World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:16, No:3, 2022

Improved BEENISH Protocol for Wireless Sensor Networks Based Upon Fuzzy Inference System

Rishabh Sharma, Renu Vig, Neeraj Sharma

***Abstract*—**The main design parameter of WSN (wireless sensor network) is the energy consumption. To compensate this parameter, hierarchical clustering is a technique that assists in extending duration of the networks life by efficiently consuming the energy. This paper focuses on dealing with the WSNs and the FIS (fuzzy interface system) which are deployed to enhance the BEENISH protocol. The node energy, mobility, pause time and density are considered for the selection of CH (cluster head). The simulation outcomes exhibited that the projected system outperforms the traditional system with regard to the energy utilization and number of packets transmitted to sink.

***Keywords*—**Wireless sensor network, sink, sensor node, routing protocol, fuzzy rule, fuzzy inference system.

I. INTRODUCTION

RESEARCH and progress in Wireless sensor network (WSN) are emerged in multiple diverse applications, ranging from warzone surveillance to home security, to monitor the environment and track the target. WSNs are made up of many miniature sensor nodes with both physical data sensing and collection, and physically sensed data advancing capabilities. A WSN has two sides: a Base Station (BS) or sink and a number of physically distributed sensing nodes that interact with the physical environment by sensing some physical parameters. These sensors carry out mainly three tasks- physical data sensing, initial data processing, and transmitting the processed data to the sink. The main tasks of the BS or sink are receiving data, processing data, and providing data to the end user for decision-making and further applications. Nodes in WSN depend on their on-board, limited, non-rechargeable, and non-changeable batteries. In addition, these sensor nodes are limited in storage, memory, and CPU processing capabilities. The environment conditions are sensed and monitored by installing a number of small and independent nodes [1]. A radio channel is utilized to establish the communication among nodes to transmit the attained information to sink node with the help of one or several hops. The sink node has extra power for interfacing the WSN with the end client due to transmission of the obtained data to the server.

The WSN sensor node comprises of a sensing unit, power unit, processing unit, and communication unit. Sensing unit further consists of a sensor and an analog to digital converter (ADC). The power unit of a sensor node is responsible for supplying the power to the sensor node. A mini battery is included in this unit. The sensor node is utilized for sensing diverse physical metrics such as temperature, light intensity and water level from the environment. For this purpose, a suitable loaded sensor unit is exploited [2].

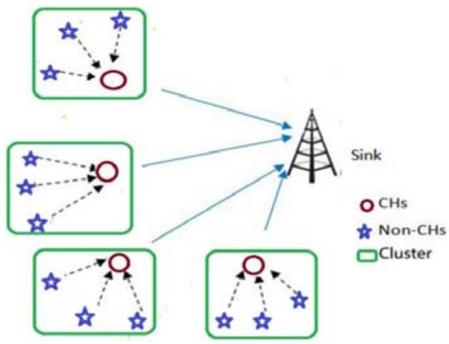


Fig. 1 Wireless sensor network

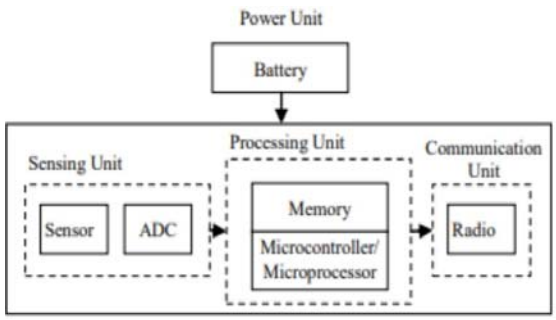


Fig. 2 Sensor Node Composition

The transformation of the output of the sensor unit is available as an analog signal, which is converted into a digital signal. The microcontroller module is based on ADC unit assist in recognizing this signal. A communication unit is considered to transmit the sensed data to the sink. In general, the sensor node is capable of establishing the communication among its peers in place of communicating directly with the sink. Therefore, the amount of energy consumed by the nodes is mitigated considering a feasible communication mode when the sequential information is transmitted to the end client.

Rishabh Sharma is with the University Institute of Engineering and Technology, South Campus Panjab University, India (corresponding author, e-mail: rishabhsharma19516ece@gmail.com).

Renu Vig and Neeraj Sharma are with the University Institute of Engineering and Technology, South Campus Panjab University, India (e-mails: renuvig@hotmail.com, nsharma.pu@gmail.com).

A. Energy Consumption in WSN

Because of the cost efficiency and miniaturization requirements, WSN nodes have few resources with insufficient memory and computation capacity. In addition, the energy is provided to the nodes via battery, thus, energy is a significant component as it affects the duration of the network [3]. Three tasks: sensing, computation, and transmitting the data consume greatest energy of nodes. A large amount of energy is consumed in the task of forwarding the data. Additionally, apart from energy consumption, design parameters also play an important role for WSN. For accomplishing the requirements related to design, the design must be hard and simulating. To illustrate, the sensor node's size is suppressed to utilize the facility. The consequences, which will suppress in physical size, are not sufficient energy sources, inadequate computing capability, and minor memory storage. Thus, the routing algorithm is optimized for saving the energy and expanding the duration of the network. The energy consumed in a WSN is based upon three major components such as sensing, processing, and transmission. The sensing energy utilization for the sensor node is determined using the explicit attributes of the sensor [4].

