Mobile Sink Based Improved Energy Efficient Routing Algorithm Using Cluster Coordinator Node in Wireless Sensor Network

Sanjay Kumar Mirania and Kanika Sharma
NITTTR, ECE, Chandigarh, UT, India
Email: sanjay.mirania.kit@gmail.com; Kanikasharma80@yahoo.com

***Abstract*—It is imperative to perform energy-effective data transmission over a Wireless Sensor Network (WSN) to maintain the efficacy of the network; the sensor nodes in the network are responsible for relaying the data from the source to the destination node. To this end, a Mobile sink is introduced by the researchers to enhance the transmission ability. Though it is proved to be efficacious still energy consumption of the nodes is higher that in turn affects the reliability of the network. Researchers have developed various methods in which they have used the mobile sink that work in a static method. Thus, a novel approach is designed in which the network is evenly divided into five sections in which sensor nodes are equally distributed. The data transmission occurred through the Cluster Coordinator node (CCO) as they are rechargeable and assist in passing data to the mobile sink in each cluster with high efficacy. The simulation of the model is performed in MATLAB software for different network areas and different radius of sink mobility to evaluate the efficacy of the network in energy consumptions. The comparison with the traditional method demonstrated that incorporation of the CCO enabled the network to consume less energy and increase the network life span of the WSN area for data communication.**

***Index Terms*—Clustering, cluster coordinator node, mobile sink, WSN**

I. Introduction

The key goal of WSN is to permit users for accessing information of interest gathered by spatially dispersed sensors. Sensors are also used in vast quantities in real-life implementations to maintain complete physical area coverage. The generation of such vast networks is anticipated to be immense [1]. The static power supply units for each sensor node in the WSNs require energy efficiency optimization and are crucial to maintaining network life [2], [3].

In several recent technologies, WSNs are implemented with mobile sinks (mWSNs). The soldiers that patrol an edge in a battlefield may behave like moving sinks that get sensing data such as thermal Infrared from IEDs (Improvised explosive devices) at an attractive spot. Similarly, by tracking sensing data in close proximity such as RF (Radio Frequency) or seismic detection that may suggest survivors, emergency workers can scan for disaster-affected areas. For such uses, it is one of the most critical goals to efficiently capture sensing data while optimizing the life of the WSN [4], [5]. The WSN is composed of a significant number of sensor nodes spatially dispersed and a base station or sink to track the field of concern together. The power of the sensor node is constrained in size for most applications. Reducing energy consumption is crucial because replacing batteries is difficult for large amount of sensor node. Further, the energy consumption of all sensor nodes should also be balanced in order to prolong network life [6].

Different models are studied in large-scale WSN for an energy-efficient routing of sensor nodes and data recovery operation. In general, the data forwarding from each sensor node is transmitted via a multi-hop network of multiple sensor nodes to a static node [7], [8], where the data becomes header points and absorbs more energy than other sensors. The sensors that come near the mobile sink node become a header node.

Organizing WSN as a cluster is considered a popular method that can save node energy [9]. The cluster head (CH) manages each cluster and also acts as an interface among cluster members with the sink. Among the members of the cluster, CH is primarily selected for the high energy which assists to collect and send perceived information from cluster members to the sink [10]. To save energy, the operation is optimized so that the nodes have to utilize the shortest transmission range. The sink would travel close to the CH to gather critical data from the CH using a limited transmitting range and thus expend low energy to reduce the energy usage of the CHs. [11]-[13]. The challenge is therefore to find an efficient mobile sink method that works around the CH. Currently, the development of wireless technologies, smartphone sinks or sinks have become a significant subject and various research is being performed in this area, taking account of the large/multimedia form of data targeting quality of services (QoS) and network lifetime routing approaches to achieve successful results in terms of both routing and enhanced network life.

Manuscript received March 3, 2021; revised May 8, 2021; accepted May 22, 2021.
Corresponding author: Sanjay Kumar Mirania (email: sanjay.mirania.kit @gmail.com).

doi: 10.18178/ijeetc.10.5.355-361

This paper presents a methodology of increasing the network lifetime by saving the energy of the sensor nodes present in the network. The proposed work applies the clustering approach in a way that equally divides the network into the same sized clusters which is given the same number of sensor nodes. The data is transmitted to the mobile sink through CCO nodes depending on the distance between the mobile sink and cluster head (CH). The paper delineates the proposed work and its results in this paper followed by the literature survey performed to understand the works done in this field.

