International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 1
DOI: https://doi.org/10.17762/ijritcc.v11i1.6085
***Article Received**: 24 November 2022 **Revised**: 28 December 2022 **Accepted**: 10 January 2023*

Spread Spectrum based QoS aware Energy Efficient Clustering Algorithm for Wireless Sensor Networks

Bandi Rambabu[1], B Vikranth[2], S Anupkanth[3], Banoth Samya[4], Nimmala Satyanarayana[5]
[1]Dept. of Computer Science and Engineering
CVR College of Engineering , Hyderabad, India
rambabubandi@gmail.com
[2]Dept. of Information Technology
CVR College of Engineering, Hyderabad, India
b.vikranth@gmail.com
[3]Dept. of Information Technology
CVR College of Engineering, Hyderabad, India
s.anupkant@cvr.ac.in
[4]Dept. of Computer Science and Engineering
CVR College of Engineering, Hyderabad, India
samyabanoth@cvr.ac.in
[5]Dept. of Computer Science and Engineering,
CVR College of Engineering, Hyderabad, India
satyauce234@gmail.com

Abstract—Wireless sensor networks (WSNs) are composed of small, resource-constrained sensor nodes that form self-organizing, infrastructure-less, and ad-hoc networks. Many energy-efficient protocols have been developed in the network layer to extend the lifetime and scalability of these networks, but they often do not consider the Quality of Service (QoS) requirements of the data flow, such as delay, data rate, reliability, and throughput. In clustering, the probabilistic and randomized approach for cluster head selection can lead to varying numbers of cluster heads in different rounds of data gathering. This paper presents a new algorithm called "Spread Spectrum based QoS aware Energy Efficient Clustering for Wireless sensor Networks" that uses spread spectrum to limit the formation of clusters and optimize the number of cluster heads in WSNs, improving energy efficiency and QoS for diverse data flows. Simulation results show that the proposed algorithm outperforms classical algorithms in terms of energy efficiency and QoS.

Keywords- Clustering, Spread Spectrum, Quality of Sevice, Artificial Bee Colony , Enegry Efficient.

I. INTRODUCTION

The development of Micro-Electro-Mechanical Systems (MEMS) has allowed for the creation of small, low-cost sensor nodes that can sense, process, and communicate data[1]. These nodes are used in a variety of Wireless Sensor Network (WSN) applications, including habitat monitoring, health monitoring, smart homes, disaster management, military surveillance, traffic monitoring, and environmental studies[2]. The transducers in sensor nodes record various environmental conditions, such as pressure and temperature, and transmit this data to a base station or sink node through single-hop or multi-hop networking. However, the limitations of low bandwidth, processing power, short communication range, limited battery life, and random deployment of sensor nodes in a wireless network have led to the development of energy and resource-efficient routing protocols in the network layer[3]. These protocols primarily focus on optimizing energy usage to improve the lifetime and scalability of the network, but often do not consider the QoS requirements of the data flow or the data-centric attributes of WSNs[4].

Protocol stacks developed for the traditional networks, such as those with sender/receiver or end-to-end communication, are not suitable for Wireless Sensor Networks (WSNs). Instead, WSNs utilize a many-to-one communication model, in which data from each sensor node is transmitted to a base station or sink node. As a result, existing QoS and routing protocols designed for traditional end-to-end networks are not suitable for WSNs[5]. In addition, the number of nodes selecting a particular node as a cluster head can impact the energy efficiency of clustering algorithms[6]. All clustering schemes utilize CDMA codes to avoid interference within clusters, but the randomized approach for cluster head selection used in the LEACH scheme can result in a variable number of cluster heads

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 1
DOI: https://doi.org/10.17762/ijritcc.v11i1.6085
***Article Received**: 24 November 2022 **Revised**: 28 December 2022 **Accepted**: 10 January 2023*

in different rounds, which consumes more energy[7]. To address this issue and reduce energy consumption and provide the required QoS to the sensed data, this paper proposes the "Spread Spectrum based QoS aware Energy Efficient Clustering algorithm in Wireless Sensor Networks," which limits the number of cluster heads and improves QoS in WSNs.

