International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8 Issue-4, November 2019

Routing Algorithm using Fuzzy Logic Based Clustering with Mobile Sink for Wireless Sensor Network

Vinod K, Kanika Sharma

Abstract*: *Minimization of the energy consumption in Wireless Sensor Network (WSN) is one of the most important area which has been explored by researchers through different methods. The use of non-stationary mobile sink has undoubtedly decreased the energy consumption within the sensor nodes and hence the life time of the system. Applying the Fuzzy Logic could effectively optimize the selection of Cluster Head. In this paper, Fuzzy Logic has been implemented for Cluster Head selection along with a mobile sink. The energy remaining in the sensor node, distance between the sink and the node, and the node degree are considered as the fuzzy inference variables. The life time of the node has been compared with the LEACH and Fuzzy logic based Clustering Combined with Mobile Sink (FCCMS) with mobile sink.

Keywords* : *Mobile Sink, Cluster Head, Fuzzy Logic, Node Degree, Node Energy, Sojourn Point.

I. INTRODUCTION

The area of Wireless Sensor Networks (WSNs) is an emerging technology attracted many researchers through the world as it yields enormous benefits which can help in a variety of fields like industrial control system, environmental and socio-economical domains [1]. Wireless sensors are self-configured embedded systems which can monitor surrounding environmental conditions like motion, humidity, temperature, vibration, sound, pressure etc.[2]. The fundamental task of the network system is to gather the data from sensor node [3]. The recent developments in embedded systems have helped in constructing low-cost tiny sensors which can communicate faster. Modern sensors are intelligent enough to acquire such data, and communicate with the nearby sensors and thus to cooperatively send the information to the destination base station or the sink.

Manuscript published on November 30, 2019.
* Correspondence Author
Vinod K*, Lecturer in Electronics in Government Polytechnic College, Trikaripur, Kerala, India.
Dr. Kanika Sharma, Assistant Professor in Electronics and Communication Department at National Institute of Technical Teachers Training and Research (NITTTR), Chandigarh.

Usually, there are hundreds or thousands of sensors in a WSN environment and they are randomly deployed which means that the distance between the sensors are not the same [4],[5]. The power unit in the sensor units are batteries, and they once deployed, are normally unable to replace or recharge. Thus the battery usage determines the life of the system.
Compared to typical ad-hoc networks, there are much more challenges in the area of wireless sensor network systems. In addition to the data loss within the wireless communication, the battery backup issue is the most challenging factor in sensor systems [8], [9]. Therefore, in each and every process of the sensor unit, the power consumption factor should be the minimum and of primary concern [10]. This includes the data acquisition, compression, storage, communication with the neighboring sensors, and data transmission to the sink node. The data path also determines the efficiency. The sensor network can have different structures. This includes single point-to-multipoint star network, mesh network, hybrid star-mesh network etc. [11]. Each of the scattered sensor nodes can collect the data and pass it to the destination which requires all the data communication protocols just like any other data network. The protocol stacks combine the data with networking protocols, combines power and routing awareness. The sensors deployed at a specific field are communicated each other to make a cluster and data is send to the base station. The station will communicate with the outer world through internet and thus to process or analyses the data. There are a lot of challenges to overcome for successfully implementing an efficient wireless sensor network. It is a well-known fact, that the lifetime of the sensor network strongly rely on the battery life. It is not possible to recharge the battery of the sensor node once it is deployed in the field. Most of the researches concerning wireless sensor networks are focused to reduce the energy consumption in the sensor node and thus to increase the lifetime of the nodes.

II. RELATED WORKS

Many routing protocols have been developed aimed on reducing the power consumption. Clustering schemes, sink mobility, load balancing algorithms and multipath routing were the interested areas attracted by the researchers to work upon. In most of the literatures, the main focus was to minimize the power consumption within the sensor nodes.

Different parameters of the sensor nodes have been analyzed to find out the different methods for cluster head selection. The residual energy of the battery, distance from the base station, and the number of sensor nodes are few among them.

The sink-hole problem may arise in situation at which the buffer inside the cluster head has filled with enough data to ransmit to the sink, and the sink is not in a range to communicate.

