BOHR International Journal of Smart Computing and Information Technology
2022, Vol. 3, No. 1, pp. 1–8
DOI: 10.54646/bijscit.2022.21
www.bohrpub.com

REVIEW

Fuzzy clustering and energy resourceful routing protocol ($FCER^2P$) for smart dust

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Received: 05 January 2022; **Accepted:** 26 January 2022; **Published:** 06 February 2022

Sensor nodes in smart dust are used to track and identify data that is being transferred to a sink. The accessibility of node energy poses a significant challenge for smart dust and may have an impact on the long-term viability of the network. As a result, constructing smart dust must take into account the need for algorithms and techniques that enable the most use of scarce resources, especially energy resources. For instance, routing algorithms are distinctive algorithms because they have a clear and direct connection with network longevity and energy. The offered routing techniques use clustering each round and single-hop data delivery to the sink. A Fuzzy Clustering and Energy Resourceful Routing Protocol ($FCER^2P$) that reduces smart dust energy consumption and lengthens lifespan of the network is proposed in this research. Using a specified threshold, $FCER^2P$ proposes a new cluster-based fuzzy routing mechanism that can make use of clustering and multiple hop routing capabilities simultaneously. This research is innovative in that it adjusts multi-hop connectivity by anticipating the optimum intermediate node for aggregating and the sink, eliminates clustering each round while taking a fixed threshold into account, and eliminates clustering per round altogether. When choosing the intermediary node to employ, some fuzzy parameters, including residual energy, the number of neighbors, and the distance to the sink, are taken into account.

Keywords: energy utilization, Fuzzy Clustering, Routing Protocol, smart dust

1. Introduction

Multiple with minimal processing capacity are widely used in smart dust, which collects atmospheric data and communicates with base stations (BS). In recent times, improvements in embedded system design have reduced the size, mass, and price of sensors while boosting processing speed and delivering more precise data. Smart dust is best employed for observing and tracking a variety of applications, as exposed in **Figure 1**. As network nodes have minimum energy, data transfer consumes the majority of energy in smart dust. Therefore, it is essential to create a structure that uses the smallest amount of energy possible when sending information to the BS. One strategy to use less energy is to design network topology with a hierarchical system. These network nodes are arranged in a hierarchy with multiple levels, with nodes in each layer sharing the same properties. Clustering is one method for creating the hierarchical system. To guarantee that all sensors are gathering information from their physical surroundings, network elements are subdivided into different clusters (1). Since smart dust are typically dynamic, energy consumption may decrease as that of the network's lifespan increases by choosing the most effective method for transferring packets from node to sink.

In smart dust, there really are three distinct routing techniques, namely, flat, hierarchical, and based on geography. Smart dust structure is seen in **Figure 2**. The rotation and flooding algorithms, in which every network node has the same function, use flatter routing. This method

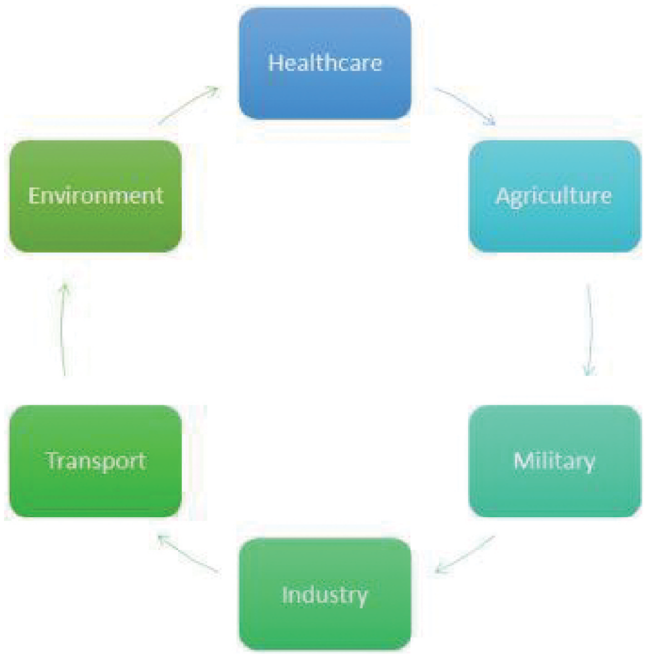

FIGURE 1 | Smart dust application.

