International Journal of Computer Engineering & Technology (IJCET)
Volume 9, Issue 3, May-June 2018, pp. 222–232, Article ID: IJCET_09_03_027
Available online at
http://www.iaeme.com/IJCET/issues.asp?JType=IJCET&VType=9&IType=3
Journal Impact Factor (2016): 9.3590(Calculated by GISI) www.jifactor.com
ISSN Print: 0976-6367 and ISSN Online: 0976–6375

FUZZY BASED ENERGY EFFICIENT CLUSTERING IN WIRELESS SENSOR NETWORK

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ABSTRACT

A Wireless Sensor Network (WSN) contains many tiny sensor nodes which have minimum battery power, low-cost, with computing and communication competences with limited range for communication with multi model and embedded sensing capability. Environment, habitat and military surveillance monitoring are the most significant application of WSN. The lifetime of the network depends on energy power of these sensor nodes. To efficiently improve the lifetime of the network, a cluster-based routing protocol is an effective scheme. In that, the numbers of sensor nodes are split into several groups known as Clusters. Based on some parameters, each cluster node will elect a node from their cluster to be the head, called as cluster head (CH). All sensor nodes gather the information from their surroundings and send it to the corresponding CHs. Afterward the data will be send to the Base Station (Sink) by the CHs. Thus, selecting the suitable CH can decline significant extent of energy dissipation. In this paper, we present a fuzzy based approach which will elect the CH with respect to energy and distance. On the other hand, we also exhibited the working benefits of using mobile sink, which travels in the network area and collects the information from sensor nodes, for improving the lifetime of the network, using different data collection strategies, instead of static base station. The Rendezvous nodes will have the ability to transfer data when the mobile sink comes near. The proposed technique is analyzed using network simulator.

Keywords: Energy Efficient, Fuzzy logic, Mobile Sink, Network Lifetime, WSN

Cite this Article: V V N A Bhargavi and Dr. G. P. Saradhi Varma, Fuzzy Based Energy Efficient Clustering in Wireless Sensor Network. *International Journal of Computer Engineering & Technology*, 9(3), 2018, pp. 222–232.
http://www.iaeme.com/IJCET/issues.asp?JType=IJCET&VType=9&IType=3.

1. INTRODUCTION

A wireless sensor network (WSN) contains hundreds or thousands of tiny sensors that uses wireless communication modules to send information to any system. Normally these sensors have batteries with limited power and are not rechargeable, thus the energy efficiency is the major issue. The clustering-based designs conserve the energy of the sensors, which helps the communication between node and base station more effective. In some cases, for transmitting the data to the sink, instead of selecting the data, any one of the Relay (member of node) with more energy will be selected for transmitting the data in a one hop network. Fig 1 shows the General WSN architecture.

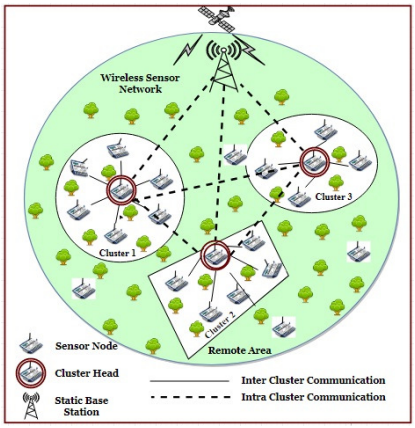

Figure 1 General WSN architecture

In the proposed work, we developed a Fuzzy based Energy Efficient Clustering (F-EEC) protocol for gathering the sensor data in WSN. It used a pure probabilistic model for selecting the cluster heads (CHs). In that the CH is elected by energy and position or distance. Unlike the other techniques the optimal value of competition ranges produces a good distribution of CHs. Furthermore, the cost of the communication is also taken into consideration, while electing the CHs. This prolongs the lifetime much more significantly than other protocols.

