

Comparison of Fuzzy-based Cluster Head Selection Algorithm with LEACH Algorithm in Wireless Sensor Networks to Maximize Network Lifetime

K.P. Aravinth¹; T. Devi^{2*}

¹Research Scholar, Department of Computer Science and Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India.

¹aravinthswamy230@gmail.com

^{2*}Project Guide, Department of Computer Science and Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India.

^{2*}devit.sse@saveetha.com

Abstract

Aim: To maximize the network lifetime using Fuzzy Based cluster head selection algorithm in comparison with LEACH algorithm. **Materials and methods:** Network Lifetime is computed with a dataset sample of size 40. The classification of nodes is performed by the Fuzzy algorithm of sample size ($N=20$), and the LEACH algorithm of sample size ($N=20$) with 100 nodes. **Result and Discussion:** The network lifetime of fuzzy algorithm is 81.76% when compared to LEACH algorithm with 72.64%. Significant difference in network lifetime ($P=0.001$) for fuzzy based cluster algorithm and ($P=0.001$) for LEACH algorithm. **Conclusion:** Within the limits of the study, Fuzzy algorithm performs better than LEACH algorithm in case of network lifetime.

Key-words: Base Station, Cluster Head, Fuzzy Based Cluster Head Selection Algorithm, LEACH Algorithm, Novel Cluster Head Communication, Network Lifetime, Nodes, Wireless Sensor Network.

1. Introduction

Network lifetime is the important factor to be considered in wireless sensor network research. The proposed work maximizes the network lifetime by using a clustering mechanism. The network lifetime stands as a significant metric in evaluating WSN. By improving the network lifetime, the node energy is improved significantly and as a result we can transfer more data to the base station. The wireless sensor networks offer cost savings and enable new functionality.(Engmann et al. 2018).The cluster head aggregates data and reports refined data to the base station in any case called

sink centre point (Abo-Zahhad et al. 2014). The main challenge of clustering is picking the suitable centre points to be cluster heads. (Rana et al. 2015). All the nodes are able to transmit data to the base station but this leads to more energy consumption and affects the lifetime of the network (Baranidharan and Santhi 2015). The research work uses clustering election strategy for effective cluster head choice. (Rana et al. 2015; Prakash and Sirsikar 2017). The sensor network is progressively dependent on the cluster heads. (Engmann et al. 2018). If a cluster head is nearing completion of energy then it leads to more retransmissions and thus more energy consumption. (Abo-Zahhad et al. 2014) The applications include intelligent transport systems, monitoring healthcare, home automation and in several surveillance activities. Fuzzy clustering algorithm & LEACH algorithm have been proposed to demonstrate an effective computation to improve the network lifetime of wireless sensor networks. (Baranidharan and Santhi 2015; Prakash and Sirsikar 2017) .Wireless sensors can be placed in locations difficult or impossible to reach with a wired system, such as rotating machinery and untethered vehicles. To monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, motion or pollutants and to cooperatively pass their data through the network to a main location or sink where the data can be observed and analysed.

LEACH and Fuzzy Clustering head selection algorithms research papers are available in IEEE and Science direct. 1550 articles are available in Google scholar and 31 articles are available in science direct and 33 articles are available in IEEE. The most cited article is as follows, (Dongyao et al. 2016) (Dynamic Cluster Head Selection Method for Wireless Sensor Network) has more citation as 105 times since their research work is based on dynamic cluster head selection method for wireless sensor network. (Nayak and Devulapalli 2016) (A Fuzzy Logic-Based Clustering Algorithm for WSN to Extend the Network Lifetime) has more citation of 210 times since their research work is based on a fuzzy logic-based clustering algorithm for WS and to extend the network lifetime. (Wan, Zhang, and Chen 2016) (On the Construction of Data Aggregation Tree With Maximizing Lifetime in Large-Scale Wireless Sensor Networks) has more citation of 78 times since their research work is based on the construction of data aggregation tree with maximising life time in large scale wireless sensor networks. (Brar et al. 2016). (Energy Efficient Direction-Based PDORP Routing Protocol for WSN) has more citation of 51 times as the research work is based on energy efficient direction Best PDORP routing protocol for WSN. Wireless Sensor Network forms the backbone of computer applications such as structural, health and security. Network lifetime is the time at which the first network node runs out of energy to send a packet because to lose a node could mean that the network could lose some functionalities.