allows nodes to interact with one another by gathering environmental data (2). A much more flexible hierarchy routing is an additional technique of data transmission to the BS. Since they have the most resources and are in charge of collecting and combining the data obtained from the nodes, headers are frequently used in hierarchical routing (3). According on how the network is set up, it is then assembled and sent in one or more hops to the BS for treatment before being received by the user. The cost of transmitting data to the sink rises as the length here between nodes as well as the sink widens. Energy can be saved, and the lifespan of the header node increased when hierarchical routing is used with the right intermediate node. Similar to what is being said, utilizing multi-hop broadcasts increases connection, range, and stability. There have been many methods for determining this header node, but determining a header node using a fuzzy system lowers the computation time. The primary goal of the proposed A Fuzzy Clustering and Energy Resourceful Routing Protocol (FCER^{2}P) is to develop an easy-to-implement energy-efficient routing mechanism that utilizes clustering with a pre-determined threshold. In the FCER^{2}P, many hops and choosing the best intermediate node are accomplished. The intermediate node is selected from the listed header locations based on the "Remoteness to BS" and "outstanding node energy" concept in order. The suggested FCER^{2}P clustering are dependent on the assertive header node, which differs from other widely used techniques in that clustering is not performed each round. Certain clustering algorithms choose their headers at random, which reduces the possibility of using the effective concentration as a cluster head (CH). A header sensor node is picked based on optimal fuzzy attribute parameters in the suggested FCER^{2}P. The present node has indeed been recognized; hence, no additional nodes are chosen in the next rounds. This approach results in a negligible amount of conflicts and the transmission of control messages.

Existing fuzzy-based clustering methods for smart dust are reviewed in the remaining parts of the article, which are described in Section 2. The planned FCER^{2}P system is covered in detail in Section 3. Section 4 discusses the simulation findings and comparability of the suggested FCER^{2}P with the evaluation findings. The results and upcoming research are shown in Sections 5 and 6.

2. Related work

The clustering methodology Multi-Objective Fuzzy Clustering Algorithm (MOFCA) (4) is built on a fuzzy inference system, and it uses fuzzy variables such as "remaining energy," "range to BS," and "intensity of every node." This technique uses an energy-based competition perimeter to select the CH. This technique was designed to address the "energetic hole" and "hot region" issues. Using the parameters such as Half Nodes Active (HNA), Foremost Node Dead (FND), and Overall Available Energy, this method calculates the lifespan of WSNs (TRE). Depending on its location from the BS, the CHS diameter calculation is determined using the residual power from the nodes. When employing effective procedures to handle WSN environments, the intensity variables are used as input variables for the fuzzy logic that has been built. To evaluate the MOFCA optimization technique with extra clustered methodologies, including Low Energy Adaptive Clustering Hierarchy (LEACH) (5), CH Election utilizing Fuzzy logic (CHEF) (6), Energy-Efficient Unequal Clustering (EEUC) (7), and Energy-Aware Unequal Clustering with Fuzzy (EAUCF) (8), a comparison analysis has been performed as a component of an innovative assessment process. In instance 1, the nodes are distributed almost uniformly using MOFCA. Depending on its location, BS of an area of interest (AOI), broadcast form, and BS placement are affected. Scenario 2 demonstrates that, with the exception of LEACH (9) and CHEF (10) implementations, multi-hop networking does have a maximum competitive radius. The BS is the AOI's center, and the nodes are arranged nearly uniformly. In instances 3 and 4, nodes are deliberately generated in a non-uniform dispersion. Though, with the latter installation, the BS is outside of the AOI. Nodes in situation 4 have their x and y positions changed by about 5 m, allowing for a broadband network.