The simulations conducted in MATLAB demonstrate that the proposed approach is able to improve upon various algorithms in terms of energy efficiency and network lifetime, etc. This paper is organized as follows: it begins with a discussion of the motivation behind the research and a review of related work. The subsequent chapters provide a detailed explanation of the proposed algorithm, describe the implementation and analysis of the simulation results, and conclude with a summary of the key findings. Overall, the results of the simulations suggest that the "Spread Spectrum based QoS aware Energy Efficient Clustering algorithm in Wireless Sensor Networks" is a promising solution for improving QoS and energy efficiency in WSNs.

II. MOTIVATION

The proposed algorithm is motivated by the need for diverse data flows in various domain-specific applications of WSNs to have different QoS requirements. For example, real-time sensing and data acquisition applications such as disaster management and military require appropriate QoS while maintaining energy efficiency and scalability[8]. The proposed model addresses these requirements by considering the data-centric nature of WSNs and utilizing a centralized, base station-assisted solution for clustering that provides energy efficiency and scalability approach. In this design, sensor nodes generate sensed data and specify the flow characteristics to the cluster head, which then uses a base station assisted QoS communication subnetwork to guarantee the required QoS in reaching the base station. It is important to note that earlier developments in energy efficiency and optimization were not considered QoS[9].

III. RELATED WORK

There are many publications that focus on energy efficient routing in wireless sensor networks (WSNs) without considering quality of service (QoS). "A Survey on Energy Efficient Routing Protocols in Wireless Sensor Networks" by Hassanien et al. [10]review a number of energy efficient routing protocols for WSNs, including LEACH (Low-Energy Adaptive Clustering Hierarchy), PEGASIS (Power-Efficient Gathering in Sensor Information Systems), and EEUC (Energy Efficient Unequal Clustering). These protocols aim to reduce the energy consumption of sensor nodes by carefully selecting the nodes that forward data and balancing the load among the nodes. However, these protocols do not consider QoS in their design. They focus solely on minimizing energy consumption, without taking into account other factors such as the reliability or latency of the data transmission[11]. This can be a limitation in some applications where QoS is an important consideration.

There have been several works that have extended the Low Energy Adaptive Clustering Hierarchy (LEACH) protocol[12] to consider Quality of Service (QoS) requirements in wireless sensor networks (WSNs).One approach is to modify the cluster formation and selection process in LEACH to prioritize QoS. Examples of this include the Priority-based Energy Efficient Clustering Algorithm (PEECA)[13], which assigns priority levels to sensor nodes based on their QoS requirements and uses this information to select cluster heads, and the QoS-aware LEACH (Q-LEACH) [12], which introduces a QoS parameter in the cluster head selection probability to prioritize nodes with higher QoS requirements. Another approach is to combine LEACH with other QoS-aware routing protocols to improve the overall performance of the network. Examples of this include the Hybrid Energy Efficient Clustering Algorithm (HEECA) [4], which combines LEACH with the Energy Efficient Routing Protocol for Quality of Service (EERP-QoS)[14], and the Enhanced LEACH (E-LEACH)[15], which integrates LEACH with the Energy Efficient and QoS-aware Routing Protocol (EEQRP)[16]. there are various approaches for incorporating QoS considerations into the LEACH protocol, including modifying the cluster formation and selection process and integrating LEACH with other QoS-aware routing protocols.

There have been several works on Quality of Service (QoS) routing in wireless sensor networks (WSNs) that do not focus specifically on energy efficiency. The QoS-aware Routing Protocol for Wireless Sensor Networks (QRP-WSN) [17] uses a fuzzy logic-based approach to select routes that satisfy QoS requirements. The protocol divides the network into clusters and uses fuzzy logic to evaluate the QoS of each potential route based on factors such as the distance to the destination, the traffic load on the route, and the residual energy of the nodes. The Adaptive QoS-aware Routing Protocol (AQRP)[18] uses a learning mechanism to adapt to changing QoS requirements in the network. The protocol consists of a QoS prediction module that uses a neural network to predict the QoS of each potential route based on various factors such as distance, traffic load, and residual energy. The QoS routing module then uses this prediction to select the best route. The QoS-aware Routing Protocol with Load Balancing (QRP-LB) [19] focuses on both QoS and load balancing in order to improve the overall performance of the network. The protocol uses a combination of multiple metrics such as distance, traffic load, and residual energy to select the best route and balance the load across the network. Overall, these publications present different