Previously our team has a rich experience in working on various research projects across multiple disciplines (Sathish and Karthick 2020; Varghese, Ramesh, and Veeraiyan 2019; S. R. Samuel, Acharya, and Rao 2020; Venu, Raju, and Subramani 2019; M. S. Samuel et al. 2019; Venu, Subramani, and Raju 2019; Mehta et al. 2019; Sharma et al. 2019; Malli Sureshbabu et al. 2019; Krishnaswamy et al. 2020; Muthukrishnan et al. 2020; Gheena and Ezhilarasan 2019; Vignesh et al. 2019; Ke et al. 2019; Vijayakumar Jain et al. 2019; Jose, Ajitha, and Subbaiyan 2020). Now the growing trend in this area motivated us to pursue this project.

In the previous research works, the cluster head spends more energy than the other nodes by data transfer to the base station, so the energy of the cluster head is depleted soon. As a result of this, the network lifetime is minimized (Baranidharan and Santhi 2015). In the proposed work, cluster head functions under cluster election system which identifies the node with the highest energy to be the cluster head. This maximizes the network lifetime of the nodes. The network lifetime in previous research work appears to have improved by 6.92%, in this existing research work the network lifetime appears to be improved by 8.52%. Compared to previous studies, the current research work achieves higher network lifetime for less energy consumption. Our primary goal is to maximize the network lifetime of nodes using Fuzzy based cluster head selection algorithm in comparison with LEACH algorithm.

2. Materials and Methods

The research work is carried out in the Saveetha School of Engineering, SIMATS, Chennai. The laboratory is utilised for improving the network lifetime of wireless sensor nodes from SPSS dataset using Network Simulator 2. The group 1 is Fuzzy based cluster head algorithm and group 2 is LEACH algorithm. The sample size is taken as $N=20$ for Fuzzy based cluster head algorithm and $N=20$ for LEACH algorithm and computation is performed using G power. The obtained actual power is 80% with a confidence interval at 95%. Alpha value is 0.05 and beta value is 0.2 (Mehra, Doja, and Alam 2020).

The proposed work makes use of 100 nodes which are clustered into 10 groups with 10 cluster heads which enables better network lifetime and energy depletion is gradually decreased. Cluster head communication is further classified into three different scenarios where the cluster head located in the middle or cluster head located in the border or cluster head located in the medium distance. Based on the position, the cluster heads can deliver a better communication without loss of energy.

Network Simulation of these algorithms are done using Network Simulator 2. NS2 is an open-source occasion driven test system planned explicitly for research. NS2 uses OTCL to create and configure a network, and uses TCL scripts to run simulation. All TCL codes need to be compiled and linked to create an executable file. Building a full NS2 package requires large memory space approximately 250MB. The algorithms are compatible with 2.3 GHz Quad-Core Intel Core i5 Processor, 32-Bit, 8GB RAM for data processing.

In sample preparation group 1, a novel cluster head communication is employed and based on this the cluster election technique is being performed. Fuzzy-based cluster head selection algorithm clusters the nodes into 10 groups with 10 cluster heads which enables better network lifetime. The energy of nodes are saved due to direct communication of cluster heads, so that remaining nodes won't lose power until it is used for communication. The node with highest energy is chosen as cluster head and when the energy depletes, the next node with the highest energy becomes the next cluster head. This process is called cluster election. During this process, critical nodes are also identified and critical nodes vary from group point of view. Short distance communication is the key for less energy consumption. Table 1 shows the pseudocode of fuzzy based cluster head selection algorithm. n (number of nodes), J (joules), abs (absolute value), m (cluster members), t (threshold), c (clusters), (Mehra, Doja, and Alam 2020).

Table 1 - Pseudocode of Fuzzy-based cluster head selection algorithm. Initialization of total values (input, output, and distances) to zero is done first. Loading the data set includes features and output. For each feature in the data set, calculation of the cluster head using a fuzzy clustering algorithm is performed. Computation of the ratios of mean features to their cluster heads and multiplying these ratios with each feature is done.