In such case the quality of the system will collapse drastically and it is to be avoided. Use of mobile sink will alleviate this problem and balances the energy consumption. The mobile sink can move within the network field and communicate with the sensor nodes. But it needs to be stationary at certain predefined locations namely sojourn points near to the sensor nodes to receive the data transmitted by the nodes. Finding out such optimized sojourn points for the mobile sink is a basic task in designing the MS's trajectory. A variable length genetic algorithm (VLGA) has been introduced by Raj et al. in [12] as a solution to find out the sojourn points. A population has been initialized with a variable number of chromosomes that denotes the number.

Mobile sink moving in circular orbit of different radii was used in [13] by Phan et al. in order to achieve higher energy efficiency. There were two methods proposed. The first one was with mobile sink in circular orbit, and the other method was with the aid of fuzzy logic. Here, the clustering head is choose by considering the residual energy, and the local distance of each node. Fuzzy logic based Clustering Combined with Mobile Sink (FCCMS) is a two-input fuzzy inference system has implemented with residual energy, and the local distance of each node as the fuzzy variables. Thus the chance of becoming the cluster head is assessed by applying fuzzy logic on each node. The circular path of different radius has shown different efficiency. The path closest to the centre of the sensor area performed better compared to other circular paths.

One of the successful methods for improving the lifetime of the sensor node is the use of mobile sink. Determining the new position of the mobile sink is a tedious task which can be made simple by the implementation of fuzzy inference system. Omar et al., in [14], have intelligently implemented a two input fuzzy inference system to accomplish this. The node power and the current distance from the active node to the base station are the two fuzzy variables which can provide nine fuzzy outputs from which the best can be selected for finding out the next position of the mobile sink.

Kambiz et al., in [15] have implemented a fuzzy inference system with three parameters for measuring the radius for each tentative cluster head. They are, the distance from the closest node, the density of the sensors, and the remaining energy of the node. Multiple mobile sinks have been introduced to optimize the performance of the sensor network by sorting out the energy-hole problem. As the distance of the node towards mobile sink trajectory decreases, the need for increasing the number of clusters has been exposed.

Mobility of the sink will maximize the energy efficiency of the nodes, but the transmission and reception of data by the sink while moving is a difficult task. The frequent updates from sink regarding its location will increase the traffic in the network which will consume more energy and may affect the performance of the system. A new method of ring routing for multiple mobile sink (RRMMS) has been put forward by Vicky et al. in [16]. The method was proposed for real time applications using multiple mobile sink The use of multiple mobile sink will reduce the waiting time for the nodes to communicate with the sink since the sink may not be near to it. Two sinks have been used to move in horizontal and vertical straight lines passing through the centre of the rectangular sensor area. The life time of the nodes has increased and the delay in data delivery gets reduced compared to ring routing (RR) without use of multiple sink.

An active area has been created around the source and sink for data routing in [17] by Sreejith et al. in which the sensor is mobile in nature and are kept in sleeping mode when not in the active area. The nodes involved the routing will stay near to the Euclidean line joining source and the sink. The sleep-awake pattern will conserve energy within the sensor nodes. Information related to the mobility of the nodes such as current location, speed, direction of movement, and the residual energy of the node is used to find out a neighbor node which will provide the connection retention time. The proposed system provides better energy efficiency without overhead of time synchronization.

In [18], Devendra et al. have described the scope of using fuzzy logic in wireless sensor network focussing on the clustering process. The selection of fuzzification methods with membership functions will affect the efficiency of the clustering. Two methods namely Fuzzy logic method for clustering in wireless sensor network -I (FCWN-I) and Fuzzy logic method for clustering in wireless sensor network -II (FCWN-II) has been proposed. The first one uses Sugeno method fuzzification in which the crisp input values has been converted to fuzzy linguistic variables. The membership function that the variables follow is triangular. Meanwhile the Mamdani method is used in FCWN-II in which the crisp values have been fuzzified into linguistic variables with Gaussian membership function. The membership functions used were the residual energy of the sensor nodes, node degree and the distance from the base station. Node degree is the parameter showing the number of neighbours of a node which is an approximation of the load that the node would have if it is selected as CH. The three linguistic variables there by yield 27 output fuzzy inference rules. The two output fuzzy variables are, Chance and Size.