In addition, a new development of sensor network application emerges. In that motion is a fundamental characteristic. For such application the sensors will be placed in the vehicle which moves around large geographic area. The statically placed control will always lag with the mobility models. Recently many approaches were developed to eliminate the troubles in forwarding data form the sensor nodes to sink. Under this process the sink will be close to a subset of sensors and collects the data with less energy consumption. This kind of mobility is useful in times of emergency for detecting and collecting the relevant information. The mobile link will monitor the sensor devices; thus, it will reduce the cost of the network.

In our paper, we present the sink mobility approach, which increases the efficiency and improve robust data delivery in WSN. In this single hop network (CH to sink) and multi hop network (CH to relay to sink) are used. In addition to that the rerouting process is also initiated for stabilization.

The objectives of our proposed work are,

- To design a Location strategic clustering mechanism for better energy consumption and for improving the lifetime of the WSNs.
- To develop a fuzzy logic for electing the cluster head to reduce the burden.
- Create appropriate data aggregation and transmission strategies for direct communication.

The rest of the paper is organized in the following sections. Section 2 depicts review of some most relevant clustering protocols and mobility sink network models. Section 3 exhibits the details about our proposed protocol F-EEC and its analysis. Section 4 evaluates the performance of F-EEC via simulation and compares with other traditional techniques. Finally, the paper is concluded, and the future extension is illustrated in Section 5.

2. RELATED WORKS

This section exhibits some of the relevant and traditional techniques and protocols which are related to our research area. In [1], *Kurmi et al* has suggested a survey for inverting power consumption in the wireless network and analyses about the possibility to reduce the power consumption in base station. This paper deals with the fuzzy logic approach to cluster head election. *Lung et al* has suggested an efficient way to generate cluster for the wireless sensor network [2]. He explains about the hierarchical agglomerative clustering (HAC) algorithm with distributed HAC (DHAC) algorithm. It combines the similar nodes before the CH, the bottom up cluster approach was provided. This technique provides high energy efficiency. In [3] *Azad et al* has presented a Fuzzy multiple attribute decision-making (MADM) approach for selecting the clustering. This approach helps to extend the life time of WSN and provides high energy efficiency. *Alkesh et al* [4] proposed a unique movement strategy for BS to minimize the energy consumption. The lifetime enhancement was an important factor for the wireless sensor network. Under this process the base station will travel around a predefined path. *Wang et al* [5] made a survey based on the recent progress in mobile WSN and checked with various models and discusses about mobility management methodologies of mobile sensor and enhancing the network coverage, and extending the lifetime of the WSN. *Heo et al* [6] proposed a distributed energy efficient deployment algorithm for mobile sensor and an ambient intelligent network was proposed. In addition, the energy efficient based on Voronoi diagram was also proposed. In this work, a decision regarding movement is included with one hop network. *Kim et al* [7] suggested a CH selection mechanism using fuzzy logic. The main contribution was to reduce the fuzzy logic calculation and collecting to improve the lifetime of the sensor. Two fuzzy sets were presented in this work as, energy and distance. The energy consumption was the major problem in clustering. To validate that the technique was compared with LEACH, thus the proposed system provides better output. *Lee et al* [8] presented a fuzzy based clustering approach for improving the life period of WSN by constant work load. In this paper all BS and sensor nodes will be static. By the received signal strength, the distances between the each nodes were computed. *Sharma et al* [9] has proposed a Fuzzy Based Master CH Election Leach (F-MCHEL) Protocol in WSN. In this paper, the fuzzy logic approach was based on proximity distance and energy and Master CH has maximum residual energy. *Chatzigiannakis et al* [10] suggested a mobility sink travelling around the network area. Along with it delivers four characteristics of mobility pattern under different data collecting strategy. This paper demonstrates the significant reduce in energy spent in relaying traffic. The energy efficient was reduced by limited multi hop approach. Any way under this method, some loss of information needs to be tolerated. *Basangi et al* [11] illustrates the merits of using controlled mobility in network, it shows the movement of sink for improving the lifetime. For determining the sink movement, the mixed integer linear programming (MILP) for finding the sink routes. It helps to move the sink from one location to another where the nodes have more residual energy. *Roy et al* [12] suggested a secure network data aggregation for a large WSN for reducing the energy consumption and communication overhead. In addition, the proposed algorithm helps for securing the predicate count even in attack. It helps to analyse the amount of error in the base station.