The MOFCA methodology (11) performs better compared to the other three techniques, with an effectiveness that is 57% higher than LEACH (5), according to the FND measurement results. The execution effectiveness of CHEF (12), EEUC (7), and EAUCF (13) is 29, 10, and 8% less than MOFCA. The deployment of WSNs and emissions reduction

FIGURE 2 | Smart dust hierarchical structure.

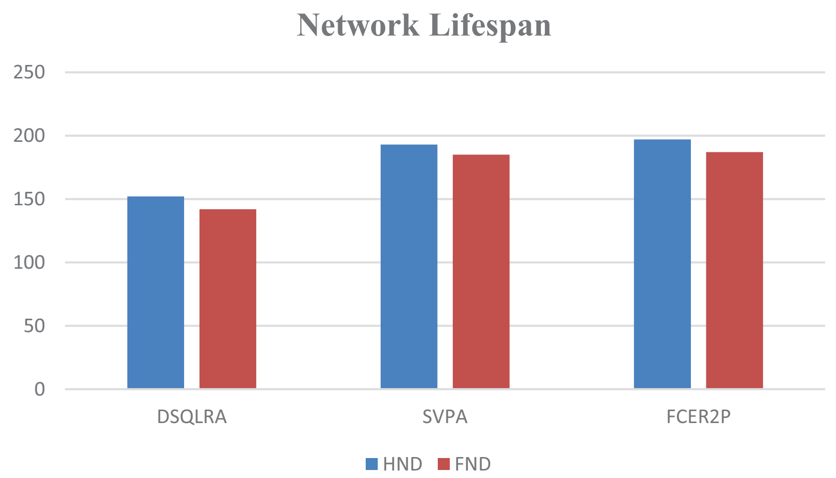

FIGURE 3 | Network life of cluster approaches.

are more adjustable if transmission lines are installed. In the studies, the MOFCA computation efficiency (4) was logically preferable when contrasted to other cases. This technique's use of asymmetrical clustering, which produces balancing energy usage, is just one of its advantages. One issue with the method is the implementation of clustering in that round. A fuzzy system-based clustering technique called EAUCF has indeed been suggested to prolong a network's lifetime. This methodology partially uses the techniques to improve node selection while also using a fuzzy system to rotate the CH on a recurring basis, which improves performance over previous methods. In real networks, this approach increases a network's lifespan, however, in node mobility, it has no effect. One of the shortcomings of the method is the complexity of the procedure due to the requirement to approximate the sizes of both clusters prior to clustering. Such a method also has the drawback of selecting a CH node without taking "node density" into consideration, which could lead to the CH being a node with few neighbors. Consistency is one benefit of this method. A methodology that uses the fuzzy system to determine the CH's contentment is Energy-Efficient Fuzzy Logic-Based Clustering Technique for Hierarchical Routing Protocols in WSNs (FL-EEC/D) (14). Furthermore, it equalizes energy use among clusters and resolves the hot zone problem. The multi-hop communication system that relies on Fibonacci sequences is used to address this. The fuzzy logical interpretation is used by Fuzzy Logic for Multi-hop WSNs (FLCAMN) methodology (15) to choose the right CHs. The networking life is examined by FND and Half Nodes Dead (HND) measurements. a comparison based on various algorithms, including LEACH (5), Energy-Aware Multi-Hop Multi-Path Hierarchical Routing Protocol for WSNs (EAMMH), and Distributed Fuzzy Logic Algorithm (DFLC) (16). At the 91st phase, the FLCMN-based FND outscored LEACH (5), EAMMH (12), DFLC (11), and FLCMN (10) by using average remaining energy as its input variable. This illustrates how well nodes' leftover energy is used in conjunction with that of their nearby nodes. As seen in **Figure 3**, FLCMN utilizes leftover energy from the broadcaster's WSNs to eventually prolong its lifespan (17).