The LEACH protocol has been renovated with the use of fuzzy logic for cluster head selection in [19] by Wided et al. The proposed algorithm uses the three input fuzzy inference variables. They are the residual energy of the nodes, the distance between the sensor node and the base station, and the number of neighbors active within the CH area. There is only one fuzzy output variable namely Chance with nine linguistic variables. Mamdani method has been used to develop the fuzzy if-then rules.

The method has provided better lifetime to the sensor nodes and thus to the network system.

The inferences drawn from the survey shoes that energy efficiency is the major problem in WSN since the sensor nodes are battery operated and once deployed, cannot be recharged. The major part of power is used for communicating with the Sink Node. The Sink node can be rechargeable so, its energy efficiency is not an issue in designing a WSN network. Cluster Heads are selected based upon the remaining energy level, the distance from the BS, distance from the centre of the area etc.

Mobile Sink can reduce the power consumption since the distance between CH and sink is much reduced. Cluster Head can be selected by using Fuzzy Logic.

III. PROPOSED WORK

The objective of the proposed work is to develop a routing algorithm using fuzzy logic based clustering combined with mobile sink for wireless sensor network in order to increase the network lifetime. The sink is made mobile in nature and the sensor nodes are randomly deployed in 100 X 100 sq.m area. Initially, Sink will be kept at the center and then it will move to new positions to become a Mobile Sink. The residual energy of the node, sensor node to sink distance and the node angle can be taken as the fuzzy variables to select the Cluster Head using Fuzzy Logic.

A. Use of Mobile Sink

In wireless sensor network, the use of Mobile Sinks can reduce the distance between the CH and the sink. In wireless communication using microwave signals, when the distance between the transmitter and the receiver increases, the power required is also increased. So, if it is possible to lessen the distance between CH and the sink, a lot of power can be saved in transmission. The use of mobile sink can achieve this task. In this work, the mobile sink is imagined to be having infinite power source. This can be accomplished by use of rechargeable or replaceable battery. So the power consumption within the mobile sink is not a parameter to be considered while designing the network system.

The sink is kept stationary at certain locations within the network area namely sojourn points for efficient data communication. Twelve such points have been selected in a circular pattern at 30 degree angular difference in the field as shown in the Fig.1. The radius of the circular path in the figure below is 25 meter.

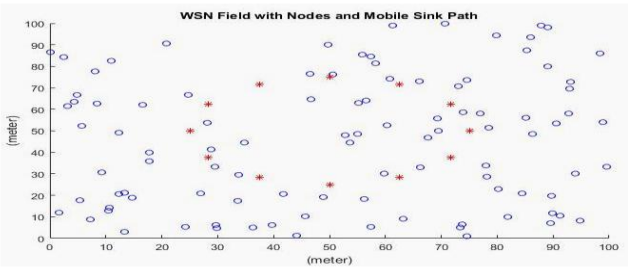

Fig.1. WSN field with mobile sink at radius 25m.

The position of the sink so called the Sojourn points, are changed after a particular number of rounds. As this number of rounds increases, the duration of the mobile sink being stationary at the sojourn point also increases.

B. Use of Fuzzy Logic

Unlike other logic systems, fuzzy logic system works similar to how a human brain thinks while decision making [43]. Fuzzy logic is a method for decision making or reasoning which provides a variety of answers. Fuzzy logic system architecture consists of a (i) fuzzifier module, (ii)knowledge base, (iii)inference engine and (iv)defuzzifier module as shown in Fig.2.