II. Related Work

This section discusses the various works done in the field of the wireless network area.

Jin Wang *et al.* [14] developed an energy-aware routing scheme combined with the versatility of groups and sinks. The entire sensor region was first divided into sectors, and by measuring the weight of its members each sector elects a CH. In the ideal case, Member Nodes determine the energy usage on various routing routes. Then CHs would be linked to an inter-cluster communication chain using the greedy algorithm. The results of simulations showed that the scheme proposed outperforms related work, such as Cluster-Chain Mobile Agent Routing (CCMAR) and Energy-efficient Cluster-based Dynamic Routing Algorithm (ECDRA). The authors also analyzed the effect of various network parameters on network efficiency and boost its performance further.

Bhatti and Kaur [15] suggested an improved Virtual Grid based energy efficient mobile sink routing (VGDRA) algorithm which is a grid-dependent routing algorithm that does not have the idea of distance-based estimating of resources. A sensor network is divided into logic k-cell grids in the proposed algorithm and a cell header (CH) were selected from every cell leading the cluster. The algorithm is energy-efficient by minimizing road-building costs because of the shortest potential sinking time.

Hung *et al*. [16] considered the mobility to maximize WSN's lifespan to achieve better energy consumption outcomes. They proposed a technique that combines moving sinks with fuzzy clustering algorithms that results in a higher efficacy as compared to LEACH, the cluster head election process, in terms of the lifespan of WSN, reliability, and packet distribution, CH Eeection mechanism using fuzzy logic (CHEF) were achieved.

Faheem and Gungor [17] designed a new multi-mobile sinks-based QoS-aware data gathering protocol (called MQRP) for WSN-based applications. The detailed simulation analysis is performed using a method called EstiNet9.0 for network simulation. The experimental data obtained shows that the work not only increased metrics of QoS performance including packet distribution, memory consumption, overhead check, energy remaining, network life, and throughput but also contributed to diminishing the packet error rate and latency in contrast to other approaches designed for collecting and transmitting data.

Radhika and Binu [18] presented an effective mobile sink routing approach that uses Ant colony optimization to detect the optimized route. The processing of data for mobile sinks was affected by an appropriate technique for clustering, which uses an energy-aware scheme for choosing cluster heads. A big technique is also followed to alert the nodes located near the mobile sink.

Gopal and Suriyakala [19] suggested a new routing strategy that takes advantage of the positive factor for data collection of virtual grid based dynamic route adjustment (VGDRA) and virtual circle combined straight routing (VCCSR). They investigate a balance of energy usage, life and average time delays by using the hybrid scheme in WSN. The authors of this paper investigated a balance in energy consumption, lifespan, and average delay in WSN by utilizing hybrid scheme. To reduce the cost of rout reconstruction the authors used VGDRA, whereas at the same time VCCSR reduces consumption of energy and increases network lifespan.

Maheshwari *et al*. [20], the butterfly optimization algorithm (BOA) was used by the researchers of this paper to select the best CH from the group of nodes. The selection of CH is maximized through the node's residual energy, neighbor's distance, base station's distance, node centrality and node degree. Ant colony optimization (ACO) was used by researchers to determine the best route among the CH and the base station, depending on residual energy, node degree, and distance. The suggested methodology's efficiency was evaluated on the basis of energy consumption, dead nodes, alive nodes, and data packets obtained by the Base Station. The suggested methodology's outcomes were compared with the conventional strategies like distributed energy-efficient clustering (DEEC) and low energy adaptive clustering hierarchy (LEACH), as well as some existing strategies like clustering and routing in wireless sensor networks using harmony search algorithm (CRHS), fuzzy based unequal clustering and ACO based routing hybrid protocol (FUCHAR), CPSO, fractional lion optimization based clustering algorithm (FLION), A biogeography-based energy saving routing architecture (BERA), and ant lion optimization for clustering (ALOC).