A fuzzy scheme hierarchical proposed technique is Fuzzy Logic-Based Energy Efficient Clustering Hierarchy

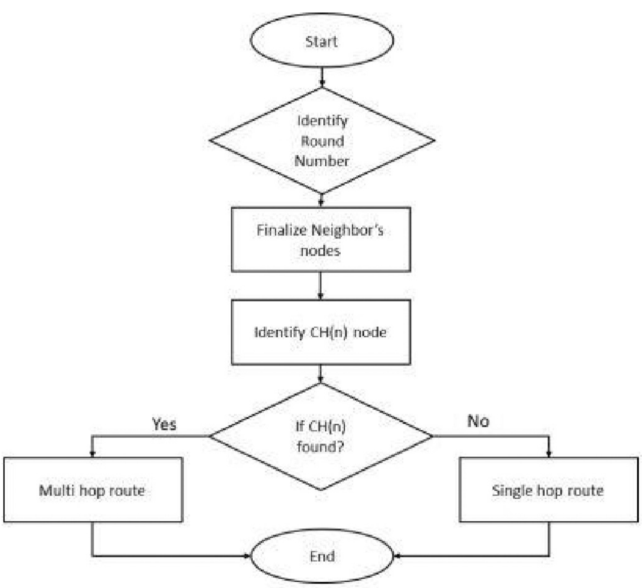

FIGURE 4 | FCER^{2}P protocol.

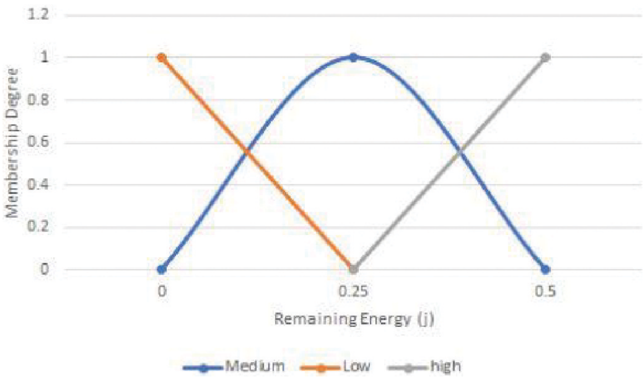

FIGURE 5 | Membership function of remaining energy input variables.

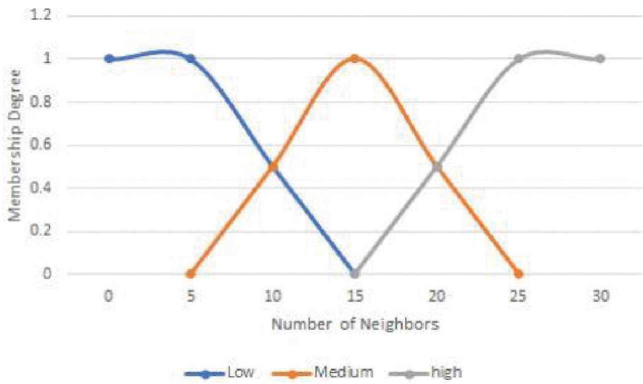

FIGURE 6 | Membership function of neighbor's quantity input values.

(FLECH) (18). Throughout this technique, "remaining energy," "focusing rate," and "length to the BS" are used to select the cluster. In various cases, the effectiveness of FLECH is compared to that of the segmentation-based visual processing algorithm (SVPA) (15), the disseminated scheduling scheme, and QoS-limited routing scheme for wireless sensor networks (DSQLRA) (2). The FLECH method performed better than other techniques in the simulation by consuming less energy and extending longevity through round data collection in the network. This strategy has the advantage of selecting the CH in a deterministic and weighted manner. This method's potential for clustering in every round is one of its drawbacks.