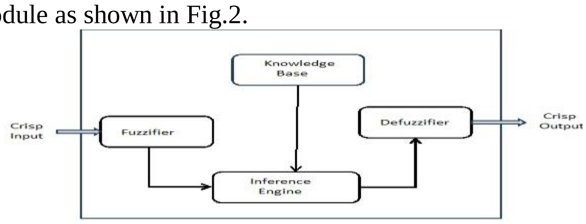

Fig.2. Fuzzy Logic Architecture

The Fuzzifier module splits the input crisp values into fuzzy sets. In the proposed system, Mamdani model is used with three crisp inputs and one output namely Chance. The inputs are the residual energy, distance between SN and the Cluster Head, and the node degree. Node degree is the parameter showing the number of neighbors of a node which is an approximation of the load that the node would bear if it is elected as CH. The Knowledge Base provides the If-Then rules according to the system design. The Defuzzifier converts the fuzzified values to crisp values. In the proposed system, the output crisp value is the "Chance" of becoming the cluster head. The Fuzzy Inference System (FIS) for the proposed method is designed in Matlab Fuzzy Logic Designer as shown in Fig 3 given below.

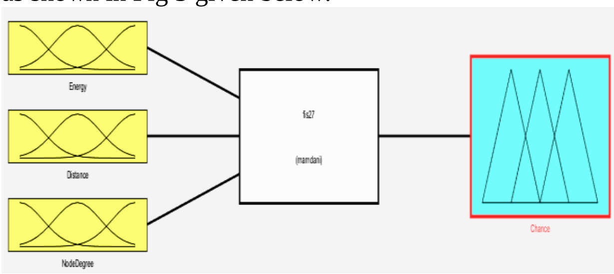

Fig.3.The FIS in Fuzzy Logic Designer

The fuzzy member ship variables are as shown in figures below. Fig.4 shows energy of the sensor node as input variable. Fig.5 is distance between the node and the CH. The number of nodes within the neighborhood is shown in Fig.6. Each input has three membership functions.

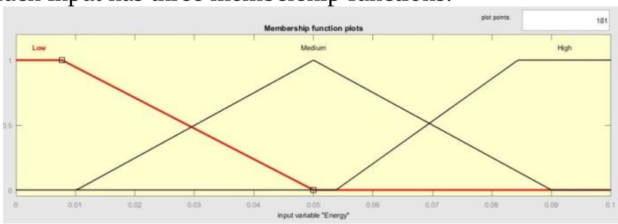

Fig.4. Node energy as input fuzzy input variable

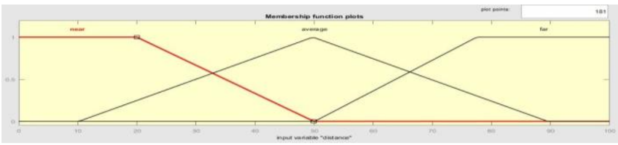

Fig.5. Distance as input fuzzy input variable

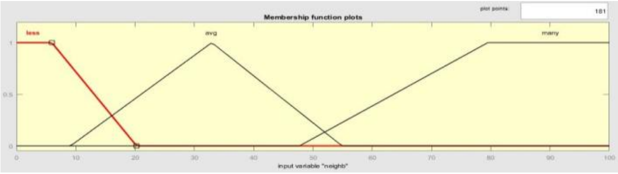

Fig.6. Node degree as input fuzzy input variable

The output from the fuzzy inference system Chance is as shown below in Fig. 7. It has 27 membership function.

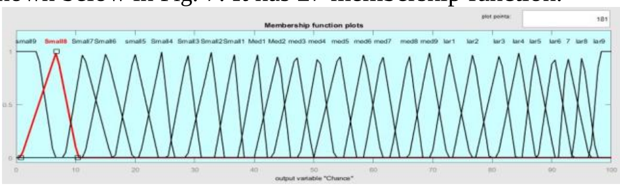

Fig.7. FIS output variable Chance

The fuzzy If-Then rule is shown in Table-I. There are 27 possible variable combinations.