Input (Total Cluster Heads) = 10
Fix c, $2 < c < n$;
Fix max iterations (100)
Choose distance (close, middle, outside the circle)
Fix m, $1 < m < \text{infinity}$
Randomly initialise $V_0 = v_1, v_2, \dots, v_c$ (cluster heads);
For t=1 to max iterations do
Update the nodes
Calculate the cluster heads
Calculate the new objective function
If (abs(J to the power t - J to the power t-1) then
break;
else
J to the power t-1 = J
End if
End for
End

Table 2 - Pseudocode of LEACH Algorithm. For each node, it gathers data that has been sensed and transfers this data that has been sensed into the cluster head in the corresponding time point. For each cluster, it gets the data from the cluster nodes, cluster heads aggregate the data and transfer data to the base station.

Input (Number of Nodes Implemented) = 100 Nodes
For Every node in S_{alive}
Send energy level to base station
$k = N_{alive} * 0.05$
Sort (Energy_Level (S_{alive})) desc_distance
choose first K notes in S_{alive}
sort(SCH) desc_energy
For every node in SCH do
If distance (node1,node2) < Minimum_distance
Minimum_distance = distance(node1,node2)
Cluster_head(node1)=node2
End if
End for
End for
Cluster_head send TDMA Slots to SCH

In sample preparation group 2, LEACH algorithm used is a hierarchical routing protocol used in wireless sensor networks to expand the network lifetime. In the LEACH protocol, the sensor nodes arrange themselves in a cluster and a single node of these nodes acts as a cluster head. Base station broadcasts the message to the entire network forming a communication path. Nodes in the cluster head will transmit data to their closest cluster head and the cluster head in turn will collect the data and transmit to the base station rather than transmitting them to the base station directly. Table 2 shows the pseudocode for LEACH algorithm. S_{alive} (set of alive nodes in the network), K(number of cluster heads), SCH (Set of cluster heads). TDMA (Time division multiple access), Nodes and cluster heads select the shortest distance nodes for communication using the shortest distance algorithm (Mehra, Doja, and Alam 2020; Dong and Li 2016)).

The data collection for the proposed work is as follows, 100 Nodes are used and each node is configured with the required bandwidth. Further it is divided into 10 groups and clustering takes place with these groups. 10 cluster heads are assigned to 10 groups where the energy level of nodes and network lifetime significantly improves and only the required amount of energy is transferred to the base station.

The statistical software used here is IBM SPSS with version 26.0, to find standard deviation, mean, standard error mean, mean difference, sig and F value. Graphical representation is created by fetching of network lifetime. The analysis is done for the independent variables and dependent

variables along with comparison of Fuzzy and LEACH algorithms. The independent variables are the number of nodes and the dependent variables are network lifetime of nodes.

3. Results

Table 3 - T-Test comparison of Fuzzy Based cluster head selection algorithm with better lifetime of 81.16% compared to LEACH algorithm with 72.64%. 20 Sample Size is taken for both proposed and existing work.

Network Lifetime	Algorithm	N	Mean	Standard deviation	Standard error mean
	Leach	20	72.6410	1.17830	-26348
	Fuzzy	20	81.1670	3.73219	-83454

From table 3, the network lifetime of two algorithms for fuzzy-based cluster head selection algorithm and LEACH algorithm is further analysed by comparing means as Group Statistic for Fuzzy based cluster head selection algorithm (81.16%) with LEACH algorithm (72.64%). The Fuzzy algorithm has better significance than the LEACH algorithm. Delay and packet loss rate gets reduced for proposed fuzzy clustering techniques. Packet loss rate for FCHS-Fuzzy Cluster Head Selector performs better by reducing loss rate than LEACH. When the size of the network increases, the packet loss gets reduced. Percentage of nodes alive for FCHS-Fuzzy Cluster Head Selector performs better than LEACH. When the size of the network increases, the percentage of nodes alive increases.