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 1
DOI: https://doi.org/10.17762/ijritcc.v11i1.6085
***Article Received**: 24 November 2022 **Revised**: 28 December 2022 **Accepted**: 10 January 2023*

approaches to QoS routing in WSNs, but do not necessarily prioritize energy efficiency as a primary concern.

In this proposed scheme, the clusters are formed based on a spread spectrum clustering approach that limits the number of cluster heads to an optimal value. This helps to reduce energy consumption by minimizing the number of nodes that are responsible for forwarding data. Additionally, the protocol uses a base station assisted communication subnet establishment algorithm based on the artificial bee colony (ABC) algorithm[20] to ensure that the required quality of service (QoS) is maintained. By using this approach, the protocol is able to achieve both energy efficiency and QoS in the network.

IV. PROPOSED ALGORITHM

A. *Introduction*

The "Spread Spectrum based QoS aware Energy Efficient Clustering (SP-QESS)) algorithm in Wireless Sensor Networks" is a solution proposed in this paper for improving the performance of wireless sensor networks.

In the first phase of the algorithm, a "Spread Spectrum-based Clustering" technique is used to improve the energy efficiency of the network by reducing the amount of energy required for communication between the nodes in the network by selecting optimal cluster heads. This is done by using spreading the communication signal over cluster area, which reduces the amount of interference with other cluster area signals and reduces the power needed to transmit the signal as well number of clusters.

The second phase of the algorithm focuses on setting up a "Quality of Service (QoS) communication sub-network" based on Artificial bee colony optimization algorithm which ensures that the communication between the nodes in the network is reliable and meets certain performance and QoS requirements. This is important for applications that require a high level of reliability or that are sensitive to delays in communication. Overall, the goal of the "Spread Spectrum based QoS aware Energy Efficient Clustering algorithm in Wireless Sensor Networks" is to improve the performance and energy efficiency of wireless sensor networks by using spread spectrum techniques and metaheuristic optimization to set up an efficient clustering and QoS communication sub-network.

B. *Spread Spectrum based Energy Efficient Clustering Algorithm.*

In first phase, Clusters are formed in a specific way to improve the efficiency of the wireless sensor network. Specifically, the clusters are formed without overlapping based on the range of the spread spectrum signal. This means that the nodes in the network are grouped together into clusters based on the frequency range of their communication signals, and the clusters are arranged in such a way that there is no overlap between the frequency ranges of different clusters. The goal of forming the clusters in this way is to ensure that the number of clusters is optimal. By minimizing the overlap between the frequency ranges of different clusters, the algorithm can reduce the amount of interference between the clusters and improve the overall performance of the network. This is especially important in wireless sensor networks, where energy efficiency is a key concern and minimizing interference can help to reduce the amount of energy needed for communication.

This phase is further divided into three sub-phases, with the first sub-phase being the "Cluster Head Selection Algorithm." The pseudo-code for this algorithm is as follows:

```
# Initialize variables
sensor_nodes = [] # List of sensor nodes
field = [] # Field where sensor nodes are deployed
base_station = None # Base station
cluster_heads = [] # List of cluster heads
# Step 1
for node in sensor_nodes:
   node. randomly_deploy(field)
# Step 2
base_station.deploy(field, center=True)
# Step 3
for node in sensor_nodes:
   node. exchange_info(base_station)
# Step 4
cluster_heads. append(base_station)
# Step 5
for node in sensor_nodes:
   if node.has_more_energy() and
node.is_not_in_spread_spectrum_zone(cluster_heads):
      cluster_heads. append(node)
# Step 6
# Preferably one and a half times the communication range
spread_spectrum_zone_radius = 1.5 *
node.communication_range
# Step 7
while not all_nodes_covered(sensor_nodes, cluster_heads):
   for node in sensor_nodes:
      if node.is_not_covered(cluster_heads):
         if node.has_more_energy() and
node.is_not_in_spread_spectrum_zone(cluster_heads,
spread_spectrum_zone_radius):
            cluster_heads.append(node)
# Step 8
   base_station.broadcast_cluster_head_info(sensor_nodes)
```

