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# Fuzzy Based Energy Efficient Clustering Protocol for WSNs

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**Abstract:** Data transmission from sensor nodes to Base Station (BS) is the major concern in Wireless Sensor Network (WSN) due to large consumption of energy. To overcome this problem, clustering approach is adopted by all the WSN. The approach where on Cluster Head (CH) is selected from a group of clusters members to transmit data of all the cluster members to BS is known as clustering. This study presents a fuzzy algorithm in clustering to select CH using residual energy, distance to base station, centrality as input parameters and gives fuzzy-cost as output in terms of chance as output parameters. Proposed algorithm using fuzzy logic is named as Fuzzy based Energy Efficient Clustering Protocol (FEECP). It uses Mamdani method for fuzzification and Centroid method for de-fuzzification. Experimental comparison of FEECP with existing techniques such as DUCF, LEACH, CHEF, SEPFL indicate that it is more energy efficient as selection of CH in FEECP is based on above said input parameters that mostly effects network efficiency.

**Key words:** Fuzzy logic, LEACH, network lifetime, residual energy, WSNs, techniques

## INTRODUCTION

A network containing large number of sensor nodes in a particular area is known as Wireless Sensor Network (WSN). A sensor node consist of various components such as battery, microcontroller, sensor interface, radio, analogue circuit (Akyildiz *et al*., 2002). When, individual sensor nodes send their data to the base-station it consumes a lot of energy and battery drained easily. To overcome this problem, clustering technique is used in WSN. It is a process in which nearby sensor nodes are grouped together and a cluster-head is selected among the grouped sensor nodes in a network. Selected CH sends a notification message to the sensor nodes of communication area to create a cluster network. Sensor nodes of cluster network send their data to the selected CH that send that data to BS consuming less energy (Abbasi and Younis, 2007; Bajaber and Awan, 2011).

This research proposed a Fuzzy based Energy Efficient Clustering Protocol (FEECP) for clustering in WSN. It involves three fuzzy input parameters residual energy, distance to base-station, centrality and chance as output parameter. Based on chance, fuzzy cost is calculated that selects the deserving CH. Selected CH send a notification message to remaining nodes about its selection as CH. After receiving acknowledgement, remaining nodes transmit their data to the CH. It send that data to the BS consuming less energy.

**Fuzzy approach:** It is used to obtain accurate results for a single parameter that involve uncertainty. Fuzzification, defuzzification, fuzzy rule base and membership function are the units of fuzzy inference system. A crisp value is given to fuzzy system and is further changed to fuzzy input set value using fuzzification and defuzzification.

**Literature review:** LEACH was the first and basic technique used for CH selection in WSN. It selects different CHs in different rounds with probability approach. Non-CH nodes transmit their information to the selected CH for the BS (Heizelman *et al*., 2002). Selection of CH in LEACH is influenced by some other parameters also such as how many times it is selected as CH as given in Eq. 1:

$$T(n) = \begin{cases} \dfrac{d}{1-d\left(k \bmod (1/d)\right)}, & n \in H \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

Where:
n = Single sensor node
d = The desired CH percentage
H = Non-CH nodes in recent
k = Rounds

Distributed balanced Unequal Clustering using Fuzzy approach (DUCF) is an unequal clustering technique used for sensor network. It uses three fuzzy input parameters node degree, residual energy, distance to base station and

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two fuzzy output parameters chance and size. Based on fuzzy parameters and fuzzy rules, deserving node gets selected as CH. Selected CH transmit data of all sensor nodes to BS resulting less consumption of energy (Baranidharan and Santh, 2016).

In CH Election using Fuzzy logic (CHEF), fuzzy technique is used to select the CHs. 'Energy level' and 'distance of nodes' are the two selection parameters. A number is generated for every node. If the generated number lies within the threshold value then it comes in the category of qualified node to become CH else it is discarded (Kim *et al*., 2008).

SEP using Fuzzy Logic (SEPFL) uses three fuzzy parameters node to BS distance, node density and energy of node. It uses their threshold values to select the CH (Tamandani and Bokhari, 2016). Selection of CH in SEPFL is within the cluster by sensor nodes than BS.

Distance-based Residual Energy-Efficient SEP (DRESEP) is proposed for heterogeneous WSN. It uses residual energy of nodes and node to BS distance to select CH node. It also provides an improvement in the lifetime of the network (Mittal and Singh, 2015). Gupta *et al*. (2005) fuzzy algorithm is used to select the CH. It uses three fuzzy input parameters residual energy, concentration of node and centrality of node. BS collects the necessary information to select the CH using fuzzy rule system.