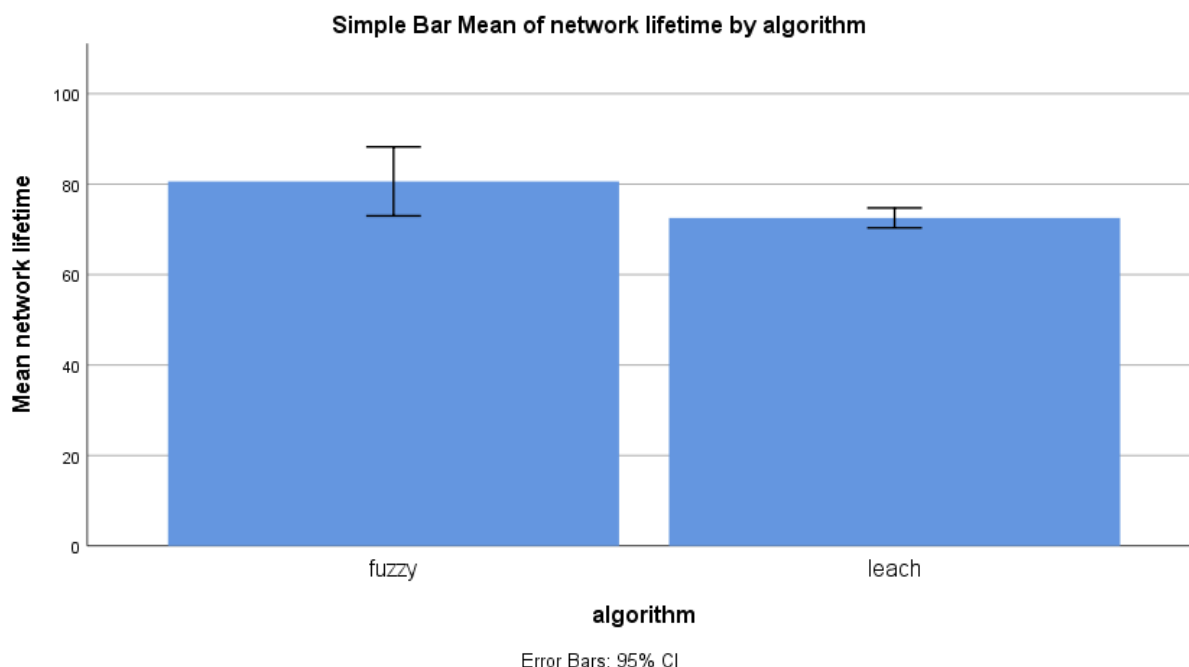
Table 4 - Independent Sample T-Test is applied for comparison of Fuzzy Based cluster head selection algorithm There is significant difference in Network Lifetime (P=0.001) and (P=0.001). 20 sample sizes are taken for both proposed and existing work with confidence intervals at 95% and level of significance as 0.001

Network lifetime		F	sig.	t	df	sig.(2-tailed)	Mean difference	Standard error Difference	Lower of 95% Confidence Interval difference	Upper of 95% Confidence Interval difference
	Equal variances assumed	33.46	0.001	-9.742	38	0.000	-8.526	0.8751	-10.2976	-6.75436
	Equal variance is not assumed	35.26	0.001	-9.742	22.75	0.000	-8.526	0.8751	-10.3374	-6.71452

From table 4, the network lifetime of two algorithms for fuzzy-based cluster head selection algorithm and LEACH algorithm is further analysed by comparing means as individual sample tests. Significant difference in network lifetime (P=0.001) and (P=0.001). The different regions in wireless communication are presented: the connected region, where connectivity is almost perfect, the transitional or gray region, where reception is very dynamic and the disconnected region where communication is not possible. While the expected packet reception rate decreases with distance, a

significant variance in the transitional region requires a stochastic perception by defining probability thresholds for low/high probability of low/high packet reception rates . The transitional region coefficient defines the ratio of the transitional to the connected region. The transitional region coefficient is independent of noise floor and output power.

Fig. 1 - Bar graph representing the comparison of Network Lifetime between LEACH (72.64%) and FUZZY (81.76%). The mean network lifetime of Fuzzy algorithm is better than LEACH algorithm and the standard deviation of Fuzzy algorithm is slightly better than LEACH algorithm. X-axis: Fuzzy algorithm vs LEACH. Y-axis: Mean network lifetime ± 1 SD.