3. Proposed methodology

3.1. Fuzzy system

In terms of cluster analysis, choosing a central role is among the most crucial choices you will have to make. Selecting the best smart dust node to act as a smart dust CH can significantly reduce energy consumption while extending the system's lifetime. The CH node has been chosen using a variety of strategies up to this moment, includes probability selection, unambiguous selection, simulated annealing, and the use of fuzzy logic inside the selection method. Fuzzy systems reduce the computation uncertainties and complexity in WSNs (12). Fuzzy logic is a form of cross-logic where every other statement's proper value can range from zero to one. A fuzzy scheme continuously converts a dataset into a fuzzy non-linear transformation. Every logical input variable is transformed into a group of fuzzy values using the application "fuzzy builder." Every fuzzy result is converted into a real corresponding value in the defuzzer section. This component analyzes fuzzy values and carries out procedures in accordance with rules. This method includes the steps of creating a classification for input variables, using fuzzy expressions, and producing a final output, among many other things.

3.2. System model

The suggested FCER^{2}P is predicated on the following hypotheses:

1. All nodes have a similar beginning energy, and they all have a homogeneous mixture.
2. The placement of nodes in a network is randomly selected.
3. The very same time is assumed to be shared by all participating nodes.
4. Every BS and node are static.
5. The Euclid algorithm is used to determine the range.
6. This header data is delivered to BS in numerous hops and, under unusual circumstances, in a single hop.
7. The neighbours of a node are nodes located at a radius of R from that node.

The energy usage prototypical for sending "1"-bit information packets between transmitter and receiver spaced "d" apart from one another is as follows:

$$E(l,d)\{l * E_{elec} + l * E_{fs} * d^2 \text{ if } d < d_0 , l * E_{elec} + l * E_{mp} * d^4 \text{ if } d < d_0 \quad (1)$$

The cost of d_0 is premeditated as follows:

$$d0 = \sqrt{}\, efs/emp \quad (2)$$

E_{elec} is the quantity of energy used by the pivot during communication for every bit of data sent and received. The parameter yields energy usage for outdoor transmitting, while the variable yields energy usage for multi-hop communication. The indicator, which would be computed using the equation below, obtains the energy needed by the receiver to obtain data.

$$E_{RX} = l * E_{elec} \quad (3)$$

The steps in the proposed FCER^{2}P methodology are shown in **Figure 4**.

3.3. Proposed FCER^{2}P

There are two components to the planned FCER^{2}P.

Clustering, the use of the fuzzy system for energy-efficient routing.

By using a pre-determined threshold, different types of clustering, and providing a mutual mechanism for sending packet to BS, it minimizes the clusters in smart dust to improve the performance of smart dust. We will examine the proposed FCER^{2}P and its operation in the remaining sections of this study. The suggested FCER^{2}P has the following properties in general:

1. During each round, fuzzy system-based distributed clustering, uneven clustering, and no categorization are used to cut down on power usage and the quantity of control signals sent out.
2. To determine the optimal node related on leftover energy and wherever it ought to be located directly in clustering, every cluster has a unique set of fuzzy input variables.
3. Setting a preset cutoff for overall maximum power has been studied as a way to decrease the regularity of header nodes re-clustering.
4. With such a multi-hop approach, the algorithms choose the best route for communications to go from every header node toward the BS.

Reduced energy consumption within the sensor network is among the most crucial things to take into account when comparing clustering methods. By consuming less energy, the network's efficiency can be increased. Hence, every node's neighbors count is thought of as an additional fuzzy variable in clustering because the clustering intensity rises as the number of nearby nodes increases. The network's energy usage stays constant when the dispersion inside the cluster's node is symmetrical. The very first cluster is therefore analyzed in cycles 1, 4, and 7, before entire cluster is generated and managed, with leftover energy and neighbor's quantity of every node being observed as fuzzy input variables.

The first cluster's fuzzy system receives input from every node's energy and size of the network. Every node in just this cluster has a chance that ranges from 0 to 1, according to the fuzzy rules connected to it, as shown in **Table 1** and **Figure 10**. The significance level is also broadcasted by every node over the range of its message after it has been calculated, and the recipient compared it with the values it has obtained from its neighbors.