Processing energy consumption [$E_{i,kproc}$] for sensor node i and task k is proportionate to the intricacy of task k and the $Eiins$ represents the average energy consumption per instruction belonged to node i which is described as:

$$E_{i,k}^{proc} = I_k \times E_i^{ins}$$

The transmission and reception energy utilization are also two important aspects, which may be described using following equation [5] –

$$P_{ij}^{T} = P_i^{T0} + P_i^{A}(\delta_{ij}) = P_i^{T0} + \frac{P_i^{Tx}(\delta_{ij})}{n_i}$$
$$P_j^{R} = P_j^{R0}$$

where P_{ij}^{T} denotes the radio frequency power consumption values utilized in transmission and P_j^{R} illustrates the radio frequency power consumption values for receiving. Also, $P_i^{A}(\delta_{ij})$ defines the power consumed through the power amplifier (PA) based on the distance δ_{ij} amid transmitting node $i$and receiving node j. The mechanisms of power consumption to transmit the circuitry represented withP_i^{T0} and receiving circuitry with P_j^{R0} [6]; $P_i^{Tx}$is the output power at node i antenna which, for trustable transmission depending upon the distance δ_{ij} ; $\eta_i$is used to illustrate the drain efficacy of the power amplifier at node i.Several protocols have been proposed in the past for energy conservation and maximizing the network lifetime by using cluster-based network architectures and allocating role assignments to the nodes. Various hierarchical energy aware routing protocols like LEACH, power efficient gathering in sensor information system (PEGASIS), threshold-Sensitive energy-efficient sensor network (TEEN), hybrid-energy-efficient distributed clustering (HEED), and adaptive threshold-sensitive energy efficient sensor network (APTEEN) were introduced as solutions for energy conservation and increased network lifetime.

B. Fuzzy Logic for Reducing Energy Consumption in WSN

The techniques planned based on Fuzzy logic (FL) are extensively utilized in WSNs as they have potential to handle the issues occurred in designing and managing the network. Fuzzy logic controllers (FLCs) are adaptable for fulfilling multiple functions and have an impact on diverse layers of the WSN protocol stack [7]. At the network level, fuzzy logic assists in splitting the entire network into clusters. The cluster nodes collect the data whose clustering is done for aggregating the CH. The clustering results in boosting the communication efficacy and network scalability. Gathered data is transmitted to the node at BS using CH. Sensor nodes having higher remaining energy are selected as the CHs. Moreover, the CHs present near to the BS have consumed more energy as they are responsible for establishing communication with BS. The disparate clustering algorithms are put forward so that such an issue can be resolved [5]. The network splits are required in these algorithms so that the clusters can establish nearer to the sink smaller than clusters present far away from it.

The data link level employs fuzzy logic centric solutions for coordinating the channel access. To illustrate, media access control (MAC) protocols are generally based on the correct network time synchronization for scheduling the broadcast and receiving phases of nodes. However, the inaccuracy among nodes is occurred due to the clock shift [8]. A FLC focuses on the clock shift and delay effects or estimates the packet scheduling consequently. Every node contains a finite buffer for provisionally storing the received packets prior to accomplishing their processing. In case of no space in buffer, the packet, which is arrived next, is rejected. The FLC is utilized for estimating: (i) the proportion of nodes with overfilled buffers, (ii) the proportion of nodes having high failure rates in their broadcast and (iii) the proportion of nodes that have not synchronized their interaction with another node due to the clock shift. In FLC, the adaption aspect is another important factor, as it defines the adaptability of the changes for better efficiency. The product of the FLC is the divergence of the adaptation aspect [9]. The length of the current interval is counted through the multiplication of this factor with the length of the former interval existing in the transmitting schedule.

The application level makes the deployment of a FL system to adjust the behavior of nodes. In particular, much effort is made for saving the energy due to the finite power of the batteries that provides energy to the nodes. Transmission energy affected the energy balance due to the highest energy consumption of a node in the broadcast.

In addition, instead, due to active constantly, a node provides energy efficiency through the sensing and communicating at regular time intervals such as with exact sampling and sleeping times [10]. Sampling in signal processing is considered as the reduction of continuous time signal into a discrete time signal, whereas sleeping time (duty cycling) is defined as turning on and off of sensor nodes in the necessary time to conserve energy. Duty cycling has become a significant mechanism to increase the lifetime of WSNs, and many related methods have been proposed in past, which have diverse effects and application areas.

1. Fuzzy Logic-Based Energy Efficient Clustering Algorithms for WSN

The analysis on clustering routing algorithms has also been conducted in previous literatures regarding WSNs. The clustering assists in alleviating the energy consumption, but still there are some issues needed to be addressed. The main concern is that the energy consumption is CH centric. For overcoming this issue, it is essential to resolve the cluster routing issues related to the apt distribution of energy consumption. The FL is utilized in various studies in addition, its efficiency is provided in clustering, especially in enhancing the energy efficacy of WSNs [11]. Some of protocols of the interest are explained as follows:

i. Fuzzy energy-aware unequal clustering (EAUCF): A FLC is adopted in this algorithm for investigating the rough clustering. For each node, the rest of the energy and the remoteness of sink are considered in this controller for computing the competing range of the node. Then, the sharing of messages is done among the nodes with the value of their competing ranges and their remaining power [12]. In case, a node having more remaining energy acquires a message from another node in its competitive range, the recipient node will leave the race of selecting the CH. The nodes, which are durable, are selected as the CHs. The Fuzzy Based Unequal Clustering (FBUC) is a modification of an enhanced version of EAUCF (Fuzzy energy-aware unequal clustering). The FBUC utilizes the fuzzy rules that take the node degree into account along with its rest of the energy and distance with the BS for computing the range of competition.
ii. Fuzzy-LEACH: The F-LEACH makes the deployment of three fuzzy descriptors in fuzzy logic controls namely energy, concentration and centrality for managing the technique of selecting the cluster head (CH) [13]. The node centrality variable is utilized to reveal the centrality of a node to the cluster, whose computation is done based on the sum of the squared distances of other nodes from the specified node. The Fuzzy-low energy adaptive clustering hierarchy (F-LEACH) protocol contains a sink, which participates in every round of selecting the cluster head. For this, the probability of every node to turn into a CH is computed with the estimation of three fuzzy descriptors. This algorithm considers that an effective cluster head is generated via sink due to awareness of the entire network to sink. All nodes available in the cluster lead to propagate k bit messages to CH. Cluster head assists in aggregating and compressing these messages into c_{nk}-bit messages, with $c \leq 1$ as the compression coefficient. There is a similarity amid the operation of this presented algorithm and LEACH. This algorithm focuses on partitioning the task to select the CH into 2 Phases: setup and steady state [14]. The processing CHs are selected using knowledge related to FL in the initial phase and the data operations are gathered and aggregated in the subsequent phase.
iii. FEAR (Fuzzy Energy Aware tree-based Routing): This protocol concentrates on enhancing the existent tree based routing protocol and expanding the duration of the network considering the inadequate energy of sensors nodes. This protocol is developed and enforced using a cross-layer technique at which the information taken from diverse layers is utilized to save energy. A list of the nearer nodes and children of a parent is included in all nodes. This protocol is executed in diverse stages such as to construct a tree, engage a novel node, transmit a message and rebuild a tree [15]. The fear analysis is based on the number of control messages transmitted and obtained and the power exhaustion based on these messages.
iv. Cluster Head Election mechanism using Fuzzy logic (CHEF): A localized CH (cluster head) election technique is utilized in this protocol in which the sink is not required for collecting the information from all nodes. There is not any necessity of the base station for gathering the clustering output from all the nodes. The reason is that the cluster head is selected through it diffusively. A probabilistic procedure is utilized for selecting the temporary CH. After that, fuzzy logic is adopted for restricting the selection to the last CHs. The characterization of the input residual energy administered to the fuzzy system is done. The Cluster Head Election mechanism using Fuzzy logic (CHEF) is effectual for expanding the life span of the network. This algorithm contains non-uniformly distributed CH in comparison with other protocols.

II. Related Work

In this section, discussions of some pertinent and predefined clustering algorithms in WSN are made. Most of the clustering algorithms use rounds to describe the lifetime of WSN. Each round consists of CH selection, cluster formation and the data collection. More the number of rounds, the longer will be the lifetime of WSN. Therefore, these energy efficient protocols play a vital role to increase the network life and efficiency of the network.

Adnan et al. hypothesized a FL (fuzzy logic) centric clustering protocol with multi-hop transmission for load balancing; reducing the energy exhaustion of nodes, and increasing the network span [16]. Uneven clusters were produced with CH (cluster head) selected through fuzzy logic with competing scopes. The distances from the sink to the node and RE (residual energy) were treated as input variables. The outcomes based on simulation confirmed the dominance of the inferred protocol by aggregating the data into a multihop WSN (Wireless Sensor Network) algorithm.

Fattoum et al. reviewed the role of clustering in reducing energy use in extensive WSNs (wireless sensor networks) [17]. A two-fold energy-efficient clustering technique based on the FL (fuzzy logic) model was presented to increase the network span. At first, a two-tier clustering scenario deployed with fuzzy logic was put forward. Next, this approach was applied to select the CH (cluster head) and form the cluster. In the simulation results, the presented technology showed good performance in the context of energy use and network duration compared to standard schemes. A novel clustering technique was presented through the COFL (Coyote Optimization based on Fuzzy Logic) algorithm [18] for heterogeneous WSNs by Mohammed et al. This technique helped support and balance the clustering operation to maximize the service period of the network and minimize the energy use.

Apart from this, the overall intracluster distance between each CH (cluster head) node and the other nodes in cluster was reduced. In addition, a new fitness function was used to mitigate the intercluster distance from the CH to the base station. Three completely contrasting conditions were considered here to conduct simulations. A comparative study was done on the technology introduced with the classical technology. According to achieved results, the technology proposed exhibited more efficiency for active nodes in the context of central tendency computation, energy use, and throughput. To select CH (cluster head) in WSN (Wireless Sensor Network), Choudhary et al. designed a FL (fuzzy logic) algorithm. In addition, a communication protocol was built based on fuzzy logic [19]. This algorithm was aimed at distributing the load across the network for improving energy efficiency and increasing the network is serving period. The new algorithmic approach helped to reduce the frequency of CH re-election and, thus, reduced message complexity, number of operations, and energy usage. To reduce energy consumption, a new data collection algorithm, namely EMFLDC (Expectation Maximization and Fuzzy Logic-Based Energy Efficient Data Collection) was designed by Swapna et al. for WSNs by virtue of mobile elements to reduce the exhaustion of energy. First, using EM (Expectation Maximization) algorithm the entire network was divided into the optimal number of clusters [20]. Subsequently, the linguistic matrix was used to select CH based on FL. This algorithm reduced the use of energy to minimal with the intension to relay data between the sensing devices and the base station, thereby increasing the time span of the network. The obtained results of simulation proved the supremacy of the developed algorithm over other algorithms. An LBCA (Load Balance Clustering Algorithm), exploiting fuzzy inference systems, was presented by Rahimi et al. to reduce and distribute the energy efficiently [21]. A scheduling algorithm based on TDMA was adopted to reduce redundant intra-cluster communication causing increased network time span and performance. The designed framework was evaluated through simulations. The results of the simulation confirmed that the designed algorithm not only improved network lifespan but also its performance. A BECR (Balance Energy Consumption Clustering Routing) protocol was designed by Zhao et al. for WSNs [22]. First, the improved FCM (Fuzzy C-Means) technique network branched the whole network into clusters and the node near the cluster centre was defined as the primary CH (cluster head). In the case of initial CH reducing energy of 20%, FLS (Fuzzy Logic System) was used to select the CH of each cluster. The simulation results obtained eventually demonstrated the practicability of the designed protocol. An FLS (Fuzzy Logic System) was reviewed by Zhang et al. to consider several factors for performing in order to increase the network span and reduce the energy used by nodes [23]. The CH (cluster head) was elected dynamically based on the relative density of nodes and the relative distance between nodes and BS (Base Stations) in the network. The simulation results confirmed that the analyzed system efficiently balanced the energy use of nodes as well as successfully increased the network lifetime. As a result, the accuracy of collecting data was increased.