Sharma *et al*. [21], by using a bio-inspired methodology, the authors of this paper described a unique wireless routing protocol for wireless sensor networks mobile or ad hoc networks. To address the difficulties encountered by resource-constrained sensors, and energy-efficient multipath routing approach that relies on the foraging behavior of ants was suggested by the authors that include several meta-heuristic effects factors to supply good robust paths through the source to destination. Diverse performance metrics, like delay, throughput, network lifespan, packet loss, etc. were used to evaluate the suggested routing algorithm. The performance metrics were used by authors to compare the developed routing algorithm to the Ad-hoc on-demand distance vector (AODV) routing protocol, where the developed routing algorithm represented an improvement of 49% in the network's lifespan.

Rodr ǵuez *et al*. [22] the researchers of this paper on the basis of the yellow saddle goatfish algorithm (YSGA) developed a unique clustering routing protocol that was energy efficient. By minimizing the consumption of energy, the proposed protocol aims to extend the network's lifespan. In its cluster configuration, the network was considered a base station and a collection of CHs. The YSGA algorithm decides the amount of CHs and the best CHs, whereas sensor nodes were allocated to the nearest CH. YSGA changes the network's cluster configuration to maintain an optimum CH distribution and minimizes the transmission distance. Experimental findings represented that the developed routing protocol consumes fewer resources, has a longer lifespan, and extends the network's stability period as compared to common routing protocols of clustering.

III. Present Work

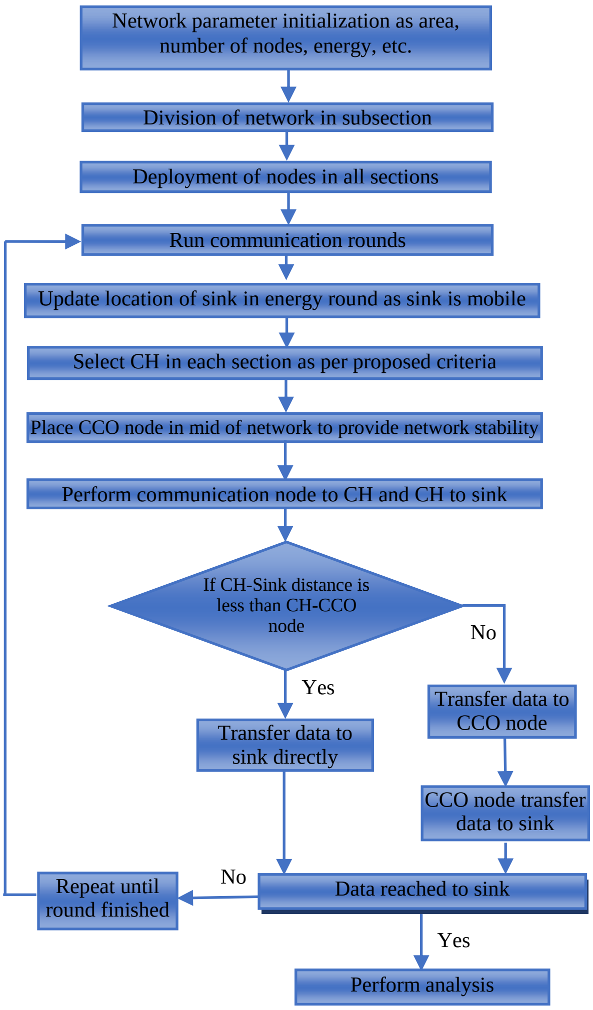

Fig. 1. Flow chart of the proposed model.