The CH is indeed the node with the highest priority in its neighborhood range, and to make sure that everyone is aware of its presence, it communicates its condition to each other node within its signal radial distance. Delivering a member connection request, the receiving node contacts the CH node, and if the obtained signal is robust, the receiving node is chosen as a cluster participant. A smart dust node accepts the membership application with the smallest ID number whenever it receives two or more CH notifications. The readers may be curious as to how the primary clustering would indeed be chosen if there were other equally likely candidates, given that clustering is part of the suggested FCER^{2}P contents. or "Is it feasible that the decisions differ in similar scenarios given that every node chooses autonomously?" Take into account that this option is likely when responding to these inquiries. There is no restriction on the node combinations in which an eligible smart dust node broadcasts smart dust CH communication to a neighboring smart dust node if multiple nodes in the vicinity possess the same likelihood of being competitors for CH. The recipient of this message accepts a qualifying node with such a low ID. The node only with a lower allocated ID is selected as the CH out of the aggregate of 107 potential nodes for every node that has the same chance, per the evaluation. To conserve energy, routing methods for WSNs are being developed. Efficiency can be enhanced and the lifespan of the network increased by launching an ideal routing plan and applying the right number of hops dependent on length among nodes as well as BS. Data delivery to the BS is accomplished in this study using a multi-hop approach. This node combines the incoming data in the suggested FCER^{2}P by concluding clustering during every round as well as transmitting sensory contextual information to CH. Through the CH node, it sends information in multi-hop toward the BS. Each CH node is picked from the list of CHs based on the ability requirements. The "remoteness to BS (D)" and "outstanding energy (E)" of the smart dust node are combined to provide the performance metric (M). These following standards must be met in order to choose a smart dust CH node:

$$M(CH(i)) = D(CH(i))/E(CH(i)) \quad (4)$$

The competitiveness radius (R), which must be determined in order to select a head node from the present CHs, is as

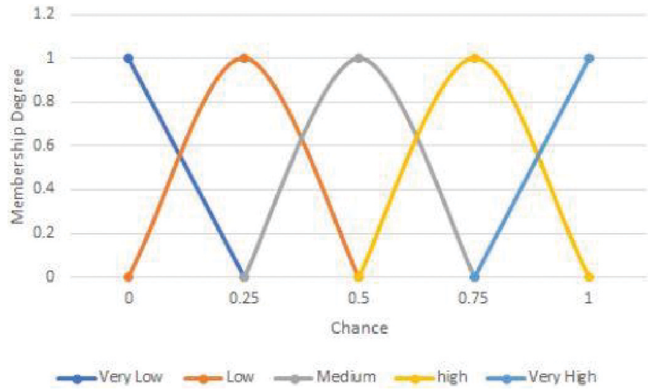

FIGURE 7 | The output variable's threshold values for a probability in the cluster.

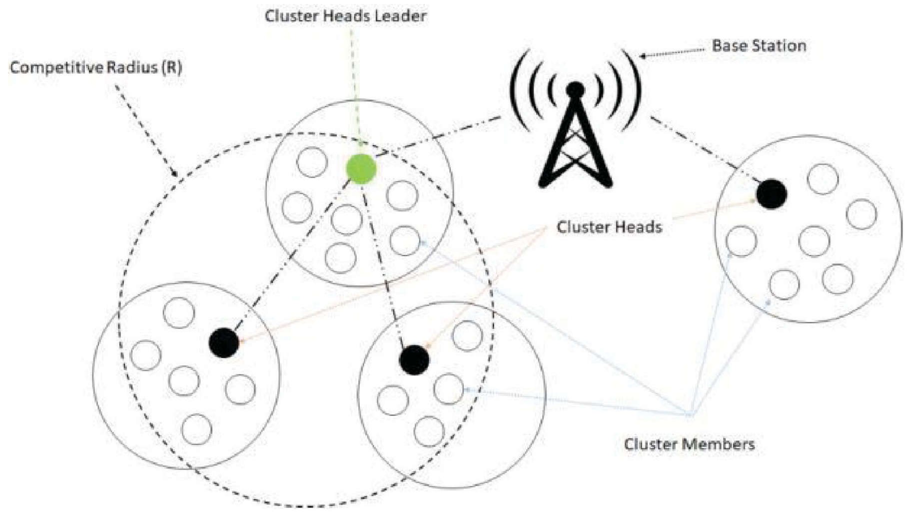

FIGURE 8 | Proposed multi-hop FCER^{2}P.