The LEACH-FC (Low-Energy Adaptive Clustering Hierarchy-Fuzzy Clustering) algorithm was presented by Lata et al. CH selection and cluster formation was performed using the notion of FL (fuzzy logic) to prolong the life of WSNs [24]. This objective was tried to be fulfilled by adopting a centralized approach. In addition, fuzzy logic was implemented for selecting the vice CH. The effectiveness of the proposed algorithmic approach was proven to balance the energy load at each node leading to increased reliability of the WSN (Wireless Sensor Network). This algorithm performed better than other algorithms to extend network survival and reduce energy usage. A fuzzy centric smart irrigation scheduling architecture was designed by Jamroen et al. for the cost-effective WSN (Wireless Sensor Network) [25]. Plant status was denoted by calculating the CWSI (Crop Water Stress Index) with respect to canopy temperature, solar irradiance, and vapour pressure loss. The designed system was validated and compared against the classic methodologies by conducting tests. The new framework reduced about 67.35% of energy usage. Abbas et al. set forth a fuzzy logic-based approach called EERP (energy-efficient routing protocol) with the aim of selecting a CH for WSNs [26]. This work introduced a technology to manage data transmission across WSNs to the reduce overall energy use and prolong the service period of the network. To simulate the presented protocol, MATLAB was used [27]. The results based on simulation confirmed the superiority of the introduced protocol with respect to energy usage and network service span.

III. Proposed Model

Fuzzy inference systems perform the dual task of managing numerical data as well as linguistic information. The use of FIS is proposed in this work in such a way that a chance value can be assigned to each node to eliminate the uncertainties that occur when selecting a CH.

Three input variables called residual energy, moving speed, and rest time are used as evidenced in Fig. 3. An output parameter is the probability of a node being selected as the cluster head. It is named "Chance". Probability of a node to be elected as the cluster head is more if the value of chance is greater than that of other nodes [19]. Fig. 4 (a) displays the fuzzy set used for observing the residual energy input variable. For this fuzzy set, the linguistic variables provided are very low (VL), medium (M), high (H), and very high (VH). The speed at which the CH candidate is progressing is given as another fuzzy input variable. Fig. 4 (b) presents the fuzzy set showing the moving speed of the input variables. Very slow (VS), slow (S), medium (M), fast (F), and very fast (VF) are the linguistic variables provided for this fuzzy set. The pause time of the CH candidate is given as another unambiguous input variable. In Fig. 4 (c), the fuzzy set through which the pause time input variable is shown is presented. The linguistic variables provided for this fuzzy set are Very Short (VS), Slow (S), Medium (M), Fast (L), and Very Fast (VF). The pause time of the CH candidate is provided as another fuzzy input variable. In Fig. 4 (c), the fuzzy set through which the pause time input variable is depicted is presented. The linguistic variables used in this fuzzy set Very short (VS), short (S), medium (M), large (L), and very large (VL). Fig. 4 (d) presents the fuzzy set to observe the node density input variables. The linguistic variables provided for this fuzzy set are very low (VL), medium (M), high (H), and very high (VH). As depicted in Fig. 4 (e), the chance of a CH candidate is given as an output variable of a fuzzy set.

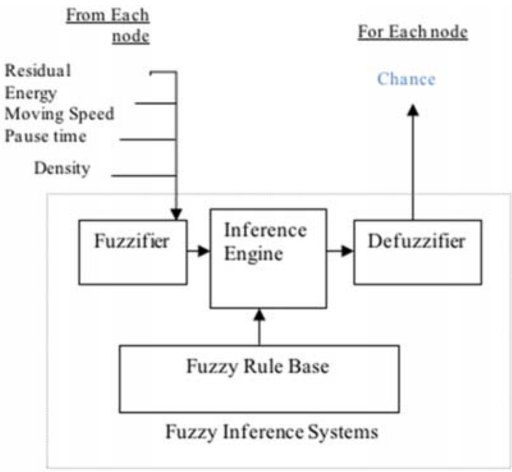
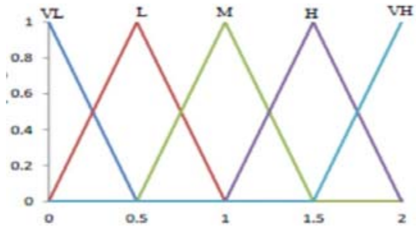
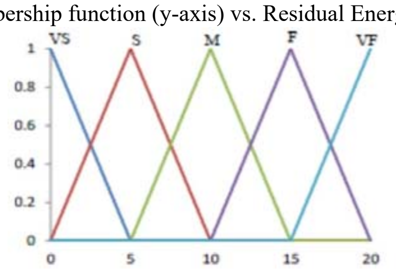