The work presented in this paper is an energy-effective approach for data transmission in WSN. This proposed method is an enhancement in the traditional approach proposed by Wang *et al*. [14] as the field of work done is similar but an updating. The traditional method gives energy effective results but the random deployment of nodes into the network, parameters used for CH selection, and chain based method used to transmit data are not much efficacious that results in increasing the load and affect the network lifetime. Thus, in the novel approach, network area is divided into equal sections amongst which the number of nodes is distributed evenly. This is done by dividing the total number of nodes with number of clusters. After equal distribution of nodes in each clusters a cluster head is chosen. The novelty in this work is that parameters for selecting CH are increased and in each cluster, a Cluster Coordinator node is introduced to relay the data to the mobile sink for the scenario when the distance between the CH and the mobile sink is larger. The introduction of Cluster Coordinator node improved the performance of the network as the coordinator nodes can be recharged when their batteries are drained, because they are connected to power source. It ensures that other nodes present in the network were less involved due to the presence of mobile sink and CCO node. A flowchart demonstrated in Fig. 1 presents the process of the proposed work in detail. The process of proposed work is defined in detail as follows.

A. *Network Model*

To start with, a network area is designed for the communication process. The wireless sensor network area is then divided into five equal sections/clusters as shown in Fig. 2. This is determined by from CH count that is taken on CH probability of 0.05. This figure demonstrates an equal number of nodes in each cluster. The black square and red star symbolize coordinator nodes and mobile sink respectively. The mobile sink rotates in the circular motion around the center of the network.

The network configuration that is considered for the proposed protocol is given in Table I below that represents factors as initial energy, network is etc.

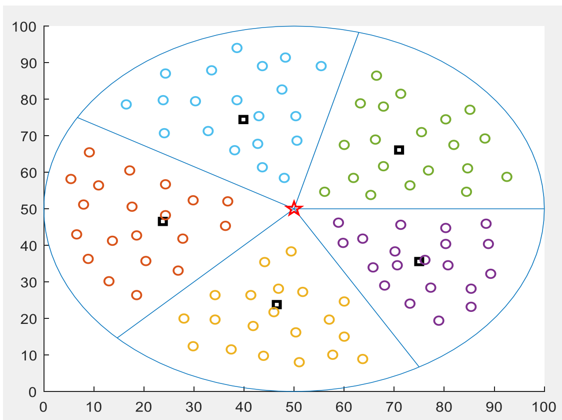

Fig. 2. Proposed network Architecture.

TABLE I: Network Configuration Factors and Their Values

Parameters	**Values**
Network Area	100 m^2
Nodes	100
Initial Energy	0.5 j
Energy For Tx and Rx	50 nJ/bit
Free Space Model value	10 $pJ/bit/m^2$
Multi-path Model value	0.0013 $pJ/bit/m^4$
Packet length (l)	500 bits

B. Deployment of Nodes

Every cluster is comprised of an equal number of sensor nodes. The distribution of an equal number of nodes in every cluster assists in maintaining the process of data communication from the source node to the destination node and it also avoids congestion in the network. Though, after the division of the network area into five different sections, the next phase is the selection of cluster head which is described in the following section.

C. Cluster Head Selection

Choosing a cluster head is an imperative task as CH is responsible for passing the data to the nodes. Different parameters are used for CH selection. In the proposed work, the following three different parameters are taken into consideration for choosing the head of the cluster:

- Distance of each node from the sink node
- The residual energy of nodes
- Distance of each node from reaming nodes in the cluster

On behalf of the aforementioned parameters, the weight of the nodes is determined. The CH node should have the highest energy and minimum distance to the sink and other nodes. To this end, the weight of the node is calculated using the above parameters, and the node having minimum weight is chosen as the cluster head.

The following equation presents the formula of computing node weight:

$$w_i = \frac{\text{Dis}_{i\_\text{to}\_\text{sink}\,k} + \text{Dis}_{i\_\text{to}\_j}}{E_{\text{residual}}} \quad (1)$$

where i presents the node, $\text{Dis}_{i\_\text{to}\_\text{sink}\,k}$ is the distance from the node to sink, $\text{Dis}_{i\_\text{to}\_j}$ is the node to node distance and E_{residual} is residual energy of the node.

Further process of routing is carried out for communication purposes.

D. Routing

Followed by the selection of the cluster heads, routing is performed. Routing involves the path for transmitting the data through nodes. When the path is long, more energy is consumed which in turn minimizes the lifetime of the network. Effective path is imperative for data relay. Conventionally, chain-based solutions, inter-cluster communication, or intra-cluster communications were carried out in which cluster head transmit the data to sink but in many cases, when CH has its data and also comprised of other nodes data, the load on CH increased which eventually consumes more energy and affect the lifespan of the network.