In this algorithm, the first step is to randomly deploy the sensor nodes in the field and the base station is deployed in the center

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 1
DOI: https://doi.org/10.17762/ijritcc.v11i1.6085
***Article Received**: 24 November 2022 **Revised**: 28 December 2022 **Accepted**: 10 January 2023*

of the field. In the third step, the sensor nodes exchange information such as their location, remaining battery power, bandwidth, and communication range (or spread spectrum factor) with the base station. In the fourth step, the base station is designated as the first cluster head, located at the center of the network field. In the fifth step, the base station selects a node to be a cluster head if it has more energy and is not located in the spread spectrum area or zone defined by any other cluster head. The spread spectrum zone is defined as an area covered by a circle with a radius that is equal to or greater than the communication range or spread spectrum range (preferably one and a half times the communication range).
This process is repeated in the seventh step until every sensor node is covered by at least one cluster head. Finally, in the eighth step, the base station broadcasts the information about the cluster heads to all the sensor nodes in the network.

- *Sub phase II: Cluster formation*

The second phase of the algorithm is the "Cluster formation" phase. The goal of this phase is to minimize the energy expenditure of the cluster members, which are the sensor nodes that belong to a cluster, and headed by a cluster head. To achieve this goal, the cluster heads broadcast "Cluster Head advertisement messages" in the network, and the sensor nodes join the nearest cluster head by calculating their distance from the cluster head through location information or the signal strength of the received advertisement messages. This method of clustering does not consider the size of the constructed clusters or even the distribution of energy expenditure within the clusters.

- *Sud-phase III: Cluster communication*

The third phase of the algorithm is the "Cluster Communication" phase. In this phase, the cluster members directly send data to the cluster head using intra-cluster communication. The cluster members assign priorities and Quality of Service (QoS) parameters to the data based on the type of data being sensed. Intra-cluster communication refers to the communication that takes place within a single cluster, between the cluster members and the cluster head. The cluster members are the sensor nodes that belong to the cluster, and the cluster head is the node responsible for collecting data from the cluster members and forwarding it to the base station or sink node. In the Cluster Communication phase, the cluster members use the assigned priorities and QoS parameters to transmit data to the cluster head. The cluster head receives the data and processes it, using the specified QoS parameters to ensure that the data is transmitted with the desired level of reliability, throughput, and delay.

Overall, the Cluster Communication phase plays a key role in the efficient and reliable communication of data within the wireless sensor network, as it allows the cluster members to transmit data to the cluster head in a way that meets the performance requirements of the application.

C. QoS Communication Subnet based on Artificial bee colony oprimazation

The QoS communication sub-network is a network within the wireless sensor network that is specifically designed to support the transmission of data with guaranteed Quality of Service (QoS). The sink node, or base station, is responsible for setting up the QoS communication sub-network. To establish the QoS communication sub-network, the sink node follows these steps:

1. The sink node determines the locations of the cluster heads in the field using a location service such as GPS or a locally referenced location service.
2. The base station derives the QoS communication network, which contains routing table configuration information for different QoS requirements, using the artificial bee colony algorithm. The QoS requirements may include metrics such as delay, throughput, and reliability.
3. The base station forwards the information about the QoS communication network to all cluster heads.
4. The cluster heads configure their routing tables to provide guaranteed QoS.
5. Each cluster head finds a path to transmit the fusion data (data that has been combined or "fused" from multiple sensor sources) to the sink node with guaranteed QoS.

In each round, a new set of cluster heads are selected, and new clusters are formed. This process ensures that the proposed algorithm provides both energy efficiency and guaranteed QoS in the wireless sensor network.