Fig. 3 Proposed FIS-based probabilistic reasoning for CH selection

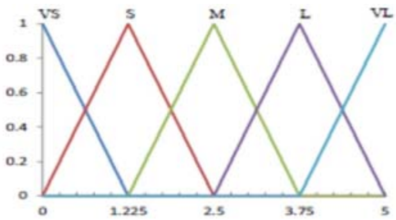
The nine linguistic variables in this set are Very low (VL), low (L), rather low (RL), medium low (ML), medium (M), medium high (MH), rather high (RH), high (H) and very high (VH). Triangular membership functions are used here to reduce the computational load to minimal. To deal with any kind of uncertainty, predefined fuzzy if-then estimation rules are used to calculate the coincidence. According to the three fuzzy input variables, 125 estimation rules are obtained, which are featured in Table I. The rules can be used to compute the fuzzy output variable chance. To put this usage into practice, the fuzzy variable should be transformed to a single crisp number. The system proposed here uses the center of area diffusion method. Thus, different crisp values occur between zero and one, even if there are multiple sensors consisting of the same linguistic variables. All sensors will be selected as CH if different number of sensors have the same crisp value of chance. Based on the Leach design, the Leech-MF technology is presented. Here, the number of clusters is supposed to be about 5% of the nodes present in the network [20]. Fuzzy rules can generally be generated using either human inference or test data. An original heuristic rule is made in this paper. The fundamental idea of this rule is that the node is more likely to be chosen as a CH if the remaining energy is more, the speed of movement is low, and the rest time involved is lengthier. Rule 105 featured in Table I is the perfect case of this scenario, while Rule 21 is the exact opposite.



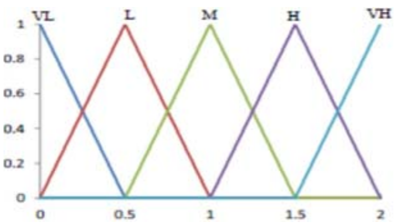
(a) Membership function (y-axis) vs. Residual Energy (x-axis)



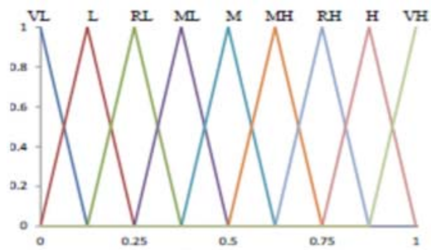
(b) Membership function (y-axis) vs. Moving Speed (x-axis)



(c) Membership function (y-axis) vs. Pause Time (x-axis)



(d) Membership function (y-axis) vs. Node Density (x-axis)



(e) Membership function (y-axis) vs. Chance (x-axis)

Fig. 4 Fuzzy sets for input variables (a) remaining energy, (b) moving speed, and (c) pause time, and for the output variable (d) Node Density, (e) chance

A. Proposed Algorithm

Input:
N: Number of sensor nodes
K: Number of Cluster head

a: Sensor node number

TABLE I
FUZZY INFERENCE RULES

Rule	Residual energy	Moving speed	Pause time	Density	Chance
1	VL	VS	VS	VL	RL
2	VL	VS	S	VL	RL
3	VL	VS	M	VL	ML
4	VL	VS	L	VL	ML
5	VL	VS	VL	VL	M
…					
21	VL	VF	VS	VL	VL
22	VL	VF	S	VL	VL
23	VL	VF	M	VL	L
…					
61	M	M	VS	M	RL
62	M	M	S	M	RL
63	M	M	M	M	ML
…					
105	VH	VS	VL	VH	VH
106	VH	S	VS	VH	M
107	VH	S	S	VH	MH
…					
121	VH	VF	VS	VH	RL
122	VH	VF	S	VH	RL
123	VH	VF	M	VH	ML
124	VH	VF	L	VH	ML
125	VH	VF	VL	VH	M

Output:
Chances of Cluster head selection
Initialization:
1. a is not a cluster head
2. Set r=0;
3. If (r= [$\frac{Numberofsensornodes}{K}$])
4. If r=0
4.1. Set T=0
5. Else
5.1 T= [$\frac{K}{NumberofSensornodes}$]
6. End If
7. If (rand (0, 1)>T)
7.1. Chance (a) =Fuzzy clustering (energy (a), speed (a), density (a), pause time (a))
8. Flood Information of a
9. Repeat Steps 8 to 9 for each node in the network
10. If (Chances (a)>Chances (a+1)
10.1 Set r=1;
11. If(r=1)
11.1. Broadcast CH selected message to each node
12. End If

IV. RESULTS AND DISCUSSIONS

This simulation makes the utilization of 100-node network. In a (100×100)-square-meter area, the initial locations of mobile nodes are distributed randomly in a uniform way. A stationary sink is located in this network at the position (50,175) meter. The initial energy offered to every node is 2 (J), its moving speed is 1-20 m/s, and 0-5 sec is the pause time. The simulation is carried out on MATLAB. Around 100 independent simulation runs are made along with a 95% confidence interval after acquiring all results for this method.

Fig. 5 (a) indicates the random deployment of 100 nodes over a 100*100 square meter area. Similarly, Fig. 5 (b) indicates the same random deployment of sensor nodes over the same area but with increased density as the number of nodes are increased to 200. These deployments are simulated using MATLAB over a fixed area to evaluate the network average life and efficiency. Based upon certain linguistic variables using fuzzy logic, the expectations or chances of the nodes to become CH are depicted.