3. PROPOSED WORK

3.1. Network model

In our model WSN is constituted with several tiny sensor nodes deployed in a remote location randomly, to monitor continuously about the environment. In that a mobile sink will be moving around an area for collecting data. Our network consists of the following:

1. Cluster Head (CH): For collecting the data, all the sensor nodes are split into several bundles, each bundle will form a cluster and the chief node is elected as CH.
2. Rendezvous nodes (RNs): the RNs are basically static, if the mobility sink come near to that, it has the ability to move and transmit the data.
3. Mobility sink (MS): It will move around the distance for collecting the data. Normally this type of mobility is used for public transportation vehicles example buses, trains etc.

3.2. Clustering approach

In direct communication technique, the sensor nodes will directly transmit the data. But in case of clustering technique, the network will be split into clusters, in that each sensor node will exchange information only with the clustering head. The fusion and aggregation will show a better result in reduction of energy consuming in sensor moreover it provides better results in bandwidth resources.

Under the clustering an excessive time delay will be allotted for every sensor nodes, and it knows there transmitting time. The sensor nodes of the network application are deployed randomly for continuous monitoring of the environment.

Some of the assumptions are given below,

1. All sensor nodes have equal initial energy and the network is homogenous.
2. Based on the distance of receiving nodes, it has the capacity of transmission power control.
3. The distance will be calculated by the received signal strength.
4. There is a symmetric radio link, in that all the nodes will consume same energy for transmission.

The proposed protocol describes a fuzzy based energy efficient cluster scheme. Its achievement is determined using distinctive benched appreciable criterions such as Packet delivery fraction, Throughput, Routing Overhead, Energy Consumption, Congestion Management and End to End delay. The main purpose of our protocol is to select suitable CH and send the collected data to the sink. In F-EEC, we elect the CH depending on the energy and distance with respect to fuzzy logic. Fig 2 shows the Flow chart of our work. The Algorithm for Clustering and Data Aggregation is given next.

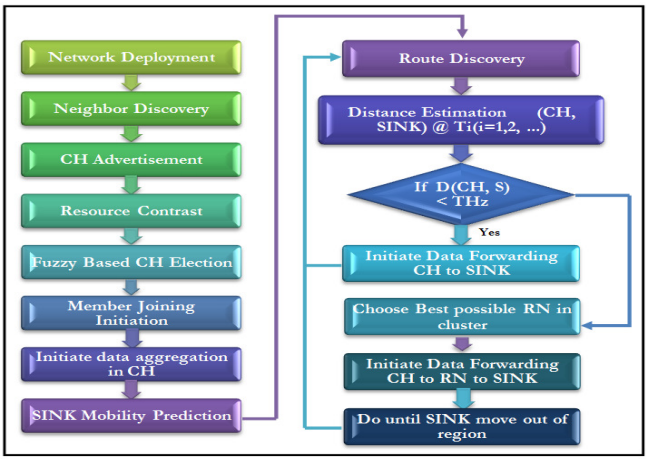

Figure 2 Flow chart of proposed work

Algorithm 1: Clustering and Data aggregation
Input: Node ID, Energy, Positions
Initiate neighbour discovery process
if adv message not received from neighbours→ (timer expired) then
Broadcast CH advertisement
end if
if adv received then
if received resource > self-resource
Set received node_id as CH
if Node is already CH
Node_ID_CH = false
end if
end if
end if
Compute head xi of cluster ci;
While (true) do
Find distance d1 and d2 of neighbour record xr, yj from;
Find k nearest neighbours (z1, z2,..., zk) of yj in X;
Calculate head of (z1,z2,...,zk);
Calculate distance d3 of yj from;
If (d2<γd3) then
    Insert yj in current cluster ci;
    Re – compute head of cluster ci;
    Remove node yj from x;
Set n = n – 1;
end if
end while
if node is normal
Send join request to CH as member