Table-I: Fuzzy IF –THEN rule

No.	Input Variables			Output
	Energy	***Distance***	***Node Degree***	***Chance***
1	Low	Far	Less	Small 9
2	Low	Far	Average	Small 8
3	Low	Far	Many	Small 7
4	Low	Average	Less	Small 6
5	Low	Average	Average	Small 5
6	Low	Average	Many	Small 4
7	Low	Near	Less	Small 3
8	Low	Near	Average	Small 2
9	Low	Near	Many	Small 1
10	Medium	Far	Less	Med1
11	Medium	Far	Average	Med2
12	Medium	Far	Many	Med3
13	Medium	Average	Less	Med4
14	Medium	Average	Average	Med5
15	Medium	Average	Many	Med6
16	Medium	Near	Less	Med7
17	Medium	Near	Average	Med8
18	Medium	Near	Many	Med9
19	High	Far	Less	Lar1
20	High	Far	Average	Lar2
21	High	Far	Many	Lar3
22	High	Average	Less	Lar4
23	High	Average	Average	Lar5
24	High	Average	Many	Lar6
25	High	Near	Less	Lar7
26	High	Near	Average	Lar8
27	High	Near	Many	Lar9

The simulation environment is designed as per the parameters shown in the Table-II given below. Assume all sensor nodes are randomly distributed in the field.

Table-II. Network parameters

Parameter	**Value**
Field Area	100m*100m
Sensor node strength (n)	100
CH selection percentage(p)	0.05
Packet length (k)	4000
SN Initial (E_0)	0.1J
Energy consumption on circuit (E_{elec})	50nJ/bit
Channel parameter in multi-path model (E_{mp})	0.0013pJ/bit/m^4
Channel parameter in free-space model (E_{fs})	10pJ/bit/m^2
Energy data aggregation (EDA)	5 nJ/bit

The flow chart of the proposed method is as shown in the Fig. 8 given below.

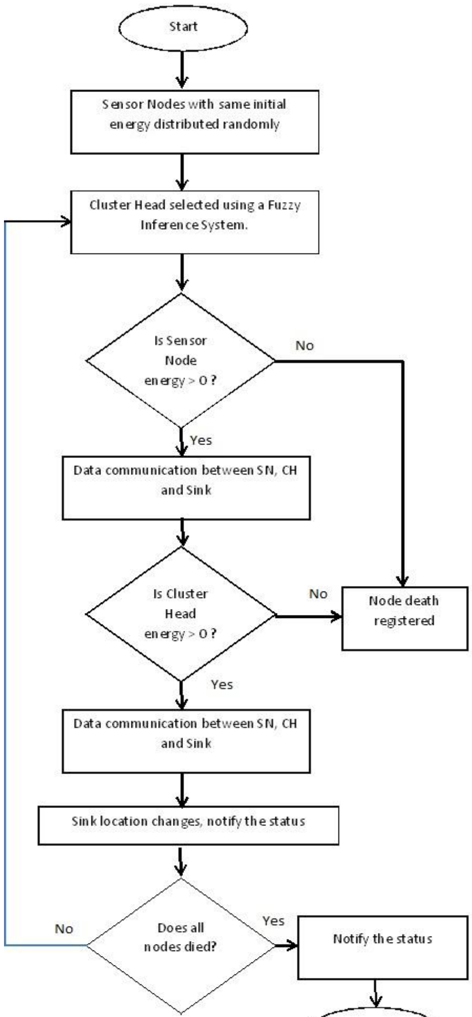

Fig. 8 Flow chart of the Proposed Method

Retrieval Number: D8629118419/2019©BEIESP
DOI:10.35940/ijrte.D8629.118419
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

IV. SIMULATION RESULTS

The testing and simulation of the proposed system is performed through Matlab simulation software. The Wireless Sensor Network field with required parameters like energy, area dimensions, and number of nodes are assigned initially. Fuzzy Logic Designer, a tool within Matlab has been used for designing the fuzzy inference system. Three parameters namely distance from the cluster head, remaining energy of the node, and the node degree are used as fuzzy inference variables. Node degree denotes the number of neighboring nodes surrounding a sensor node.

The network life time of the proposed method has been compared with the traditional LEACH protocol and the FCCMS method under consideration. Fig.9 shows this comparison based on the energy decaying versus the number of rounds.