TABLE II
THE PARAMETERS THAT ARE INVOLVED WITHIN THE SIMULATION EXPERIMENTS

Type	Parameter	Value
Network Topology	Number of Nodes	100
	Expected number of clusters	(5% of nodes)
	Network Coverage	(0,0)-(100,100) m
	Base station location	at (50,175) m
Node Setting	Initial energy	2 J
First-Order Radio model	$E_{elec}^{Tx}/E_{elec}^{Rx}$	50 nJ/bit
	E_{fs}	10 pJ/bit/m2
	E_{mp}	0.0013 pJ/bit/m4
Mobility Model	Percentage of mobile nodes	10-100 %
	Moving speed	0-5 m/s
	Pause time	0-5 sec
Application	Data packet size	500 bytes

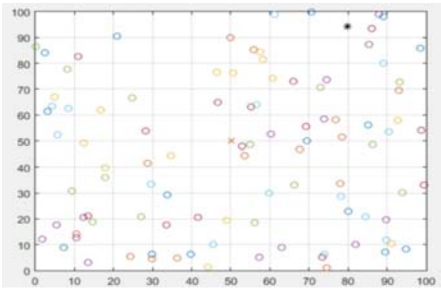


Fig 5 (a) Random Deployment of 100 nodes over a 100*100 square meter area

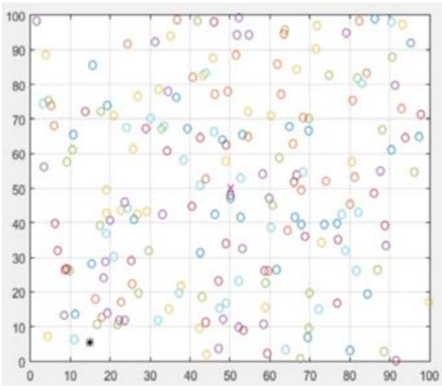


Fig 5 (b) Random Deployment of 200 nodes over a 100*100 square meter area

Table III shows the comparison of dead nodes after a certain number of rounds are finished in the case of F-LEACH, BEENISH, and improved BEENISH protocol (proposed model). Improved protocol adds the mobility model to mitigate and improve the dead nodes count and increases the lifetime and efficiency of WSN network. As it is clear from the table, the improved BEENISH protocol has very fewer dead nodes even after the 1000 rounds, whereas the numbers of dead nodes are higher in the case of BEENISH and F-LEACH protocol. By using fuzzy logic based upon the calculation of four linguistic variables such as remaining energy, moving speed, pause time, and node density, provides better results than previous protocols.

Fig. 6 represents comparison of the number of dead nodes of BEENISH with the improved BEENISH protocol. The BEENISH protocol is the protocol in which basic fuzzy rules are implemented and in the improved BEENISH protocol mobility model is introduced. The mobility model assisted in mitigating the number of dead nodes as compared to BEENISH protocol. Furthermore, the application of FLC for decision making and adaption aspect leads to this result, which is remarkably efficient.

TABLE III
NUMBER OF DEAD NODES

Number of Rounds	F-LEACH Protocol	BEENISH Protocol	Improved BEENISH Protocol
200	5	3	0
400	8	5	2
600	12	8	4
1000	15	11	5

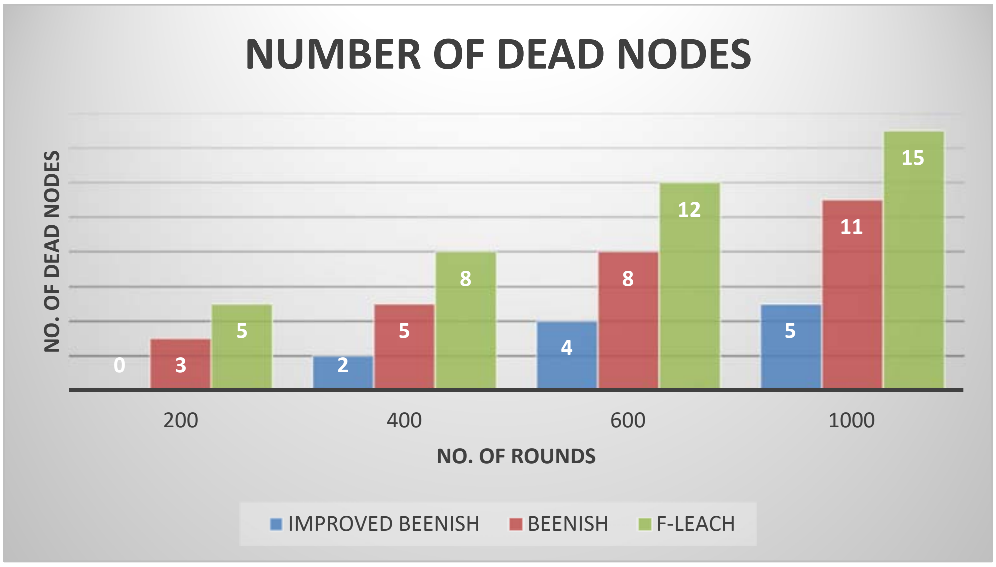


Fig. 6 Number of Dead Nodes Analysis

Table IV shows the comparison of alive nodes after a certain number of rounds are finished in case of F-LEACH, BEENISH and improved BEENISH protocol (proposed model). Improved protocol adds the mobility model as well as application of FLC for decision-making and improves the performance of the standard BEENISH protocol. For the given comparison, 200 nodes are randomly deployed over a 100*100 square meter area. This will increase the node density, hence complicates the process of CH selection. Due to the increased node density, each cluster in the given scenario is more intensive, and the communication condition is more complex.

TABLE IV
NUMBER OF ALIVE NODES

Number of Rounds	BEENISH Protocol	Improved BEENISH Protocol	F-LEACH
1000	193	185	175
2000	143	120	105
3000	83	75	65
4000	43	30	15

Fig. 7 exhibits the comparison of BEENISH protocol with the Improved BEENISH protocol and F-LEACH concerning alive nodes. As it is clear from the figure, after various rounds, the number of alive nodes is greater in improved BEENISH protocol. This will increase the network life and network efficiency compared to various other protocols. The main reasons for these improved results are: (i) usage of improved node density as a decision making parameter, (ii) improved linguistic variables consideration, and (iii) improving the process of CH selection. Therefore, Fig. 7 concludes that the BEENISH protocol and F-LEACH protocol have low number of alive nodes as compared to Improved BEENISH protocol.