TABLE 1: SIMULATION PARAMETERS

Simulation parameters	Values
Network area	200X200
Number of sensor nodes	100
Maximum Lifetime	5000
Size of data packets	4000
Data aggregation rate	5×10^{-9}
Initial energy of sensor nodes	0.1 Joule
Receiver energy	50×10^{-9} Joules
Transmitter energy	50×10^{-9} Joules

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 1
DOI: https://doi.org/10.17762/ijritcc.v11i1.6085
***Article Received**: 24 November 2022 **Revised**: 28 December 2022 **Accepted**: 10 January 2023*

V. ANALYSIS OF RESULTS

The proposed scheme, which includes the spread spectrum-based energy-efficient clustering algorithm and the Quality of Service (QoS) communication sub-network, was analyzed through simulations run in MATLAB. In these simulations, a network of 100 sensor nodes with homogeneous characteristics was assumed to be deployed in a field of size 200 x 200. Other simulation parameters are listed in Table 1. The performance of the proposed scheme was compared to the performance of the QRP-WSN, AQRP and LEACH, schemes in terms of live nodes i.e., stability period, optimal number of clusters, residual energy and throughput. Stability period refers to the amount of time that the network remains operational before it becomes unstable or fails. The optimal number of clusters refers to the number of clusters that provides the best performance for the given network and application. Throughput refers to the amount of data that can be transmitted successfully over a given period.

In this simulation of WSN, the number of rounds is treated as the lifetime of the network, and the percentage of alive nodes decreases due to the energy consumption in intra-cluster communication and communication among cluster heads to reach the sink node.

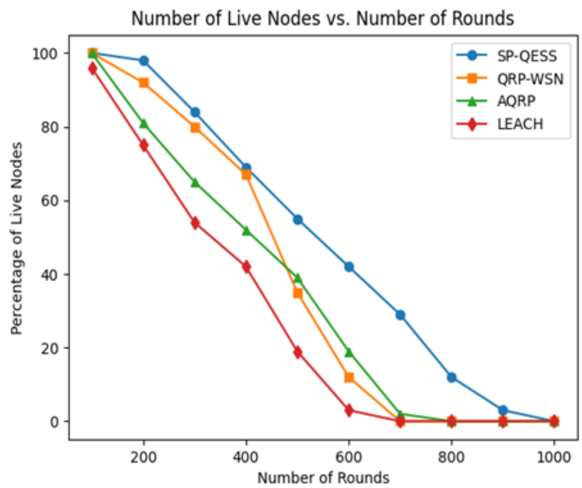

Figure 1

In figure 1, The results for the proposed SP-QESS algorithm show that the percentage of live nodes decreases from 100% at 100 rounds to 0% at 902 rounds. The percentage of live nodes for the QRP-WSN algorithm decreases from 100% at 85 rounds to 0% at 630 rounds. The percentage of live nodes for the AQRP algorithm decreases from 100% at 83 rounds to 0% at 593 rounds. Finally, the percentage of live nodes for the LEACH algorithm decreases from 100% at 71 rounds to 0% at 454 rounds. Overall, the SP-QESS algorithm appears to perform the best, as it has the highest percentage of live nodes at all rounds compared to the other algorithms. The QRP-WSN algorithm has a relatively high percentage of live nodes at early rounds but performance decreases significantly after round 600. The AQRP algorithm performs similarly to the QRP-WSN algorithm, with a relatively high percentage of live nodes at early rounds but a sharp decrease after round 500. The LEACH algorithm has the lowest percentage of live nodes at all rounds, with a significant drop in performance after round 400.

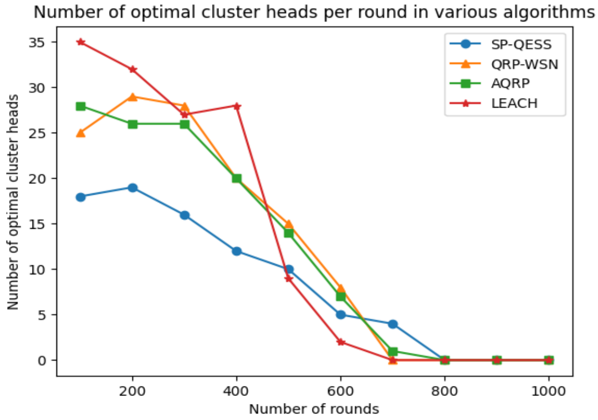

Figure 2

In figure 2, the SP-QESS algorithm performs relatively well compared to the other algorithms in terms of the number of optimal cluster heads per round.