## MATERIALS AND METHODS

**Proposed algorithms:** FEECP is proposed to obtain energy efficient network using fuzzy logic approach to select CH. Three input parameters 'residual energy', 'distance to base station' and 'centrality' are used for the selection of CH node. Used parameters are as follows:

**Residual energy:** Data aggregation and data transmission are the main functions of a selected CH. So, it should have sufficient residual energy to perform above said functions in an efficient manner.

**Distance to base station:** If the selected CH is far from the BS then it contains more cluster members means more energy is required for their data transmission. This problem is known as hot problem. ACH should have minimum distance to BS for an energy efficient network.

**Centrality:** Centrality of a network defines the position of a node with its neighbour node. It prefers a node to become a CH having a same and minimum distance with its cluster members.

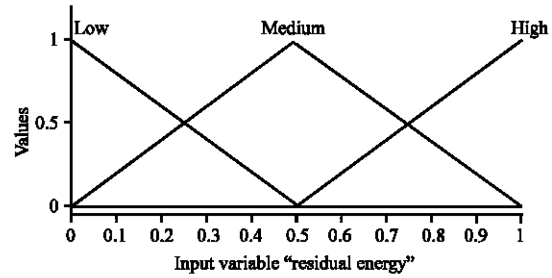


Fig. 1: Representation of 'residual energy' using membership function

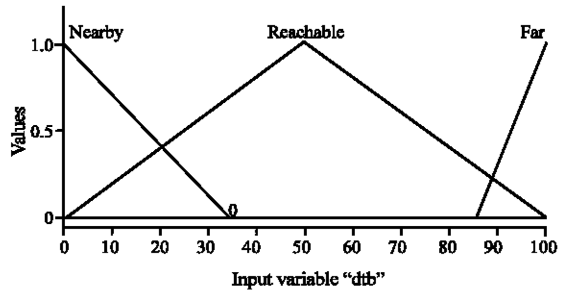


Fig. 2: Representation of 'distance to base station' using membership function

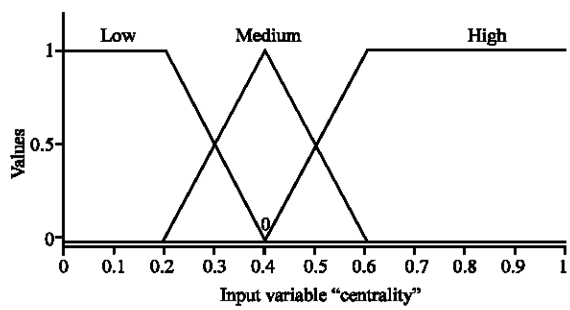


Fig. 3: Representation of 'centrality' using membership function

**Chance:** Chance is the fuzzy output parameter represents the possibility of sensor node to get selected as CH. It selects the higher eligible node as CH based on the three input parameters.

It operates in three phases CH election phase, CH formation phase and data transmission phase. All the above three phases are as follows.

**CH election phase:** During CH election, a crisp value is given as input to the fuzzy inference system. It is fuzzified to fuzzy linguistic variables. The fuzzy linguistic variables used for 'residual energy', centrality and 'distance to base station' are shown in Fig. 1-3. Trapezoidal and triangular

Table 1: Fuzzy rules

| Input parameters | | | Output parameters |
|---|---|---|---|
| Residual energy | Distance to base station | Centrality | Chance |
| High | Nearby | Low | Rather high |
| High | Nearby | Medium | High |
| High | Nearby | High | Very high |
| High | Reachable | Low | Rather high |
| High | Reachable | Medium | High |
| High | Reachable | High | Very high |
| High | Far | Low | Rather high |
| High | Far | Medium | High |
| High | Far | High | Very high |
| Medium | Nearby | Low | Low medium |
| Medium | Nearby | Medium | Medium |
| Medium | Nearby | High | High medium |
| Medium | Reachable | Low | Low medium |
| Medium | Reachable | Medium | Medium |
| Medium | Reachable | High | High medium |
| Medium | Far | Low | Low medium |
| Medium | Far | Medium | Medium |
| Medium | Far | High | High medium |
| Low | Nearby | Low | Very low |
| Low | Nearby | Medium | Low |
| Low | Nearby | High | Rather low |
| Low | Reachable | Low | Very low |
| Low | Reachable | Medium | Low |
| Low | Reachable | High | Rather low |
| Low | Far | Low | Very low |
| Low | Far | Medium | Low |
| Low | Far | High | Rather low |