Receive the slot for communication

Initiate pairing with CH

Transmit data to CH

end if

In this paper, the proposed clustering algorithm configures the clustering and data aggregation. Based on energy and positions, the CH will be calculated. The algorithm initiates the nearest neighbour discovery process. If any of the messages is not received with the time limit, it will broadcast the CH advertisement. Once the advertisement is received, the CH will be determined. For electing the cluster head, the transmission energy need to be calculated is shown in (1).

$$T_E = \begin{Bmatrix} l * E_e + l * \varepsilon_{fs} * d^2 (d1 < d2) \\ l * E_e + l * \varepsilon_{mp} * d^4 (d1 \geq d2) \end{Bmatrix} \quad (1)$$

In that,

TE is the transmitting energy

Ee is the elected energy

L represents the length

ε_{fs} represents the amplification energy consumption under free space

ε_{mp} represents the radio model under multiple path.

After selecting the node, the cluster head will be analysed. In that it will check for the current cluster or the new cluster for the CH. Find the distance d1 and d2 of neighbour record. In that, threshold value is given as (2)

$$d2 = \sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}} \quad (2)$$

The free space or multipath fading channel model is employed based on the distance (d). The k nearest cluster head will be calculated and with the respective distance.

Energy required by each node to the receive data is given in (3)

$$RX_E = l * E_e \quad (3)$$

For calculating the energy of the nodes, equation (4) is initiated. In that T_{XE} is the transmission energy and R_{XE} is the reception energy of the node.

In which,

$$E_{CH} = Rx_{bs_E} + \left(Tx_{m_E} + Rx_{m_E}\right) * m + DA_E + Tx_{bs_E} \quad (4)$$

$$E_{M_{ID}} = Rx_{ch_E} + Tx_{ch_E} \quad (5)$$

Where,

Rx_{bs_E} CH energy consumption with respect to the reception of message from BS

Tx_{m_E} CH energy consumption with respect to transmission of message to its cluster members (CMs)

Rx_{m_E} CH energy consumption with respect to reception of data from a CM

m quantity of CM

DA_E CH energy consumption with respect to aggregation of data

Tx_{bs_E} CH energy consumption for transmission of aggregated data of sink

Rx_{ch_E} Node energy consumption for messages receiving from CH

Tx_{ch_E} Node energy consumed for data transmission from a node to CH

If the node is normal, the node will send the join request to the cluster head as a member and allocate the slot for communication. Then the node initiates the pairing to the CH and it will transmit the data to CH.

3.3. Data aggregation

The data aggregation is an important paradigm for routing in wireless sensor network. It helps to combines the data from various resources for reducing the transmission rate and provides better energy consumption. It will find the shortest route by altering the traditional centric address approach. In this paper, after sending the data to the cluster head, the mobility prediction sink will be initiated and discovers the route for reaching the sink in an efficient way. Fig 3 shows the Basic structure of Rendezvous design using clusters.

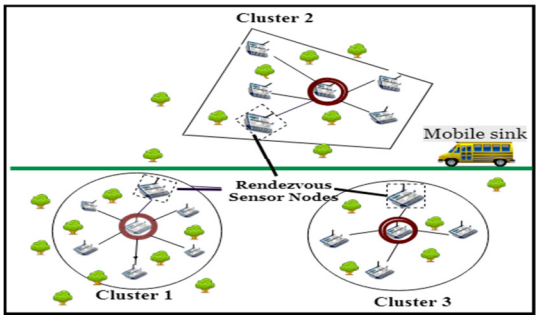

Figure 3 Basic structure of Rendezvous design using cluster

For finding the shortest path the route will be analysed for single hop network and multi hop network.