V. CONCLUSION

The major concern occurring in the WSN is the energy consumption. WSNs that support mobility are capable of resolving the issue of density and topology change in the network. This paper introduces an enhanced BEENISH protocol for prolonging the duration and number of packets transmitted in the network. The CH is selected using the FL method in this protocol. The sensor nodes having greater energy, lower mobility, longer pause time, and highest density can be chosen as Cluster Head. MATLAB is utilized to conduct the simulation. The simulation results reveal that introduced protocol is applicable for mitigating the energy consumption and maximizing the number of packets transmitted to the sink in contrast to the existing protocol. This paper achieves enhancing the duration of the network effectively. The future work may be directed towards the compressive sensing for enhancing other metrics.

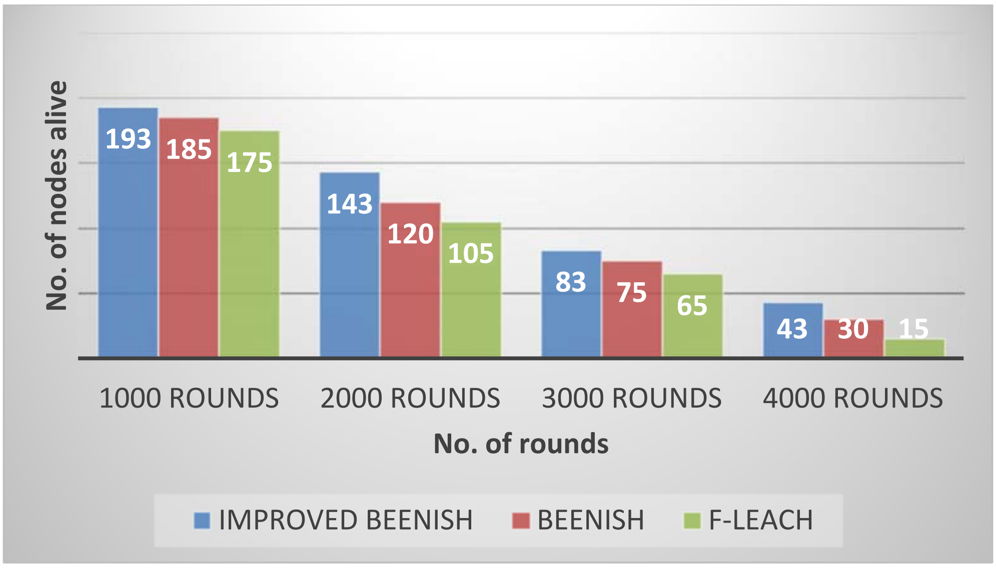


Fig. 7 Number of Alive Nodes

ACKNOWLEDGMENT

The proposed work, idea, simulation, data interpretation and results are done by Rishabh Sharma but it was totally possible under the sharp guidance of Renu Vig and Neeraj Sharma.

REFERENCES

[1] M. Benaddy, B. El Habil, M. El Ouali, O. El Meslouhi, S. Krit, “A mutlipath routing algorithm for wireless sensor networks under distance and energy consumption constraints for reliable data transmission”, 2017, International Conference on Engineering & MIS (ICEMIS), https://doi.org/10.1109/ICEMIS.2017.8273076

[2] Đ. Banđur, B. Jakšić, M. Banđur, S. Jović, “An Analysis of Energy Efficiency in Wireless Sensor Networks (WSNs) Applied in Smart Agriculture”, 2019, Computers and Electronics in Agriculture, Vol. 3, No. 26, pp. 564-573, https://doi.org/10.1016/j.compag.2018.12.016

[3] N. F. Ali, A. Md Said, K. Nisar, I. A. Aziz, “A Survey on Software Defined Network Approaches for Achieving Energy Efficiency in Wireless Sensor Network”, 2017, IEEE Conference on Wireless Sensors, Vol. 21, No. 17, pp. 674-682, https://doi.org/10.1109/ICWISE.2017.8267157

[4] Peyman Neamatollahi & Mahmoud Naghibzadeh, “Distributed unequal clustering algorithm in large-scale wireless sensor networks using fuzzy logic”, 2018, The Journal for Supercomputing, https://doi.org/10.1007/s11227-018-2261-5

[5] Trong-The Nguyen, Chin-Shiuh Shieh, Thi-Kien Dao, Jaw-Shyang Wu, Wu-Chih Hu, “Prolonging of the Network Lifetime of WSN Using Fuzzy Clustering Topology”, 2013, Second International Conference on Robot, Vision and Signal Processing, https://doi.org/10.1109/RVSP.2013.10

[6] D.V. Pushpalatha, Padmalaya Nayak, “A Clustering Algorithm for WSN to Optimize the Network Lifetime Using Type-2 Fuzzy Logic Model”, 2015, 3rd International Conference on Artificial Intelligence, Modelling and Simulation (AIMS), https://doi.org/10.1109/AIMS.2015.19

[7] Qi Wang, Elis Kulla, Gjergji Mino, Leonard Barolli, “Prediction of Sensor Lifetime in Wireless Sensor Networks Using Fuzzy Logic”, 2014, IEEE 28th International Conference on Advanced Information Networking and Applications, https://doi.org/10.1109/AINA.2014.137

[8] Gaurav Srikar, Reshmi TR, “A Fuzzy-Logic Based Clustering Algorithm in WSN to Extend NetworkLifetime”, International Journal of Applied Engineering Research, Volume 13, Number 10 (2018) pp. 7711-7718, https://doi.org/10.1109/JSEN.2015.2472970

[9] Hassan El Alami, AbdellahNajid, “Fuzzy Logic Based Clustering Algorithmfor Wireless Sensor Networks”, 2017, International Journal of Fuzzy System Applications, Volume 6, Issue 4, 10.4018/978-1-7998-2454-1.ch018