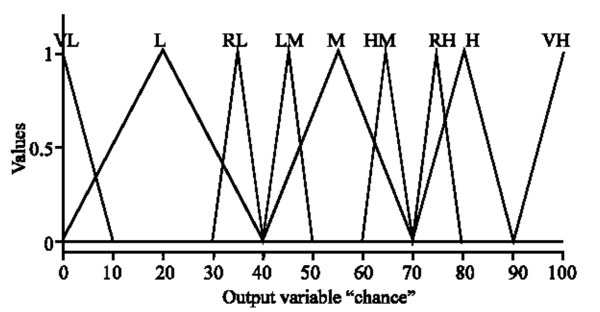


Fig. 4: Representation of 'chance' using membership function

membership functions are used to represent these linguistic variables. Membership functions are selected based on the results obtained by (Aderohunmu *et al*., 2011). 'Chance' is the fuzzy output parameter with nine fuzzy linguistic variables as shown in Fig. 4.

Above described linguistic variables are further processed with the help of fuzzy rule base using Mamdani method. It consists of 27 rules using fuzzy linguistic variables as in Table 1.

**Cluster formation phase:** In cluster building phase, after the computation of chance every node sends a CANDIDATE_CH message along with ID and 'chance' value to the neighbour nodes in the communication radius 'k'. Node with higher 'chance' value get elected as a CH sending a WON_CH control message in its communication radius 'R'. There is also a possibility that a node sometimes may receive two or three WON_CH messages simultaneously. It selects only the closer one CH by forwarding a JOIN_CM message to that CH. Control messages used by FEECP are shown in Table 2.

Table 2: Control messages

| Messages | Function of control messages |
|---|---|
| CANDIDATE_CH | Broadcasted by all nodes to neighbour ones in its communication area 'k' |
| WON_CH | Broadcasted by elected Cluster Head to remaining other nodes along radius 'R' |
| JOIN_CH | Used by non-CH nodes to request CH node for joining CH |

**Data transmission phase:** For the data transmission, firstly selected CH collects the data from all the cluster members. It uses a Time Division Multiple Access (TDMA) providing a time slot to every cluster member node to send their data. Cluster member nodes send their data in the given time slot only and remain in sleep mode for the rest of time. CH aggregate the information received from cluster members to a single packet for the transmission to BS in multi-hop manner. Sometimes, data sent by cluster member node may be received by other CHs that create inter-cluster interference. To avoid such problem, a spread code of concerned CH is sent by every cluster member node along with its data.

**Energy used during data transmission phase:** Inter-cluster transmission ($E_{ICT}$) and Intra-cluster transmission ($E_{IACT}$) are the two factors responsible for the energy consumption during data transmission phase:

$$E_{IACT} = E_{C(CM_{CH})} + E_{C(DR)} + E_{C(DAN)} \quad (2)$$

where, $E_{C(CMCH)}$ the transmission energy between cluster members and CH's is represented by Eq. 3 where d is the no. of clusters in a network, $n_i$ represents the members up to ith cluster and (k, $CH_i$) is the transmission of energy between CH of ith cluster and k node:

$$E_{C(CM_{CH})} = \sum_{i=1}^{d}\sum_{k=1}^{n_i} E_{Tr}(k, CH_i) \quad (3)$$

$E_{C(DR)}$ is the consumption of energy occurs during reception of data by CH from its cluster members and is represented by Eq. 4 where is the received energy:

$$E_{C(DR)} = \sum_{i=1}^{d} n_i \times E_{rc} \quad (4)$$

$E_{C(DAN)}$ is the energy consumption due to aggregation of data and is represented by Eq. 5, where Y, represents no. of bits and is the energy consumed by single bit data:

$$E_{(DAN)} = \sum_{i=1}^{d} Y \times n_i \times E_{sbd} \quad (5)$$

When intermediate nodes exist between CH and BS, Eq. 6 represents the energy consumption:

$$E_{ICT} = E_{TR}(f, CH) + \sum_{k=2}^{u} E_{Tr}(CH_{(K-1)}, CH_K) + E_{Tr}(CH_b, BS) \quad (6)$$

Where:

f = Intermediate node between CH and BS in next round
u = No. of in between BS and CH
b = The CH node that is near to BS in the path of long distance CH

Algorithm 1 shows FEECP algorithm and calculate fuzzy() is a fuzzy based function.