From Fig 1, the Fuzzy algorithm has a better network lifetime of 81.76% than LEACH algorithm which is 72.64%. Fuzzy appears to produce the most consistent results with its standard deviation ranging from the lower 75's to higher 80's. LEACH appears to produce the most variable results with its standard deviation ranging from the lower 70's to the upper 73's. There is a significant difference between Fuzzy and LEACH ($p < 0.05$ Independent sample test). Sensor nodes due to their usage and places of deployment are expected to be smaller in size; this becomes a challenge when antennas for energy transmission and reception must both be attached to ordinary nodes for receiving and transmitting energy. The need to design special nodes that could have contained both transmitter and receiver antennas on small sized nodes will enable the efficient implementation of energy transfer. There is also the need to develop optimal energy routing protocols to support multihop energy transfer that have the MAC and link layer support.

4. Discussion

The network lifetime of LEACH algorithm is 72.64% and Fuzzy based clustering head selection algorithm is 81.76%. The algorithms employ the probability to select cluster heads and alternate the cluster heads periodically in order to distribute energy consumption. The energy efficiency of network lifetime of nodes is not extended by LEACH algorithm. The existing method compared holds less amount of 8.52% energy, the proposed method holds 81.16% and significant difference in network lifetime of fuzzy based cluster head selection algorithm is ($P=0.001$) and LEACH algorithm is ($P=0.001$).

(Brar et al. 2016) (Energy Efficient Direction-Based PDORP Routing Protocol for WSN) has implemented PDORP protocol which has the characteristics of both power efficient gathering sense of information system and DSR routing protocol. (Wan, Zhang, and Chen 2016) (On the Construction of Data Aggregation Tree With Maximizing Lifetime in Large-Scale Wireless Sensor Networks) have compared and analysed an angular division routing algorithm and query region division routing with LEACH which reduces network hotspots. (Jia et al. 2016) (Dynamic Cluster Head Selection Method for Wireless Sensor Network) Two dynamic cluster heads selection methods for a wireless sensor network are put forward in order to solve the problem of the unreasonable cluster head selection that may lead to overlapping coverage and unbalanced energy consumption in the cluster communication. Clustering methods, node data transactions to the base station and cluster head communication are inherited from the previous papers. In previous research work, the network lifetime changes if the percentage of nodes increases. The network lifetime in previous research work appears to have improved by 6.92%, in this existing research work the network lifetime appears to be improved by 8.52%. Compared to previous studies, the current research work achieves higher network lifetime for less energy consumption.

The factors affecting the study are less energy nodes, long distance communication and absence of clustering mechanisms. When the nodes have less energy, nodes will deplete soon. Energy efficiency is the significant factor in fuzzy clustering head selection algorithms for wireless sensor networks. The increase in network lifetime is recognizable when the base station is located in the middle. It includes the energy it consumes over time and the energy that is available for the particular node. The energy efficiency of the sensor node is affected by the number of nodes used as a cluster head. LEACH protocol assumes that all sensor nodes have enough energy to communicate with the base station. The energy will be consumed more if nodes are far away from the base station. And there will be a required amount of energy if it is a short distance communication. Long distance

communication takes more time to transfer data to the base station as a result of which more energy is consumed. Absence of clustering mechanism results in random node depletion and increase in dead nodes.

Our institution is passionate about high quality evidence based research and has excelled in various fields ((Vijayashree Priyadharsini 2019; Ezhilarasan, Apoorva, and Ashok Vardhan 2019; Ramesh et al. 2018; Mathew et al. 2020; Sridharan et al. 2019; Pc, Marimuthu, and Devadoss 2018; Ramadurai et al. 2019). We hope this study adds to this rich legacy.

Limitations of fuzzy based cluster head selection algorithm is to recover from database corruption and speed of which the data is generated. The future work of the research would be using other parameters like node degree and residual energy of a node. Node degrees are known as advance nodes due to their high energy level compared to normal nodes. Normal nodes are used for sensing and data forwarding, node degrees are used for transmitting and receiving messages where the communication cost is decreased using tiny sensor nodes.

5. Conclusion

The network lifetime of Fuzzy based cluster head selection algorithm is better than LEACH algorithm. As a result of improving network lifetime, nodes can communicate for a long period and can transfer more data to the base station.

Declarations

Conflict of interests: No conflict of interest in this manuscript.

Author Contributions

Author Aravinth was involved in data collection, analysis of data and writing of manuscript. Author Devi.T was involved in data validation and review of manuscript.

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