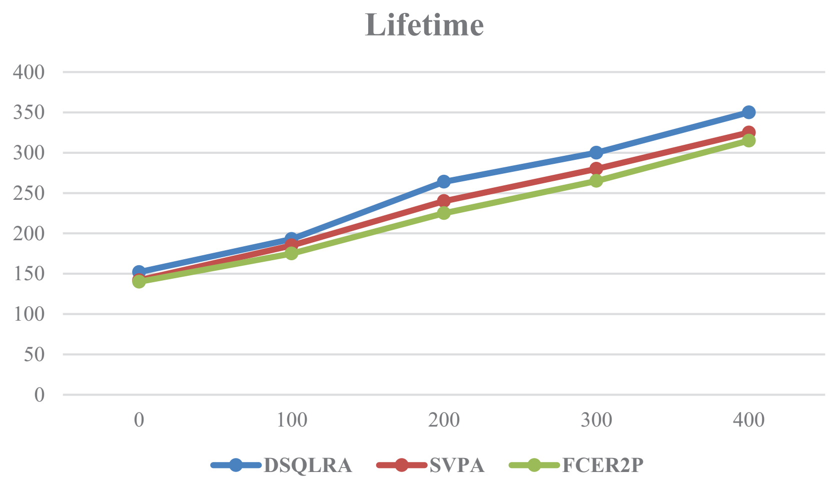

FIGURE 9 | Duration of the network.

follows:

$$R = (CH(i))/2 \quad (5)$$

For instance, the smart dust CH with the greatest suitability metric is considered CH(i) if CH(j) smart dust nodes and CH(k) smart dust nodes are located inside the competing radius (R) to also be considered CH(i) (i). This technique uses single or multiple routing to transfer information to the BS. Let us say that there are no other CH nodes within the CH node's competition radius (R) that have an appropriate proficiency measure (M) (i). In that situation, the single-hop method informs the BS. The suggested FCER^{2}P is depicted as a multi-hop in **Figure 8**.

4. Results and discussion

To see if the proposed approach is more scalable in respect of node quantity, node density, and BS placement, it is contrasted to the DSQLRA (2) and SVPA (15) methodologies in the same scenarios. The strategies were assessed using the MATLAB program according to the network lifetime measure, which includes the FND, HND, and LND variables in addition to the amount of energy consumed per cycle as well as the quantity of lifeless smart dust nodes every cycle. The work space in this experiment measures 100 × 100 m^2. All through the ecosystem, 300 smart dust nodes with just an energy difference of 0.5 joules are dispersed arbitrarily. Using only a star topology, the position of BS is beyond the workplace, and the length from the node to BS is 130 miles longer. The outcomes of comparing methods in terms of network lifespan are shown in **Figure 9**. In respect of FND, HND, and LND, the suggested FCER^{2}P performs better than alternative techniques.

As shown in **Figures 10**, **11**, it seems that sending multi-hop data from each CH toward the BS, as well as reducing the amount of clustering instances, lowers the amount of control alerts given, while maintaining a balanced energy