Specifically, the SP-QESS algorithm has the lowest number of cluster heads at most rounds, with the exception of rounds 100 and 200 where it has 19 and 16 cluster heads respectively. In comparison, the QRP-WSN algorithm has 25 and 29 cluster heads at rounds 100 and 200, the AQRP algorithm has 28 and 26 cluster heads at these rounds, and the LEACH algorithm has 35 and 32 cluster heads.

Overall, the SP-QESS algorithm has fewer cluster heads than the QRP-WSN, AQRP, and LEACH algorithms at most rounds, with the exception of a few rounds where the QRP-WSN and AQRP algorithms have slightly fewer cluster heads. This suggests that the SP-QESS algorithm is effective at selecting optimal cluster heads without overlapping of clusters, and that it is able to achieve a relatively low number of cluster heads per round. This is generally considered to be a good performance in

International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 1
DOI: https://doi.org/10.17762/ijritcc.v11i1.6085
***Article Received**: 24 November 2022 **Revised**: 28 December 2022 **Accepted**: 10 January 2023*

the context of wireless sensor networks, as it can help to reduce energy consumption and improve network efficiency.

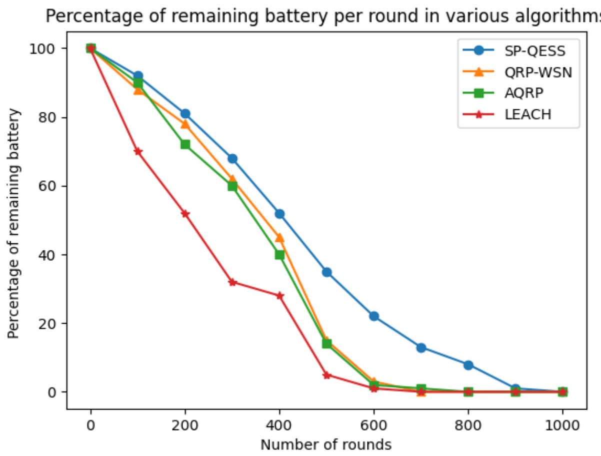

Figure 3

In figure 3, 0% of battery remaining occurred at round 902 for the SP-QESS algorithm, at round 630 for the QRP-WSN algorithm, at round 593 for the AQRP algorithm, and at round 551 for the LEACH algorithm. This means that by the end of these rounds, the battery of the network has been completely depleted for these algorithms. it appears that the SP-QESS algorithm performs relatively well in terms of the percentage of remaining battery, with a higher percentage of remaining battery at most rounds compared to the QRP-WSN, AQRP, and LEACH algorithms. The AQRP algorithm also has relatively higher percentages of remaining battery at most rounds compared to the QRP-WSN and LEACH algorithms