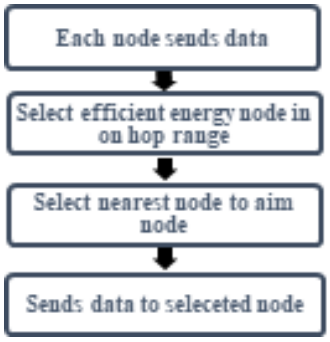

Figure 4 Routing of Multi Hop F-EEC Protocol

When the nodes are communicating with the minimum power requirement to reach the destination, if power is the major concern then the short Hop strategy is the most power efficient. In the single hop the collected data present in the CH will be transmitted directly to the sink. In the multi hop each node will send data, from that the efficient energy node will be selected. From that node the data will be transmitted to reach the sink. The rerouting process will be carried out for improving the stabilization of the network. Fig 4 shows Routing of Multi Hop F-EEC Protocol

4. PERFORMANCE ANALYSIS

The proposed clustering algorithm is compared with existing protocols PEGASIS, EDHRP and LEACH based on the parameters such as Packet Delivery Fraction, Throughput, Routing Overhead, Energy Consumption, Congestion Management and End to End delay. The simulation analysis is carried out by network simulator NS2. Tables 1 illustrate the simulation parameter used for the analysis.

Table 1 Simulation parameter

Simulation Parameter	Value
NS2 Version	ns-allinone-2.35
Protocol	AODV-Fuzzy
Coverage Area	1000m X 1000m
Simulation Time	200
Antenna Type	Omni Antenna
Energy Model	Energy Model (true)
Initial energy	10000mjoules
Number of Sensor Nodes	100, 200 …500
Mobile Sink	1
Data Rate	~256-512
Interface Type	Wireless Physical Interface
Radio Range for Node	~200m

4.1. Packet delivery fraction

Packet delivery fraction is a ratio of total data packets successfully received and total data sent by continuous bit rate. Fig 5 illustrates that the proposed technique is having very high packet delivery fraction. To prove that the proposed method is compared with some of the existing techniques like AntQHSen [13], Facor [14], ANTALG [15].

4.2. Throughput

The throughput depends on transmission energy and mobility of the relay node. The increase in the throughput may only increase when the transmission energy of each packet increases. This proves that the relay mobility reduces the transmission energy. Fig6 illustrates the comparative analysis between the proposed work and existing techniques, in that the F-EEC takes the lead as compared with the traditional techniques.

4.3. Routing overhead

In the network the control packets are exchanged for neighbour maintenance, selecting relay node and route estimation and maintenance. This will affect the network lifetime. Based on the results Fig 7 illustrates the comparative analysis of the routing overhead. The comparative results states that the F-EEC has minimum routing overhead as compared with the existing techniques.

4.4. Energy consumption

The proposed work is mainly developed for minimizing the energy consumption. For better understanding, the F-EEC is compared with the existing protocols for energy consumption. Fig 8 shows that F-EEC provides more balancing and optimal energy consumption, thus the lifetime of the network also increases. To validate this the proposed technique is compared with LEACH, PEGASIS, and EDHRP[16].

4.5. Congestion Management

The congestion control protocol is used for the wireless sensor network, to avoid congestion and to improve the quality and performance. It is used for monitoring of control mechanism for energy conservation. Fig 9 shows the comparative analysis of Congestion Management. In that our protocol F-EEC is more efficient than the existing techniques. The congestion management is calculated based on the node density.

4.6. End to End Delay

This analysis is used to analyses the time taken by a packet when it is generated by the source node to the time taken to reach the sink node. High delay indicates there is congestion due to retransmission of packets while low delay indicates increased performance. Fig 10 shows that the time delay is very minimum in F-EEC as compared to the Existing techniques like PEGASIS, EDHRP and LEACH.