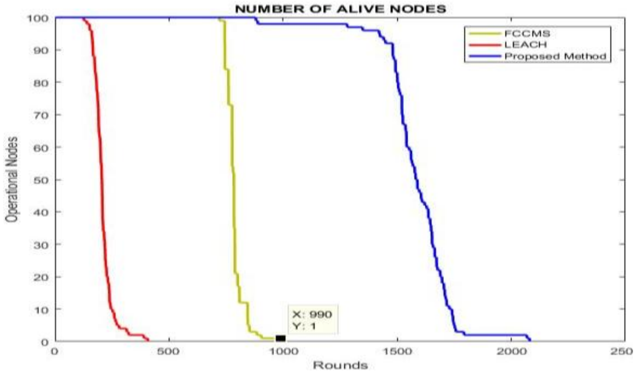

Fig.9. Comparison between Proposed Method (radius=15) with LEACH and FCCMS

The plot given above clearly denotes that the life time of the nodes is significantly increased in the proposed method. The First Node Died (FND) in FCCMS method was at 700 rounds and the Last Node Died (LND) at 980 rounds. The Half Node Died (HND) has been determined by considering the number of rounds completed when the energy of the 50 nodes are depleted. These FND and LND are improved to 880 and 2081 respectively in the proposed method. The proposed method used in the above plot is based upon twelve sojourn points situating in a circular pattern with a radius of 15m and each such location is shifted after every three rounds. The number rounds for which the sink being stationary at a point denotes the speed of the mobile sink. The network lifetime comparison details are shown is Table-III.

Table-III: Network Lifetime Comparison Table between LEACH, FCCMS and the Proposed Method (r=15m)

Protocol used	First Node Died (FND)	Half Node Died (HND)	Last Node Died (LND)
LEACH	126	205	406
FCCMS	700	773	990
Proposed Method (Radius=15m)	880	1580	2081

The experiment on changing the radius of the circular trajectory of the system gave the result as shown in Fig.10. The plot shows that as the radius of the sink trajectory reduces the life time of the nodes increases. The selected radii are 50 m, 25 m and 15 m.

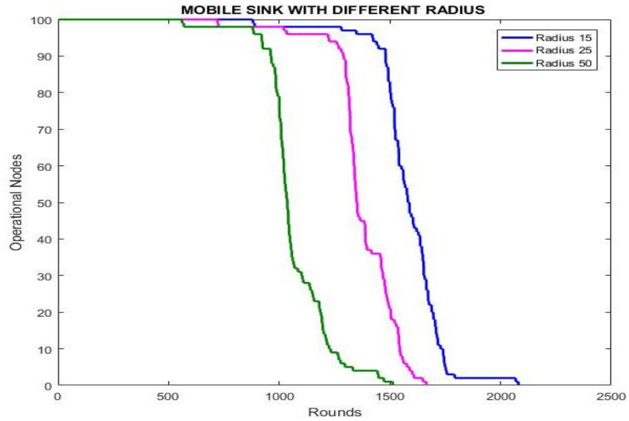

Fig.10. Comparison of sink at different radius of circular trajectory (Radius 50, 25 and 15).

The above plot yield values of FND, HND and LND as given in the Table-IV.

Table-IV: Performance comparison at different radius of circular trajectory

Method used	First Node Died (FND)	Half Node Died (HND)	Last Node Died (LND)
Radius=50m	560	1020	1510
Radius=25m	725	1350	1665
Radius=15m	880	1580	2080

The proposed method has been experimented with different sojourn points of the mobile sink in the field. Fig.11 compares the system with four sojourn points and twelve sojourn points both with radius 15m. In the Four Sojourn point system, the points are selected at an angular difference of 90 degree.