In this work, different aspects are considered before finalizing the route. The novelty includes the introduction of Cluster coordinator (CCO) nodes in every cluster to increase the efficacy. CCO nodes are rechargeable nodes because they are connected to power source that can help in reducing the burden on the cluster head as its energy can have restored by recharging it while sending data to the sink.

Though, CCO nodes are introduced in every cluster but placing them in the network at a certain place was a complicated task. Thus, to localize CCO nodes in the cluster, the center of the cluster is taken as the best place for placing the CCO node because it allows the common distance of the nodes from every side of the cluster to the CCO node. The CCO node is presented in Fig. 2 by black squares in each cluster.

Afterwards, the communication takes place as follows:

- When the distance between CH and mobile sink is very less, then data is directly sent out to the sink without using the CCO node.
- When the distance between the sink and the CH is more, CH transfer the data to CCO, and the CCO node sends it to the sink and it saves the energy of other nodes present in the network.

Overall, the nodes in the network send data to the cluster head, and further, the data is sent to the sink through CCO nodes depending on the distance between the mobile sink and CH.

Eventually, the performance of the model is determined for the number of dead nodes and alive nodes that indicate the lifetime of the network and it is discussed in the following section.

IV. Results and Discussion

The results of the proposed model are described in this section with respect to varying network area and radius of the mobile sink. For simulation purposes, the areas considered are 100m^2, 200m^2, 300m^2, and 400m^2. The results are achieved for the number of dead nodes, the number of alive nodes, and the sum of energy conservation. The result is explained in two cases where case 1 show the results for different network areas and case 2 demonstrates results for the different radius in which the mobile sink is moving in the network.

A. CASE 1: Varying Network Size

This section discussed the results achieved for varying network sizes. The graphs present the output for different areas taken into consideration.

The count of alive nodes for different network area is demonstrated in Fig. 3. It is cleared from the figure that, when the area is large the number of alive nodes descends with the rise in the number of rounds. The highest number of alive nodes is achieved for the minimum area with 100m^2.

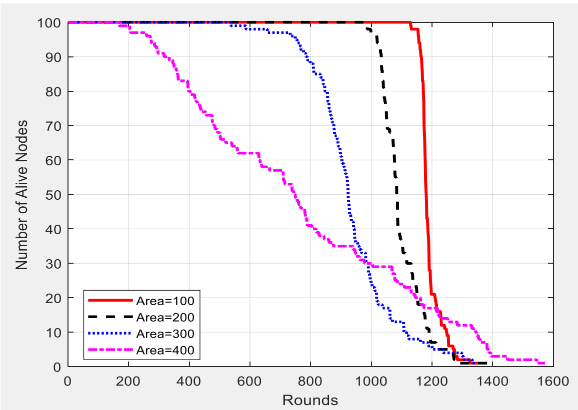

Fig. 3. Comparison of alive nodes.

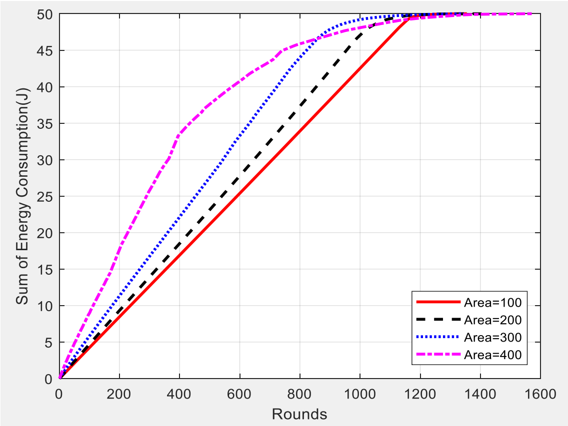

Fig. 4. Sum of energy consumption.