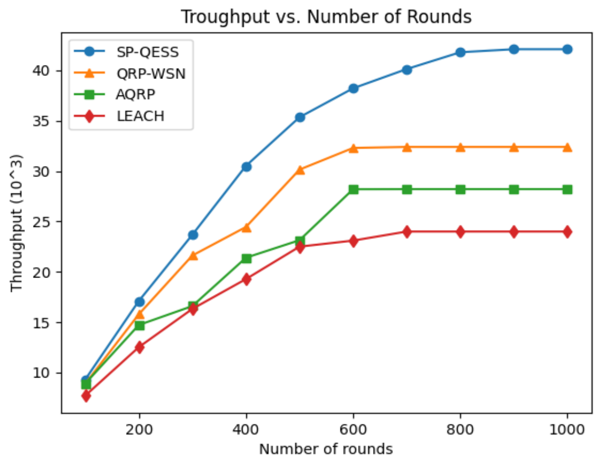

Figure 4

In figure 4, the number of rounds is treated as the lifetime of the network, and one of the vital QoS characteristics is throughput, which is defined as the number of packets received by the base station in the wireless sensor network. In this scenario, we are comparing the throughput of the SP-QESS, QRP-WSN, AQRP, and LEACH algorithms over the number of rounds. the SP-QESS algorithm has the highest throughput the network lifetime, followed by the QRP-WSN, AQRP, and LEACH algorithms. The throughput of all algorithms increases as the number of rounds increases, but the rate of increase differs between the algorithms.One possible reason for the differences in throughput between the algorithms is the number of live nodes and cluster heads in the network. If there are more live nodes and fewer cluster heads, the throughput may be increased, as there are more nodes available to transmit data. This could explain why the SP-QESS algorithm, which has a higher percentage of live nodes and fewer cluster heads, has a higher throughput compared to the other algorithms. On the other hand, the QRP-WSN, AQRP, and LEACH algorithms, which have a lower percentage of live nodes and more cluster heads, may have a lower throughput.

VI. Conclusion

the Spread Spectrum-based QoS aware Energy Efficient Clustering (SP-QESS) algorithm has been proposed as a protocol for improving the energy efficiency and lifetime of Wireless Sensor Networks (WSNs). The proposed algorithm is a centralized adaptive clustering algorithm that uses a QoS communication subnetwork to guarantee required QoS. In this process, sensor nodes forward information such as location, energy remaining, and link capacity to the base station, which then selects cluster heads and configures the QoS communication subnetwork based on QoS metrics.

Through experimentation, it was found that the SP-QESS algorithm performs better than the QRP-WSN, AQRP, and LEACH algorithms in terms of stability period, network lifetime, throughput, and energy conservation. The SP-QESS algorithm has a higher percentage of live nodes and fewer cluster heads than the other algorithms at most rounds, leading to improved performance in terms of remaining battery and throughput.

Overall, the SP-QESS algorithm appears to be a promising solution for improving the energy efficiency and lifetime of WSNs, while also supporting the required QoS. Further research may be needed to further evaluate the performance of the SP-QESS algorithm in different WSN scenarios.

REFERENCES

[1]. S. Janakiraman and B. Rambabu, "Improved Symbiosis Organism Search Algorithm-Based Clustering Scheme for Enhancing Longevity in Wireless Sensor Networks (WSNs)," *Lect. Notes Networks Syst.*, vol. 341, pp. 799–808, 2022, doi: 10.1007/978-981-16-7118-0_68/COVER.

[2]. F. Wang, L. Hu, J. Hu, J. Zhou, and K. Zhao, "Recent Advances in the Internet of Things: Multiple Perspectives," *IETE Technical Review (Institution of Electronics and*

Telecommunication Engineers, India), vol. 34, no. 2. Taylor and Francis Ltd., pp. 122–132, Mar. 2017, doi: 10.1080/02564602.2016.1155419.

[3]. A. V. R. S. J. B Rambabu, "Hybrid artificial bee colony and monarchy butterfly optimization algorithm (HABC-MBOA)-based cluster head selection for WSNs," *J. King Saud Univ. - Comput. Inf. Sci.*, vol. 3, no. 2, pp. 67–79, 2019.

[4]. M. Gamal, R. Rizk, H. Mahdi, and B. E. Elnaghi, "Osmotic Bio-Inspired Load Balancing Algorithm in Cloud Computing," *IEEE Access*, vol. 7, pp. 42735–42744, 2019, doi: 10.1109/ACCESS.2019.2907615.

[5]. M. Gheisari *et al.*, "A Survey on Clustering Algorithms in Wireless Sensor Networks: Challenges, Research, and Trends," *Proc. - 2020 Int. Comput. Symp. ICS 2020*, pp. 294–299, Dec. 2020, doi: 10.1109/ICS51289.2020.00065.