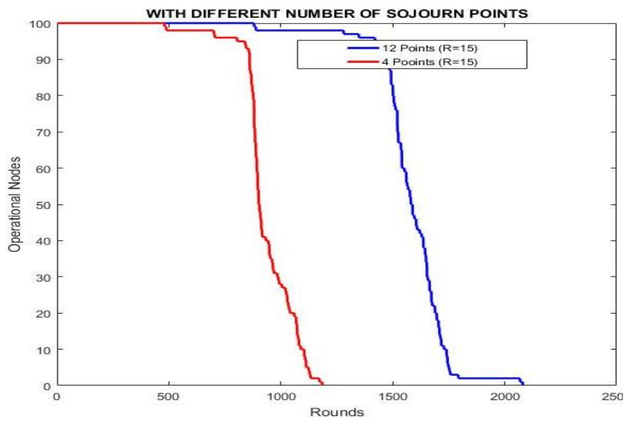

Fig.11. Comparison between 4-Sojourn point and 12-Sojourn point method at radius=15m.

The details regarding the above plot is as shown in the below Table-V.

TABLE 4.4 Comparison Table between 4-Sojourn Point and 12-Sojourn Point Method at radius=15m.

Method	First Node Died (FND)	Half Node Died (HND)	Last Node Died (LND)
4-Sojourn Point	480	903	1185
12- Sojourn Point	880	1580	2081

The plot and the table clearly show an increased lifetime for the sensor nodes in 12-point method compared to the 4-point method. The maximum distance from the sensor nodes to the CH will get reduced when the number of sojourn point is increased. This will increase the life time of the nodes and thus that of the system.

V. CONCLUSION

In this paper, mobile sink has been used along with a fuzzy logic based cluster head selection method. The residual energy, distance between SN and the Cluster Head and the node degree are considered as the fuzzy inference variables. Node degree is the parameter showing the number of neighbors of a node which is an approximation of the load that the node would be handling if it is elected as CH. The use of fuzzy logic gave an optimized method to conserve energy. Comparing with the two-variable method as in FCCMS, and LEACH, the FND and LND of the system has increased to improve the lifetime of the nodes. The life time of the system also varies with varying radius of the circular trajectory. Comparing with radius of 50 meter and 25 meter, 15 meter provides better result. These parameters also vary when the number of sojourn points is changed. The twelve-point method shows better lifetime than the four-point method. This shows that if the nodes get the CH near to it, more energy can be saved in data transmission. Implementation of fuzzy logic in choosing the optimized position of the mobile sink can further increase the life time of the network.