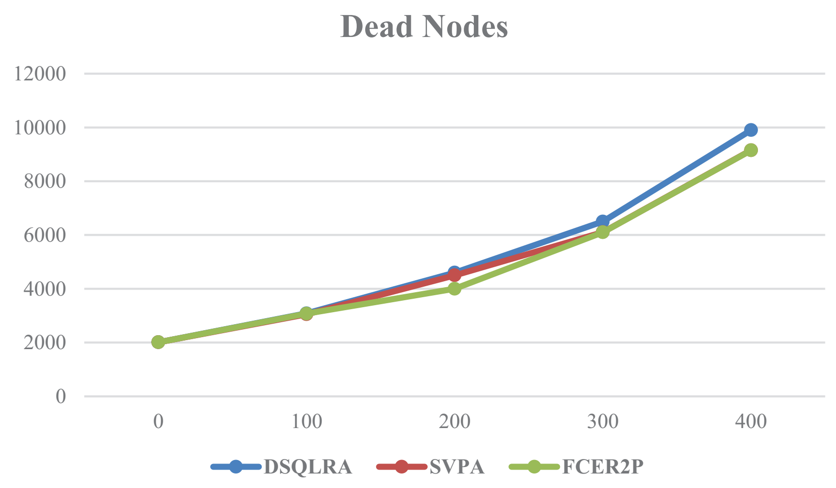

FIGURE 10 | Amount of dead nodes in every cycle.

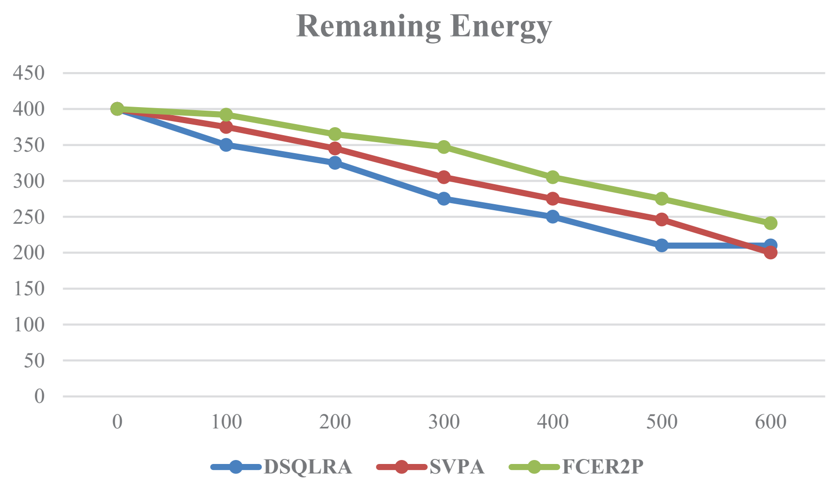

FIGURE 11 | The quantity of remaining energy in every cycle.

usage and plummeting quantity of lifeless nodes per cycle. Additionally, compared to other algorithms, the effectiveness of the suggested approach is more reliable. Because they use the CH as well as are clustered with different cluster sizes, the DSQLRA and SVPA techniques were chosen and compared to FCER^{2}P. In other terms, we made an effort to compare FCER^{2}P in a completely fair manner to several new and reliable techniques. The prevention of grouping in every round and the utilization of a cutting-edge routing protocol are among FCER^{2}P standout features. The lifetime of the network variables was assessed by taking into account the variety of nodes as well as the position of a BS in the middle of the working environment in order to successfully evaluate FCER^{2}P to other approaches. In comparison to other approaches, the results show that FCER^{2}P performs the best in terms of lengthening the lifespan of the network. The suggested FCER^{2}P has a lifespan of the network of 687, which is a 65% enhancement over the better network lifespan of 417 achieved by other techniques.

5. Conclusion

This research concentration is on extending the lifespan of WSNs and energy conservation. Moreover, it aims to minimize the transmission of control signals. In a MATLAB simulation, we applied our suggested clustering-related routing strategy with a preset cutoff and multi-hop propagation. Fuzzy Clustering and Energy Resourceful Routing Protocol (FCER^{2}P) applications were tested to determine how well they scaled in terms of smart dust node count, network magnitude, and BS place. The investigation shows that the suggested FCER^{2}P technique optimizes the FND, HND, and LND factors; minimizes the number of control packets broadcast; and uses less energy. With a pre-defined threshold, various clustering strategies, multi-hop routing with the right intermediate node, as well as other parameters, the network's lifespan is extended due to the absence of clustering in every round. Network efficiency is enhanced by employing the CH node's peak energy in combination with a pre-determined threshold.

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