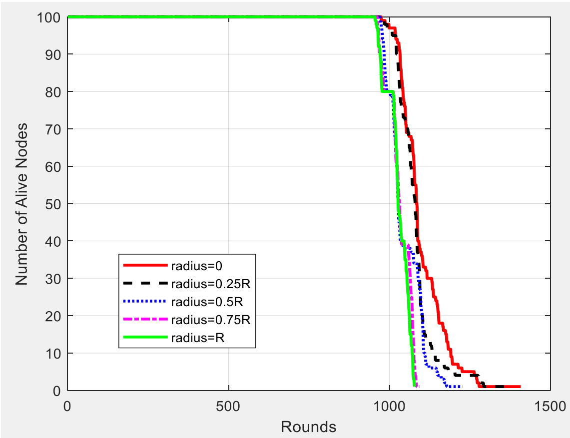

Fig. 5. Number of alive nodes attained for varying radius.

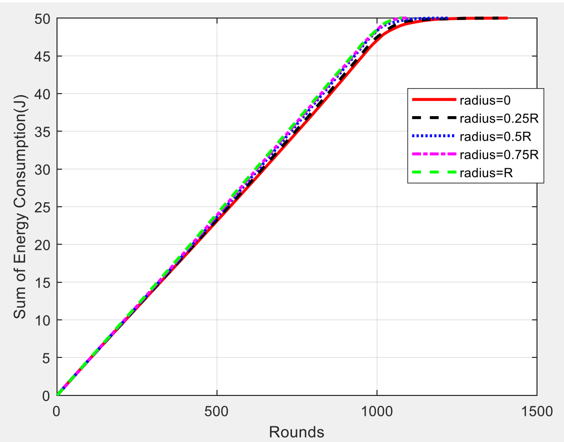

Fig. 6. Energy consumption with respect to the different radius of the network.

The energy consumption of nodes in WSN is presented for different areas in Fig. 4. Energy increases as the number of rounds increased. Similarly, more energy is consumed by the larger network area as it comprises of more number of nodes. The consumption of energy decreased as the network area is decreased.

B. CASE 2: Varying Radius of Mobile Sink

This section explains the results for varying radius of sink in network area. The radius refers to the path of the mobile sink moving in the network. To evaluate the performance five different radius such as 0, 0.25R, 0.5R, 0.75R, R are taken into account and the results are shown below. The results are shown for are 200 units.

The alive nodes are determined for varying radius in which sink moved and the results are shown in Fig. 5. It clearly shows the same number of nodes remain alive for approximately 1000 rounds. It ensures that the network with the minimum radius has a maximum lifespan and minimum energy consumption. Further, the number reduced gradually but with a significant difference for each radius.

The graph in Fig. 6 presents the energy consumption of nodes in different networks with different radius. Energy devouring increased with the increase in the number of rounds. As compared to the different radius, hence sink moves around the smaller radius, network experience has minimum consumption, and the larger radius-based network consumed a high amount of energy.

C. Comparative Analysis of Proposed and Traditional System

The comparison is carried out for area $100m^2$ and 100 nodes. The graph in Fig. 7 delineates the comparison for the alive nodes achieved by the proposed and traditional technique [14]. It is clear from the graph that nodes remain alive for a higher number of rounds as compared to that of traditional techniques. This showed that the proposed approach helps in enhancing the network lifetime.

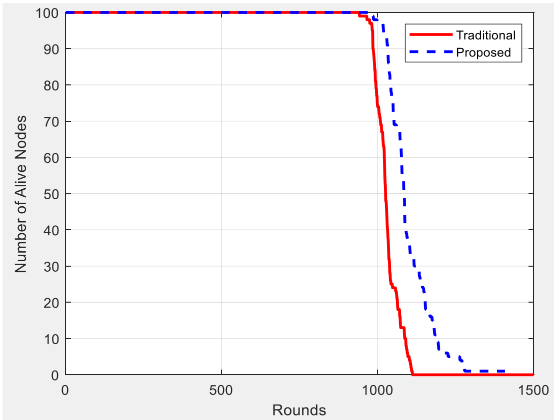

Fig. 7. Comparison of alive nodes for proposed and traditional method.