**Algorithm 1 (FEECP Algorithm):**

```
i = define a single sensor node in any network
M = total number of nodes contained by a network
for x = 1: M
        x.RE = Residual Energy of nodes
        x.DB = Distance between nodes and base station
        x.C = Centrality between nodes and CHs
        chance = calculatefuzzy (x. RE, x. DB, x. C,)
end
for y = 1: M
        forward CANDIDATE_CH to all neighbour nodes
        n = list of all CANDIDATE_CH from neighbour nodes
if (chance> chance(n))
       advertise WON_CH
       state = Final Cluster Head
else
       send JOIN_CM to next closest Cluster Head node
end
end
       n.state = member node
else
       Declare itself as Cluster Head
       n state = final Cluster Head
end
end
```

**Simulation setup:** For simulation, FEECP algorithm undergoes comparison with different fuzzy logic techniques such as DUCF, LEACH, SEPFL, CHEF. Comparison of above said techniques is proposed by considering different setups shown in Fig. 5 and 6. In setup 1, BS is placed at position of (50, 50) with network area of 100×100 m having 100 nodes present in it; in setup 2, BS is placed at position of (100-275) with network area of 200 ×200 m having 100 nodes present in it.

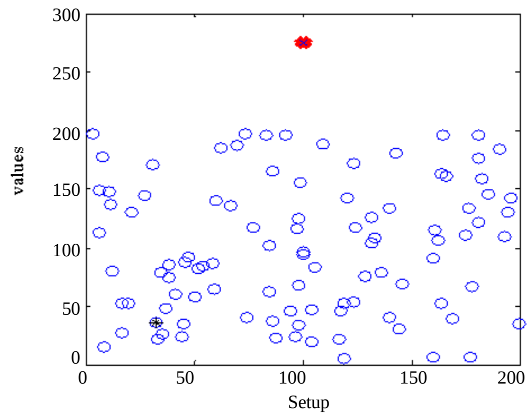


Fig. 5: Setup 1 (BS is placed at position of 50, 50)

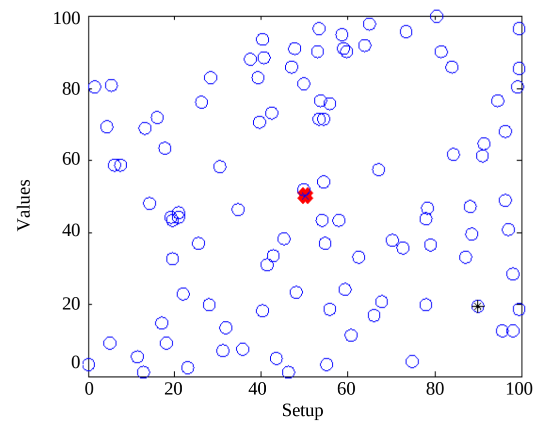


Fig. 6: Setup 2 (BS is placed at position of 100, 275)

Red dot in the network indicate the position of BS. In every setup, algorithm is calculated using some factors such as:

- Average energy dissipation: it is the overall energy dissipation for simulation process
- Lifetime of network: number of rounds achieved by network before first node dead and half node dead is known as network lifetime

Both transmission and energy models are taken from (Kulkarni *et al*., 2011) and are as follows:

$$\text{Transmission Energy}(E_{tr}) = \begin{cases} x \times E_d + \varepsilon_{fs} \times t^2 \text{ if } t_< t_o \\ x \times E_d + \varepsilon_{mp} \times t^4 \text{ if } t_> t_o \end{cases} \quad (8)$$

$$\text{Reception Energy}(E_{rc}) = X^{*Ed} \quad (9)$$

Table 3: Parameters used for simulation with their values

| Parameters used | Values |
|---|---|
| X | 4000 |
| $E_d$ | 50 $nj^{bit-1}$ |
| $\varepsilon_{fs}$ | 10 $pjbit^{-1}$ |
| $E_{mp}$ | 0.0013 $pjbit^{-1}$ |
| $t_0$ | 87 m |
| Node's initial energy | 1j |
| Size of data packet | 500 bytes |
| Size of control packet | 25 bytes |

Transmitted bits are represented by 'X', Energy dissipation on transmission and reception of data is represented by '$E_d$', Energy dissipation in free space is denoted by '$E_{fs}$', Energy dissipated for multipath propagation is represented by $E_{mp}$, distance between two nodes is represented by 't' and '$t_o$'denotes threshold value of 't' to check the propagation type. Table 3 describe that initial energy for network processing is 1j and size of both control packet and data packet is 25 bytes and 500 bytes.

## RESULTS AND DISCUSSION

Results have been taken for network lifetime and energy efficiency of the network. 'Alive nodes' and 'average energy dissipation' are the two parameters considered for comparison with existing DUCF, LEACH, SEPFL, CHEF protocols.

**Network lifetime:** Figure 8 and 9 shows the results for number of alive nodes versus rounds considering two different setups. In setup 1, Fig. 7 indicate that FEECP shows approximately 12.19% improvement for LEACH, 27% for DUCF, 15% for CHEF for number of alive nodes of the network. In case of SEPFL, firstly FEECP lags behind the SEPFL but as the number of rounds increases it start improving.

