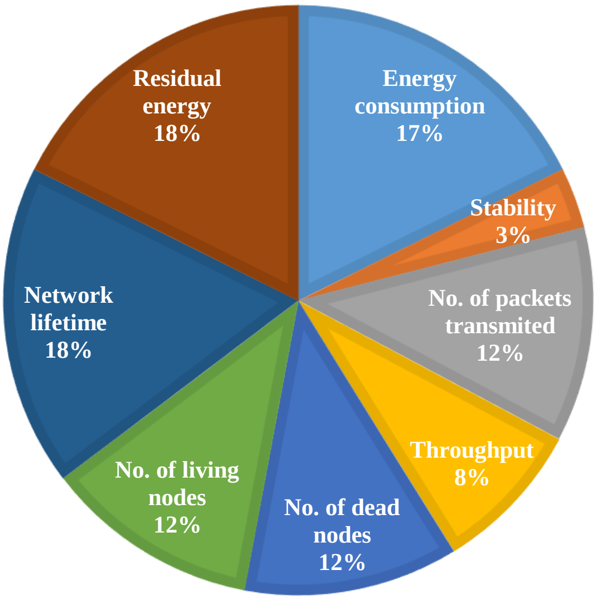



FIG. 7. THE PERFORMANCE METRICS.

## III. CONCLUSIONS

Insufficient energy supply to the sensor node is a common design concern for WSNs. When appropriate CH selection procedures are used, network longevity increases significantly. This paper explores many techniques for selecting CHs using optimization techniques, especially those that are related to PSO. The purpose of this study is to discuss several clustering, CH-selection, and routing processes and their associated CH selection techniques. Then, the research gaps discovered in each technique for optimizing CH selection and routing methods are described, in order to facilitate future research on CH selection and routing techniques. Increasing complexity in creating any technology has many algorithms, and fitness functions with many limitations, combined to create that technology gives excellent results in extending WSN lifespan but at the expense of consuming additional hardware resources. Additionally, an analysis is conducted to determine the energy efficiency, network lifespan, number of living and dead nodes, energy consumption, and residual energy of the tools used for installation and performance assessment. The analysis of these techniques led us to the following conclusions: (1) The majority of techniques utilize homogeneous nodes (86%) at the expense of heterogeneous ones (14%). (2) MATLAB is the most popular program for simulating these techniques' implementation. As a natural consequence of the evolution of hardware resources, the majority of researchers tend to add a great deal of complexity to their algorithm creation. In the future, we will present a comprehensive investigation of all optimization algorithms that address the issues of WSNs in terms of optimizing energy consumption and other issues.

Received 04/May/2022; Accepted 25/May/2022

DOI: https://doi.org/10.33103/uot.ijccce.23.2.2

## REFERENCES

[1] S. A. Hashim, M. M. Jawad, and B. M. S. Wheedd, "Study of Energy Management in Wireless Visual Sensor Networks," *Iraqi J. Comput. Commun. Control Syst. Eng.*, no. July, pp. 68–75, 2020, doi: 10.33103/uot.ijccce.20.1.7.

[2] H. I. Mutar and D. M. M. Jawad, "Enhancing Energy Utilization in Wireless Sensor Networks ( WSNs ) by Particle Swarm Optimization ( PSO )," *Webology*, vol. 19, no. 1, pp. 6089–6107, 2022, [Online]. Available: https://www.webology.org/abstract.php?id=1337.

[3] S. A. Hashim, M. M. Jawad, and B. M. S. Wheedd, "A Sustainable Scheme for Minimizing Energy in Visual Sensor Network using Disjoint Set Cover Approach," *Eng. Technol. J.*, vol. 38, no. 1, pp. 1–7, 2020.

[4] J. Kennedy and R. Eberhart, "Particle swarm optimization," in *Proceedings of ICNN'95-international conference on neural networks*, 1995, vol. 4, no. 2, pp. 1942–1948.

[5] M. K. Mishra, "A Review of Wireless Sensor Networks," *Int. J. Res. Appl. Sci. Eng. Technol.*, vol. 7, no. 4, pp. 2446–2448, 2013, doi: 10.22214/ijraset.2019.4445.

[6] M. K. Singh, S. I. Amin, S. A. Imam, V. K. Sachan, and A. Choudhary, "A Survey of Wireless Sensor Network and its types," *Proc. - IEEE 2018 Int. Conf. Adv. Comput. Commun. Control Networking, ICACCCN 2018*, pp. 326–330, 2018, doi: 10.1109/ICACCCN.2018.8748710.