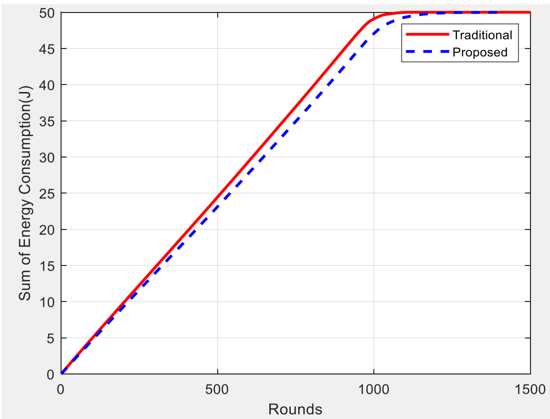

Fig. 8. Comparison of energy consumption nodes for proposed and traditional method.

The energy consumption by traditional and proposed approaches is displayed in Fig. 8. Node energy in the proposed work is less consumed whereas for the traditional method it is high. The lesser the energy consumption higher is the network stability and reliability that indicates the long lifetime.

Overall, the results of the proposed model showed that the network is more effective and has a maximum lifetime when the network size is smaller and the mobile sink moves on the path with a short radius. In addition to this, the proposed model is also better than the traditional technique in terms of energy consumption and lifespan.

V. Conclusion and Future Scope

Sensor nodes devour energy as it transmits the data that affects the reliability of the network. Mobile sinks are used in the network to save energy but in static network, the rate of dead nodes in the network is higher, thus, this research proposed a technique of saving node energy and enhancing the network lifetime by introducing coordinator nodes and mobile sink. The process is initiated by carrying out division of network into equal clusters with even distribution of nodes and a Cluster Coordinator node (CCO). CCO node passes the data to the sink when the distance between the sink and other nodes is more which in turn saved the energy of sensor nodes and make the network more reliable. The results of the anticipated model are achieved using MATLAB software and the outcome is compared with the traditional approach that showed the supremacy of the proposed work in terms of less energy consumption and a higher number of alive nodes.

Although the proposed work gives effective outcome, the work can be improved in future by implementing latest technology. To this end, soft computing and different optimization algorithms can be used to improve the network performance.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Both the author's conducted the research; Sanjay Kumar Mirania wrote the paper; Kanika Sharma helped in simulation work; both authors had approved the final version.

References

[1] A. Abuarqoub, "Optimal mobile sink selection scheme for multiple sink mobile wireless sensor networks," in *Proc. European Intelligence and Security Informatics Conference*, 2015.

[2] M. Prabha, S. S. Darly, and B. J. Rabi, "Energy conservative mobile sink path routing for wireless sensor networks," in *Proc. International Conference on Smart Structures and Systems*, 2019.

[3] Z. Vincze, D. Vass, R. Vida, A. Vidacs, and A. Telcs, "Adaptive sink mobility in event-driven multi-hop wireless sensor networks," in *Proc. First International Conference on Integrated Internet Ad hoc and Sensor Networks*, Nice, France, May 30- May 31, 2006.

[4] X. Cao and S. Madria, "An efficient trajectory-based routing using virtual coordinates for low-power WSNs with mobile sink," in *Proc. 15th International Conference on Distributed Computing in Sensor Systems* (DCOSS), 2019.

[5] B. Kang and H. Choo, "An energy-efficient routing scheme by using GPS information for wireless sensor networks," *International Journal of Sensor Networks*, vol. 26, no 2, pp. 136–143, 2018.

[6] M. A. Khan, A. I. Umar, B. Nazir, N. Amin, S. Mehmood, and K. Habib, "Energy efficient clustering using fixed sink mobility for wireless sensor networks," *International Journal of Advanced Computer Science and Applications*, vol. 7, no. 2, 2016

[7] Y. Bi, L. Sun, J. Ma, N. Li, I. Khan, and C. Chen, "An autonomous moving strategy in data gathering sensor networks," *EURASIP Journal on Wireless Communication and Networking*, 2007.

[8] C. Wang and W. Wu, "A load-balance routing algorithm for multi-sink wireless sensor networks," in *Proc. International Conference on Communication Software and Networks*, Macau, China, February 2009, pp. 380–384.

[9] V. Chauhan and S. Soni, "Mobile sink-based energy efficient cluster head selection strategy for wireless sensor networks," *J. Ambient Intell Human Comput*, vol. 11, pp. 4453–4466, 2020.