[6]. R. Bandi, V. R. Ananthula, and S. Janakiraman, "Self Adapting Differential Search Strategies Improved Artificial Bee Colony Algorithm-Based Cluster Head Selection Scheme for WSNs," *Wirel. Pers. Commun.*, vol. 121, no. 3, pp. 2251–2272, Dec. 2021, doi: 10.1007/S11277-021-08821-5/METRICS.

[7]. F. A. Khan, A. Ahmad, and M. Imran, "Energy Optimization of PR-LEACH Routing Scheme Using Distance Awareness in Internet of Things Networks," *Int. J. Parallel Program.*, vol. 48, no. 2, pp. 244–263, Apr. 2020, doi: 10.1007/S10766-018-0586-6.

[8]. R. F. Mansour *et al.*, "Energy aware fault tolerant clustering with routing protocol for improved survivability in wireless sensor networks," *Comput. Networks*, vol. 212, Jul. 2022, doi: 10.1016/j.comnet.2022.109049.

[9]. "A Hybrid Artificial Bee Colony and Bacterial Foraging Algorithm for Optimized Clustering in Wireless Sensor Network," doi: 10.35940/ijitee.J9391.0881019.

[10]. A. Khan, S. Gupta, and S. K. Gupta, "Multi-hazard disaster studies: Monitoring, detection, recovery, and management, based on emerging technologies and optimal techniques," *Int. J. Disaster Risk Reduct.*, vol. 47, Aug. 2020, doi: 10.1016/j.ijdrr.2020.101642.

[11]. 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, pp. 111–142, Sep. 2019, doi: 10.1016/j.jnca.2019.04.021.

[12]. 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, p. 102409, Apr. 2021, doi: 10.1016/J.ADHOC.2020.102409.

[13]. A. K. Subramanian and I. Paramasivam, "PRIN: A Priority-Based Energy Efficient MAC Protocol for Wireless Sensor Networks Varying the Sample Inter-Arrival Time," *Wirel. Pers. Commun.*, vol. 92, no. 3, pp. 863–881, Feb. 2017, doi: 10.1007/S11277-016-3581-5.

[14]. 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, Jun. 2020, doi: 10.1016/j.fss.2019.11.015.

[15]. A. O. Abu Salem and N. Shudifat, "Enhanced LEACH protocol for increasing a lifetime of WSNs," *Pers. Ubiquitous Comput.*, vol. 23, no. 5–6, pp. 901–907, Nov. 2019, doi: 10.1007/S00779-019-01205-4/METRICS.

[16]. M. Fonoage, M. Cardei, and A. Ambrose, "A QoS based routing protocol for wireless sensor networks," *Conf. Proc. IEEE Int. Performance, Comput. Commun. Conf.*, pp. 122–129, 2010, doi: 10.1109/PCCC.2010.5682321.

[17]. B. Nazir and H. Hasbullah, "Energy efficient and QoS aware routing protocol for Clustered Wireless Sensor Network," *Comput. Electr. Eng.*, vol. 39, no. 8, pp. 2425–2441, Nov. 2013, doi: 10.1016/J.COMPELECENG.2013.06.011.

[18]. S. Peng, S. X. Yang, S. Gregori, and F. Tian, "An adaptive QoS and energy-aware routing algorithm for wireless sensor networks," *Proc. 2008 IEEE Int. Conf. Inf. Autom. ICIA 2008*, pp. 578–583, 2008, doi: 10.1109/ICINFA.2008.4608066.

[19]. K. A. Darabkh, M. Z. El-Yabroudi, and A. H. El-Mousa, "BPA-CRP: A balanced power-aware clustering and routing protocol for wireless sensor networks," *Ad Hoc Networks*, vol. 82, pp. 155–171, Jan. 2019, doi: 10.1016/j.adhoc.2018.08.012.

[20]. K. Arutchelvan, R. S. Priya, and C. Bhuvaneswari, "Honey Badger Algorithm Based Clustering with Routing Protocol for Wireless Sensor Networks," *Intell. Autom. Soft Comput.*, vol. 35, no. 3, pp. 3199–3212, 2023, doi: 10.32604/IASC.2023.029804.