[7] I. Daanoune, B. Abdennaceur, and A. Ballouk, "A comprehensive survey on LEACH-based clustering routing protocols in Wireless Sensor Networks," *Ad Hoc Networks*, vol. 114, no. July 2020, p. 102409, 2021, doi: 10.1016/j.adhoc.2020.102409.

[8] Ian F. Akyildiz and M. C. Vuran, *Wireless Sensor Networks*, First. The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom For: John Wiley & Sons Ltd, 2010.

[9] A. S. Rostami, M. Badkoobe, F. Mohanna, H. keshavarz, A. A. R. Hosseinabadi, and A. K. Sangaiah, *Survey on clustering in heterogeneous and homogeneous wireless sensor networks*, vol. 74, no. 1. Springer US, 2018.

[10] P. K. Mishra and S. K. Verma, "A survey on clustering in wireless sensor network," *2020 11th Int. Conf. Comput. Commun. Netw. Technol. ICCCNT 2020*, 2020, doi: 10.1109/ICCCNT49239.2020.9225420.

[11] P. Rawat and S. Chauhan, "Clustering protocols in wireless sensor network: A survey, classification, issues, and future directions," *Comput. Sci. Rev.*, vol. 40, p. 100396, 2021, doi: 10.1016/j.cosrev.2021.100396.

[12] A. Shahraki, A. Taherkordi, Ø. Haugen, and F. Eliassen, "Clustering objectives in wireless sensor networks: A survey and research direction analysis," *Comput. Networks*, vol. 180, p. 107376, 2020, doi: 10.1016/j.comnet.2020.107376.

[13] 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.

[14] X. Liu, *A survey on clustering routing protocols in wireless sensor networks*, vol. 12, no. 8. 2012.

[15] F. Fanian and M. Kuchaki Rafsanjani, "Cluster-based routing protocols in wireless sensor networks: A survey based on methodology," *J. Netw. Comput. Appl.*, vol. 142, no. September 2018, pp. 111–142, 2019, doi: 10.1016/j.jnca.2019.04.021.

[16] P. C. S. Rao, P. K. Jana, and H. Banka, "A particle swarm optimization based energy efficient cluster head selection algorithm for wireless sensor networks," *Wirel. Networks*, vol. 9, no. 3, pp. 667–676, 2016, doi: 10.1007/s11276-016-1270-7.

[17] D. Goyal and M. R. Tripathy, "Routing protocols in wireless sensor networks: A survey," *Proc. - 2012 2nd Int. Conf. Adv. Comput. Commun. Technol. ACCT 2012*, pp. 474–480, 2012, doi: 10.1109/ACCT.2012.98.

[18] J. Rejinaparvin and C. Vasanthanayaki, "Particle swarm optimization-based clustering by preventing residual nodes in wireless sensor networks," *IEEE Sens. J.*, vol. 15, no. 8, pp. 4264–4274, 2015, doi: 10.1109/JSEN.2015.2416208.

[19] B. F. Solaiman and A. Sheta, "Energy optimization in wireless sensor networks using a hybrid K-means PSO clustering algorithm," *Turkish J. Electr. Eng. Comput. Sci.*, vol. 24, no. 4, pp. 2679–2695, 2016, doi: 10.3906/elk-1403-293.

[20] C. Vimalarani, R. Subramanian, and S. N. Sivanandam, "An Enhanced PSO-Based Clustering Energy Optimization Algorithm for Wireless Sensor Network," *Sci. World J.*, vol. 2016, 2016, doi: 10.1155/2016/8658760.

[21] P. C. S. Rao, P. K. Jana, and H. Banka, "A particle swarm optimization based energy efficient cluster head selection algorithm for wireless sensor networks," *Wirel. Networks*, 2016, doi: 10.1007/s11276-016-1270-7.

[22] Y. Zhou, N. Wang, and W. Xiang, "Clustering Hierarchy Protocol in Wireless Sensor Networks Using an Improved PSO Algorithm," *IEEE Access*, vol. 5, no. c, pp. 2241–2253, 2017, doi: 10.1109/ACCESS.2016.2633826.

[23] A. Yadav, S. Kumar, and S. Vijendra, "Network life time analysis of WSNs using particle swarm optimization," *Procedia Comput. Sci.*, vol. 132, pp. 805–815, 2018, doi: 10.1016/j.procs.2018.05.092.

[24] P. Kanchan and S. D. Pushparaj, "A quantum inspired PSO algorithm for energy efficient clustering in wireless sensor networks," *Cogent Eng.*, vol. 5, no. 1, pp. 1–16, 2018, doi: 10.1080/23311916.2018.1522086.