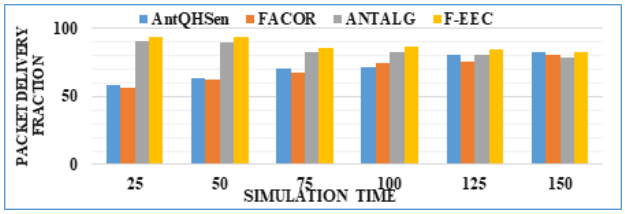

Figure 5 Comparison for Packet delivery fraction

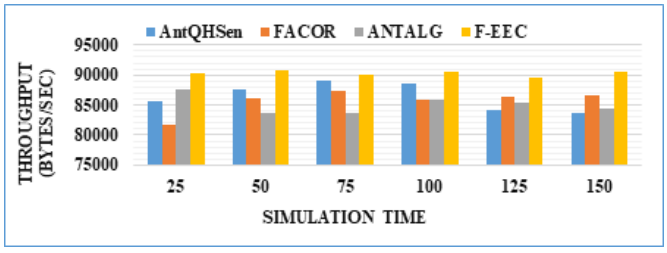

Figure 6 Comparative Analysis for Throughput

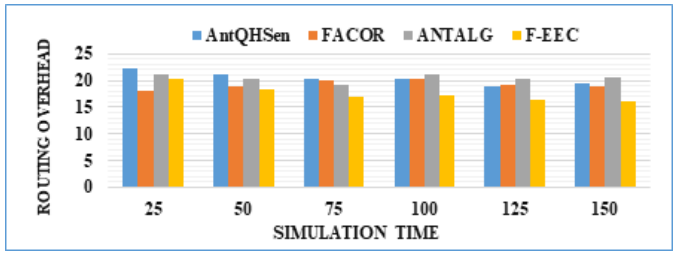

Figure 7 Comparison for Routing Overhead

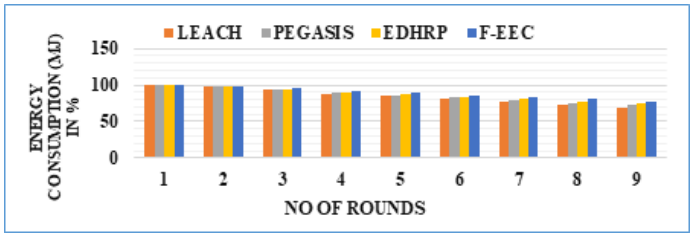

Figure 8 Comparative Analysis of Energy Consumption

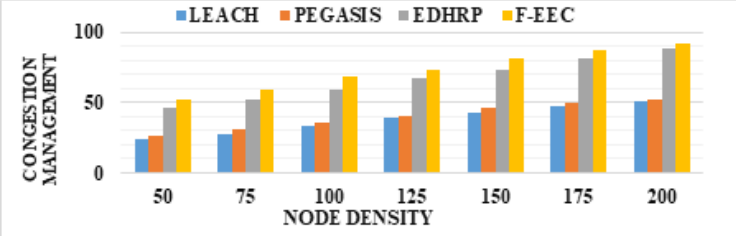

Figure 9 Comparison of Congestion Management.

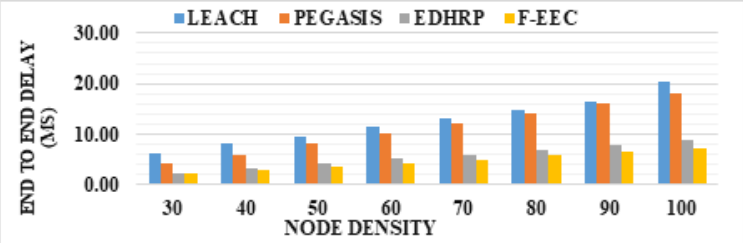

Figure 10 Comparative analysis on End to End delay

5. CONCLUSION

In this paper, F-EEC algorithm is developed for the WSN network. The proposed protocol selected the suitable CHs by clustering the sensor nodes into bundles and each bundle will form a cluster. With this system model a sustainable increase in the lifetime of the network is achieved. By finding the efficient way of transmitting data to the mobile sink, will guarantee the increase of energy consumption. The Rendezvous nodes-based network model will help to reach the shortest path of transmission. Although for performance analysis the proposed system is compared with the existing technique likes PEGASIS, EDHRP and LEACH with several parameters. The results justify that, while comparing with the other routing techniques the proposed work performs well.

Further, the research will be extended to analyse the performance of the routing system under a more complicated spare heterogeneous scenarios, more that the nodes with various capabilities can be analysed to prove the strength of the scheme.

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