In setup 2, Fig. 8 shows that again all the protocols start diminishing earliery than FEECP when BS is placed at much large distance as compared to setup 1. Observations indicate that still FEECP is dominating over all the protocols. It shows approximately 65% improvement in number of alive nodes for DUCF, 19% for CHEF, 78% for SEPFL. In case of LEACH simulation results for both FEECP and LEACH are almost comparable.

**Average energy dissipation:** Figure 9 and 10 shows an average energy dissipation for LEACH, CHEF, DUCF, SEPFL and FEECP by considering above two setups. In Setup 1, Fig. 9 shows that average energy dissipation for FEECP takes longer time as compared to other protocols. FEECP shows an improvement of approximately 12% for CHEF, 22% for SEPFL, 31% for LEACH and 11% for DUCF

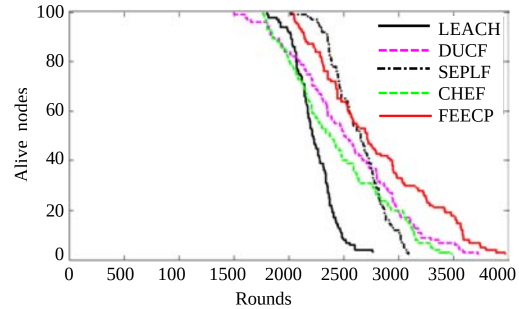


Fig. 7: Setup 1 for alive nodes (nodes: 100, area: 100×100 m BS: 50, 50

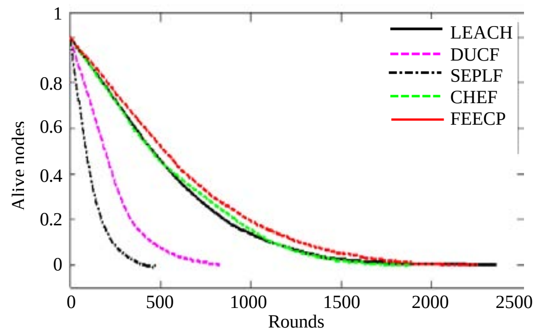


Fig. 8: Setup 2 for alive nodes (nodes: 100, area: 200×200 m BS: 100, 275

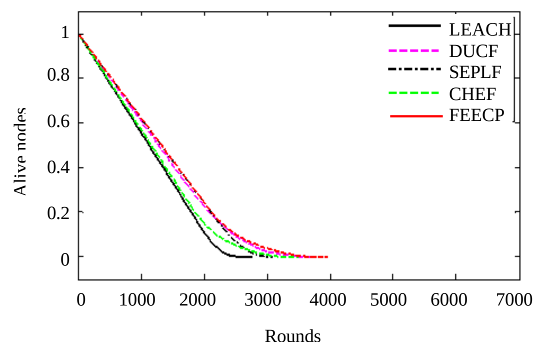


Fig. 9: Setup 1 for average energy (nodes: 100, area: 100×100 m; BS: 50, 50)

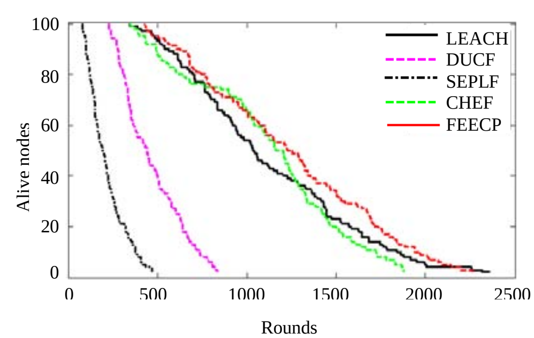


Fig. 10: Setup 2 for average energy (nodes: 100, area: 200×200m, BS: 100, 275)

for average energy dissipation In setup 2, it is observed that average energy dissipation for FEECP and LEACH is again almost equal but DUCF and SEPFL protocols diminishes too earlierly due to distant BS as shown in Fig. 10. FEECP shows an improvement of approximately 79% for SEPFL and 68% for DUCF for average energy dissipation.

## CONCLUSION

Energy dissipation is the major concerns in WSNs. The proposed FEECP algorithm provide an energy efficient solutions by selecting CH 'residual energy', 'distance to BS', 'centrality' as input parameters using fuzzy logic. All the selected parameters are considered with an aim to reduce the overall energy dissipation of the network. Simulation results show that FEECP provides an improvement over alive nodes in the network and average energy dissipation when compared with existing protocols.

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