[10] Pankaj Kumar Mishra, and Shashi Kant Verma, “FFMCP: Feed-Forward Multi-Clustering Protocol Using FuzzyLogic for Wireless Sensor Networks (WSNs)”, 2021, Energies, https://doi.org/10.3390/en14102866

[11] Md. Abdul Alim, Yucheng Wu, Wei Wang, “A Fuzzy Based Clustering Protocol for Energy-efficient Wireless Sensor Networks”, 2013, Proceedings of the 2nd International Conference on Computer Science and Electronics Engineering, https://doi.org/10.4028/www.scientific.net/AMR.760-762.685

[12] Abdulmughni Hamzah, Mohammad Shurman, Omar Al-JarrahandEyadTaqieddin, “Energy-Efficient Fuzzy-Logic-Based Clustering Technique for Hierarchical Routing Protocols in Wireless Sensor Networks”, 2019, Sensors, https://doi.org/10.3390/s19030561

[13] Abhishek Rai, Kanika Sharma, “A Fuzzy Based Techniques for Energy Efficient Cluster Head Selection for Wireless Sensor Network”, 2019, International Journal of Engineering and Advanced Technology (IJEAT), Volume8, Issue6, 10.35940/ijeat.F8560.088619

[14] Vinod K, Kanika Sharma, “Routing Algorithm using Fuzzy Logic BasedClustering with Mobile Sink for Wireless SensorNetwork”, 2019, International Journal of Recent Technology and Engineering (IJRTE), Volume-8 Issue-4, November 2019, 10.35940/ijrte.D8629.118419

[15] Baranidharan Balakrishnan and Santhi Balachandran, “FLECH: Fuzzy Logic Based Energy Efficient Clustering Hierarchyfor Nonuniform Wireless Sensor Networks”, 2017, Hindawi, https://doi.org/10.1155/2017/1214720

[16] Mohd Adnan, Liu Yang, Tazeem Ahmad, Yang Tao, “An Unequally Clustered Multi-hop Routing Protocol Based on Fuzzy Logic for Wireless Sensor Networks”, 2021, IEEE Access, https://doi.org/10.1109/ACCESS.2021.3063097

[17] Marwa Fattoum, ZakiaJellali, Leïla Najjar Atallah, “Fuzzy Logic-based Two-Level Clustering for Data Aggregation in WSN”, 2020, 17th International Multi-Conference on Systems, Signals & Devices (SSD), https://doi.org/10.1109/SSD49366.2020.9364181

[18] Asmaa Mohamed, WalaaSaber, Ibrahim Elnahry, Aboul Ella Hassanien, “Coyote Optimization Based on a Fuzzy Logic Algorithm for Energy-Efficiency in Wireless Sensor Networks”, 2020, IEEE Access, https://doi.org/10.1109/ACCESS.2020.3029683

[19] Devendra Choudhary, Iti Sharma, “Using fuzzy logic for clustering in wireless sensor networks”, 2017, International Conference on Intelligent

Computing, Instrumentation and Control Technologies (ICICICT), https://doi.org/10.1109/ICICICT1.2017.8342678

[20] Swapna Ch, Vijayashree R Budyal, "Expectation Maximization and Fuzzy Logic Based Energy Efficient Data Collection in Wireless Sensor Networks with Mobile Elements", 2020, 7th International Conference on Signal Processing and Integrated Networks (SPIN), http://dx.doi.org/10.1109/SPIN48934.2020.9071055

[21] Payam Rahimi, ChrysostomosChrysostomou, "Improving the Network Lifetime and Performance of Wireless Sensor Networks for IoT Applications Based on Fuzzy Logic", 2019, 15th International Conference on Distributed Computing in Sensor Systems (DCOSS), https://doi.org/10.1109/DCOSS.2019.00120

[22] Xin Zhao, Zhiqiang Wei, Yanping Cong, Bo Yin, "A Balances Energy Consumption Clustering Routing Protocol for a Wireless Sensor Network", 2018, IEEE 4th Information Technology and Mechatronics Engineering Conference (ITOEC), https://doi.org/10.1109/ITOEC.2018.8740385

[23] Wenqi Zhang, Jingjing Yu, Xingchun Liu, Ying Tao, Shubo Ren, "Low-Energy Dynamic Clustering Scheme for Wireless Sensor Networks", 2019, 20th International Conference on Parallel and Distributed Computing, Applications and Technologies (PDCAT), https://doi.org/10.1109/PDCAT46702.2019.00031

[24] Sonam Lata, Shabana Mehfuz, Shabana Urooj, FadwaAlrowais, "Fuzzy Clustering Algorithm for Enhancing Reliability and Network Lifetime of Wireless Sensor Networks", 2020, IEEE Access, https://doi.org/10.1109/ACCESS.2020.2985495

[25] ChaowananJamroen, PreechaKomkum, ChanonFongkerd, WipaKrongpha, "An Intelligent Irrigation Scheduling System Using Low-Cost Wireless Sensor Network Toward Sustainable and Precision Agriculture", 2020, IEEE Access, https://doi.org/10.1109/ACCESS.2020.3025590

[26] Safana H. Abbas, Israa M. Khanjar, "Managing Data Transmission to Improve Lifetime of Wireless Sensor Network", 2019, First International Conference of Computer and Applied Sciences (CAS), https://doi.org/10.1109/CAS47993.2019.9075466

[27] Amir Abbas Baradaran a, Keivan Navi b, "HQCA-WSN: High-quality clustering algorithm and optimal cluster head selection using fuzzy logic in wireless sensor networks ", 2019, Article in Press, Elsevier, https://doi.org/10.1016/j.fss.2019.11.015