[10] J. R. Srivastava and T. S. B. Sudarshan, "A genetic fuzzy system based optimized zone based energy efficient routing protocol for mobile sensor networks (OZEEP)," *Appl Soft Comput*, vol. 37, pp. 863–886, 2015.

[11] W. Liu and J. Yu, "Energy efficient clustering and routing scheme for wireless sensor networks," in *Proc. IEEE ICIS*, vol. 3, pp. 612–616, 2009.

[12] L. Arboleda and N. Nasser, "Comparison of clustering algorithms and protocols for wireless sensor networks," in *Proc. of CCECE '06*, May 2006, pp. 1787–1792.

[13] D. J. Dechene, A. El Jardali, M. Luccini, and A. Sauer, "A survey of clustering algorithms for wireless sensor networks," Project Report, 2006

[14] J. Wang, Y. Gao , W. Liu, A. K. Sangaiah, and H. J. Kim, "Energy efficient routing algorithm with mobile sink support for wireless sensor networks," *Sensors*, vol. 19, no. 1494, pp. 1-19, 2019.

[15] R. Bhatti and G. Kaur, "Virtual grid based energy efficient mobile sink routing algorithm for WSN," in *Proc. 11th International Conference on Intelligent Systems and Control*, Coimbatore, 2017, pp. 30-33.

[16] P. T. The, V. N. Manh, T. C. Hung, and L. D. Tam, "Improving network lifetime in wireless sensor network using fuzzy logic based clustering combined with mobile sink," in *Proc. 20th International Conference on Advanced Communication Technology*, Chuncheon-si Gangwon-do, Korea (South), 2018, pp. 113-119.

[17] M. Faheem and V. C. Gungor, "MQRP: Mobile sinks-based QoS-aware data gathering protocol for wireless sensor networks-based smart grid applications in the context of industry 4.0-based on internet of things," *FGCS*, vol. 82, pp. 358-374, 2018.

[18] R. Radhika and G. S. Binu, "An enhanced energy efficient routing method for mobile sink using ant colony optimisation based clustering in WSN," in *Proc. ICCSDET*, Kottayam, India, 2018, pp. 1-6.

[19] D. Gopal and C. D. Suriyakala, "Performance evaluation of hybrid energy efficient cluster based routing scheme for mobile sink based WSN," in *Proc. ICCICCT*, Kumaracoil, 2015, pp. 558-564.

[20] P. Maheshwari, A. K. Sharma, and K. Verma, "Energy efficient cluster based routing protocol for WSN using butterfly optimization algorithm and ant colony optimization," *Ad Hoc Networks*, vol. 110, 2021.

[21] A. S. Sharma and D. S. Kim, "Energy efficient multipath ant colony based routing algorithm for mobile ad hoc networks," *Ad Hoc Networks*, vol. 113, no. 15, March 2021.

[22] A. Rodríguez, C. Del-Valle-Soto, and R. Velázquez, "Energy-Efficient clustering routing protocol for wireless sensor networks based on yellow saddle goatfish algorithm," *Mathematics*, vol. 8, 2020.

Sanjay Kumar Mirania received B.E. degree in electronics & telecommunication engineering from Pt. Ravi Shankar Shukla University, Raipur, Chhattisgarh, India in 2003; Pursuing M.E. degree in electronics & communication from NITTTR, Punjab University, Chandigarh, India. He is employed as an assistant professor of the Department of Electronics & Telecommunication Engineering, Kirodimal Institute of Technology, Raigarh (C.G.), India. Research interests: wireless sensor networks and analog electronic circuit.

Dr. Kanika Sharma received B.E. degree in electronics & communication from Maharishi Dayanand University, Rohtak, India in 2001; M.E. degree in electronics & communication from PEC, Panjab University, Chandigarh, India in 2004; Ph.D. degree in electronics & communication from Punjab Technical University, Jalandhar, India in 2015. She is employed as an assistant professor of the Dept. of Electronics & Communication Engineering, NITTTR, Chandigarh, India. Research interests: embedded systems, digital system designing, wireless sensor networks, and mobile communication.