[25] G. Asha and Gowrishankar, "An Energy aware Routing Mechanism in WSNs using PSO and GSO Algorithm," in *2018 5th International Conference on Signal Processing and Integrated Networks, SPIN 2018*, 2018, pp. 7–12, doi: 10.1109/SPIN.2018.8474140.

*Received 04/May/2022; Accepted 25/May/2022*

DOI: https://doi.org/10.33103/uot.ijccce.23.2.2

[26] K. Vijayalakshmi and P. Anandan, “A multi objective Tabu particle swarm optimization for effective cluster head selection in WSN,” *Cluster Comput.*, vol. 22, pp. 12275–12282, 2018, doi: 10.1007/s10586-017-1608-7.

[27] S. Tabibi and A. Ghaffari, “Energy-Efficient Routing Mechanism for Mobile Sink in Wireless Sensor Networks Using Particle Swarm Optimization Algorithm,” *Wirel. Pers. Commun.*, vol. 104, no. 1, pp. 199–216, 2018, doi: 10.1007/s11277-018-6015-8.

[28] G. Shanthi and M. Sundarambal, “FSO–PSO based multihop clustering in WSN for efficient Medical Building Management System,” *Cluster Comput.*, vol. 22, pp. 12157–12168, 2019, doi: 10.1007/s10586-017-1569-x.

[29] J. Wang, Y. Gao, W. Liu, A. K. Sangaiah, and H. J. Kim, “An Improved Routing Schema with Special Clustering Using PSO Algorithm for Wireless Sensor Network,” *Sensors (Switzerland)*, vol. 19, no. 3, pp. 15–24, 2019, doi: 10.3390/s19030671.

[30] C. Jothikumar and R. Venkataraman, “EODC: An Energy Optimized Dynamic Clustering protocol for Wireless Sensor Networks using PSO approach,” *Int. J. Comput. Commun. Control*, vol. 14, no. 2, pp. 183–198, 2019, doi: 10.15837/ijccc.2019.2.3379.

[31] S. Battar and R. Kumar, “A Hybrid Approach to Increase Network Lifetime in WSN Using PSO and Firefly Optimization,” 2019, doi: 10.1109/ICECCT.2019.8869445.

[32] T. Preethiya, A. Muthukumar, and S. Durairaj, “Double Cluster Head Heterogeneous Clustering for Optimization in Hybrid Wireless Sensor Network,” *Wirel. Pers. Commun.*, vol. 110, no. 4, pp. 1751–1768, 2019, doi: 10.1007/s11277-019-06810-3.

[33] A. Pushpalatha, R. Mahima, K. S. Kiruthik Ruba, E. Mohanraj, P. Rajaram, and S. Ramesh, “Energy Optimized data routing using PSO in WSN,” *Int. J. Adv. Sci. Technol.*, vol. 29, no. 3, pp. 8298–8303, 2020.

[34] A. S. Shinde and R. S. Bichkar, “Optimal Cluster Head Selection and Clustering for WSN using PSO,” *Int. J. Innov. Technol. Explor. Eng.*, vol. 9, no. 3, pp. 389–395, 2020, doi: 10.35940/ijitee.b7607.019320.

[35] B. Zhang, S. Wang, and M. Wang, “Area double cluster head APTEEN routing protocol-based particle swarm optimization for wireless sensor networks,” *Eurasip J. Wirel. Commun. Netw.*, vol. 2020, no. 1, 2020, doi: 10.1186/s13638-020-01770-w.

[36] B. M. Sahoo, T. Amgoth, and H. M. Pandey, “Particle swarm optimization based energy efficient clustering and sink mobility in heterogeneous wireless sensor network,” *Ad Hoc Networks*, vol. 106, 2020, doi: 10.1016/j.adhoc.2020.102237.

[37] Moorthi and R. Thiagarajan, “Energy consumption and network connectivity based on Novel-LEACH-POS protocol networks,” *Comput. Commun.*, vol. 149, pp. 90–98, 2020, doi: 10.1016/j.comcom.2019.10.006.

[38] S. Loganathan and J. Arumugam, “Energy Efficient Clustering Algorithm Based on Particle Swarm Optimization Technique for Wireless Sensor Networks,” *Wirel. Pers. Commun.*, vol. 119, no. 1, pp. 815–843, 2021, doi: 10.1007/s11277-021-08239-z.

Received 04/May/2022; Accepted 25/May/2022

ISSN (Print) 1811-9212 ISSN (Online) 2617-3352