REFERENCES

1. Hoon Kim, and Sang-wook Han, "An Efficient Sensor Deployment Scheme for Large-Scale Wireless Sensor Networks", IEEE Communications Letters, Vol. 19, No. 1, pp. 98-101, 2015.
2. Ravi Yadav , A.K Daniel , "Fuzzy Based Smart Farming Using Wireless Sensor Network", 5th IEEE Uttar Pradesh Section International Conference on Electrical, Electronics and Computer Engineering (UPCON), pp.1-6, 2018.
3. Md. Ahsan Habib, Sajeeb Saha, Fernaz Narin Nur, Md. Abdur Razzaque, Md. Mamun-Or-Rashid, "An Efficient Mobile-Sink Trajectory to Maximize Network Lifetime in Wireless Sensor Network", International Conference on Innovation and Technology (ICIET) , pp.1-5, 2018.
4. Omar Banimelhem, Muhammad Naserllah, and Alaa Abu-Hantash, "An Efficient Coverage in Wireless Sensor Networks Using Fuzzy Logic-Based Control for the Mobile Node Movement", 2017 Advances in Wireless and Optical Communication, pp.239-244, 2017.
5. YoungSang Yun, Ye Xia, Behnam Behdani, and J. Cole Smith, "Distributed Algorithm for Lifetime Maximization in a Delay-Tolerant Wireless Sensor Network with a Mobile Sink", IEEE Transactions on Mobile Computing, Vol. 12, No. 10, pp. 1920-1930, 2013.
6. Zaheeruddin, Aruna Pathak, "A Bee Colony Inspired Clustering Protocol for Wireless Sensor Networks", International Conference on Computing, Communication and Automation (ICCCA2017), pp.570-575, 2017.
7. Tanvi Sood, Kanika Sharma, "A comparative analysis on the Scheduling Algorithms for Wireless Sensor Networks", IEEE International Conference on Industrial and Information Systems (ICIIS) , pp.236-245, 2018.
8. Aniji John, K. Vinoth Babu, "Two Phase Dynamic Method for Cluster Head Selection in Wireless Sensor Network for Internet of Things Applications", IEEE WiSPNET 2017 conference., pp.1228-1232, 2017.
9. Raghunandan.G.H, Dr.A.Shobha Rani, Nanditha.S.Y, Swathi.G, "Hierarchical Agglomerative Clustering Based Routing Algorithm for Overall Efficiency of Wireless Sensor Network", International Conference on Intelligent Computing,Instrumentation and Control Technologies (ICICICT), pp.1290-1293, 2017.
10. Hamza Fahim, Nadeem Javaid, Zahoor Ali Khan, Umar Qasim, Shumaila Javed, DanishnMahmood, Xafar Iqbal, "Multilevel Routing Protocol for Energy Optimization in Wireless Sensor Networks", 9th International Conference on Innovative Mobile and Internet Services in Ubiquitious Computing, pp.86-93, 2015.
11. M.A. Martin and M.M.Islam, "Overview of Wireless Sensor Network", INTECH, pp.1-24, 2012.
12. Raj Anwit, Prasanta K. Jana, "A Variable Length Genetic Algorithm Approach to Optimize Data Collection Using Mobile Sink in Wireless Sensor Networks", 5th International Conference on Signal Processing and Integrated Networks (SPIN), pp.73-77, 2018.
13. Phan Thi The, Vu Nhu Manh, Tran Cong Hung, Le Dien Tam, "Improving Network Lifetime in Wireless Sensor Network Using Fuzzy Logic Based Clustering Combined with Mobile Sink" , International Conference on Advanced Communications Technology(ICACT), pp.11-14, February 2018.
14. Omar Banimelhem and Alaa Abu-Hantash, "Fuzzy Logic- Based Clustering Approach with Mobile Sink for WSNs", pp. 36-40, IEEE,2018.
15. Kambiz Koosheshi, Saeed Ebadi, "An Energy Efficient New Protocol for Wireless Sensor Networks with Multiple Mobile Sinks" , IEEE 2017.
16. Vicky Kumar, Gaurav, Ashok Kumar, and Manjeet Singh, "Improving Network Lifetime and Reporting Delay in Wireless Sensor Networks Using Multiple Mobile Sinks", pp. 1675-1678, 2016.
17. V. Sreejith, Rutuja Surve, Nikhil Vyas, K.R. Anupama, Lucy J. Gudino, "Area Based Routing Protocol for Mobile Wireless Sensor Networks", ICOIN 2018, pp.782-786, 2018.
18. Devendra Choudhary, Iti Sharma, "Using Fuzzy Logic For Clustering In Wireless Sensor Networks", International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT), pp.861-866, 2017.
19. Wided Abidi, Tahar Ezzedine, "Fuzzy Cluster Head Election Algorithm Based on LEACH Protocol for Wireless Sensor Networks", pp.993-997, IEEE, 2017.

AUTHORS PROFILE

Vinod K, ME scholar in Electronics and Communication Department at National Institute of Technical Teachers Training and Research (NITTTR), Chandigarh under Punjab University. Graduate in Electronics and Communication Engineering from University of Calicut in 1999 and currently working as a Lecturer in Electronics in Government Polytechnic College, Trikaripur, Kerala, India. His interested area include wireless sensor networks and embedded systems.

Dr. Kanika Sharma, Assistant Professor in Electronics and Communication Department at National Institute of Technical Teachers Training and Research (NITTTR), Chandigarh. Ph.D from Punjab Technical University, Chandigarh, ME from PEC, Punjab University, Chandigarh and BE from Maharishin Dayanand University, Rohtak. Her **Publication Topics includes** wireless sensor networks, telecommunication power management, routing protocols, energy conservation, pattern clustering, telecommunication scheduling, Internet of Things, copy protection, copyright, data integrity, data protection, decision making, digital rights management, discrete cosine transforms, embedded systems, image coding, image watermarking, intelligent systems, low-power electronics, maximum likelihood estimation, message authentication, optimisation, sensor placement, shift registers, smart power grids etc.