Enhancement of Network Lifetime using Fuzzy based Cluster Head Selection Algorithm

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Abstract: The lifetime of a network is the time for which the nodes are active in a wireless sensor network. To enhance the lifetime of the network, an efficient method for cluster head selection using fuzzy logic is presented in this paper. The algorithm presented uses a fuzzy logic which considers residual energy of node, throughput of node and distance from the sink as the parameters for selection of node to become a cluster head. The membership function of output parameter, probability of becoming a CH can be found out with the different combinations of the three input variables.

Keywords: Wireless sensor networks, network life time, throughput, threshold value.

Introduction

A WSN is a network composed of thousands of tiny nodes placed at a certain distance, having equal sensing capabilities. These nodes are battery driven which cannot be recharged and hence result in reduced network life time [1]. The deployment of these nodes in the network is done in the absence of any infrastructure to recharge the battery of these nodes. The function of these nodes is to sense the environment, process the information thus collected and communicate this information to the sink nodes [2]. The energy efficiency of the network can be increased by using the concept of clustering in WSN [3]. The whole network can be fragmented into cluster having a certain number of sensor nodes as cluster members and a cluster head [4].

Literature Review

Clustering is a popular and an efficient method for enhancing lifetime as well as energy of wireless sensor networks and had been proposed earlier [5]. Heizelman et.al [6] proposed LEACH algorithm which divide the network into number of clusters and choose a cluster head, on the basis of threshold energy available, which aggregated the data and passed it to the sink. Lindsey and Raghavendra [7] in their paper introduced a greedy algorithm named PEGASIS. In this algorithm a single path is followed pass by each node, in case of any failure that occurs a new path needs to be discovered. This protocol does not taken into account QoS. Singh and Khandari [8], in their paper introduced K-SEP protocol is introduced which took Residual energy into account, as a factor for becoming a clusterhead. Patole and Abraham [9] use Eulicidean distance as a mechanism to determine the closeness for nodes in a cluster.

Fuzzy logic Based Algorithm for Selection of Cluster Head

The algorithm presented in this paper makes use of residual energy, distance and throughput as the criteria for selection of cluster head. Based on which the fuzzy logic will calculate the probability of node of becoming a cluster head.

Fuzzy Interference system design for cluster head selection

Input variables for fuzzification

Residual energy (RESIDUAL): It is the energy available in the nodes after each round. After each round some amount of energy is dissipiated in sensor nodes as a result of transmission of information to CH and In CH due to transmission and reception of Packets. The node havinghigher residual energy available hashigher probability of becoming a clusterhead.
The radio energy model describes energy expenditure [10-11] for transmission of single bit over a distance D.
The energy expended is then given as by

$$E_{TRAX} = \begin{cases} pE_{elc} + p\varepsilon_{frs}D^2, & D<d_o \\ pE_{elc} + p\varepsilon_{frs}D^4, & D>d_o \end{cases} \qquad \text{..................(1)}$$

Where $E_{elc}$is the energy dissipated per bit to run the transmitter and the receiver circuit
p= packetLength
d_o= minimum threshold value of distance
D is the distance between given node and the BS or sink.
If the distance is less than the minimum threshold value of distance, then in that case free space model isused. If the distance is more than the minimum threshold value of distance in that case system consists of multipaths and hence multipath model is used. Now, total energydissipiationin the network for given number of rounds is given by:

$$E_{roun} = L(2NE_{ele} + NE_{DA} + M\varepsilon_{amp}d_{toBS}^4 + N\varepsilon_{frs}d_{toCH}^4) \quad \text{...........(2)}$$

where M is number of clusters.

d_{toBS} = Average distance between CH and BS

d_{toCH} = Average distance between CH and the cluster members

Throughput (THROUGHPUT): Throughput may be defined as the number of bits transmitted per round. Nodes with HIGHER threshold will send more number of bits. So this factor should be considered while selecting cluster heads.

$$\text{Throughput} = \frac{number\ of\ bits\ transmitted}{number\ of\ rounds} \quad \text{..........(3)}$$

Distance from Sink (DISTANCE): The energy consumption by the node while communicating with the sink increases when the distance between them increases as a result of which it is vulnerable to drain most of energy and result in insufficient coverage as well as reducing the network lifetime [9]. So distance parameter needs to be considered in order to select the CH [12].

Fuzzy Interference System Variables
Probability of Becoming a CH (Represented By PROBAB): A Large probability means higher chances of becoming a CH. Linguistic Variables for PROBAB are VERY SMALL, SMALLER, SMALL, MID, RATHER MID, LARGE, LARGER and VERY LARGE
Linguistic variables for Residual, Distance, threshold values for nodes are LESSER, MIDDLE, HIGHER. Member function :Fuzzy inputs are represented by triangular membership function

Table 1 Fuzzy Rule Defined for algorithm

S.No	**RESIDUAL**	**THOUGHPUT**	**DISTANCE**	**PROBAB**
1	LESSER	LESSER	LESSER	VERY SMALL
2	LESSER	LESSER	MIDDLE	SMALLER
3	LESSER	LESSER	HIGHER	SMALL
4	LESSER	MIDDLE	LESSER	SMALL
5	LESSER	MIDDLE	MIDDLE	MID
6.	LESSER	MIDDLE	HIGHER	MID
7.	LESSER	HIGHER	LESSER	VERY SMALL
8.	LESSER	HIGHER	MIDDLE	SMALL
9.	LESSER	HIGHER	HIGHER	SMALLER

10.	MIDDLE	LESSER	LESSER	LARGER
11.	MIDDLE	LESSER	MIDDLE	LARGER
12.	MIDDLE	LESSER	HIGHER	SMALL
13	MIDDLE	MIDDLE	LESSER	RATHER MID
14	MIDDLE	MIDDLE	MIDDLE	LARGER
15	MIDDLE	MIDDLE	HIGHER	SMALL
16	MIDDLE	HIGHER	LESSER	SMALLER
17	MIDDLE	HIGHER	MIDDLE	MID
18	MIDDLE	HIGHER	HIGHER	LARGER
19	HIGHER	LESSER	LESSER	LARGER
20	HIGHER	LESSER	MIDDLE	SMALL
21	HIGHER	LESSER	HIGHER	VERY LARGE
22	HIGHER	MIDDLE	LESSER	LARGE
23	HIGHER	MIDDLE	MIDDLE	LARGER
24	HIGHER	MIDDLE	HIGHER	SMALL
25	HIGHER	HIGHER	LESSER	MID
26	HIGHER	HIGHER	MIDDLE	LARGER
27	HIGHER	HIGHER	HIGHER	SMALL

Simulation Settings

The wireless sensor networks consisting 100 nodes randomly placed in a network field having dimension of $100m \times 100m$. In this scenario we considered that sink or base station is placed at the middle of field.

Table 2: Parameters of given network

Network Parameters	**Values of given parameters**
Network Area	100 m x 100 m
Total number of nodes	100 nodes
Eo(Normal node energy available at the initial phase)	0.5Joule
Length of the Message	4000
Transmission energy (*ETX)*	50nJ/bit
Free Space Energy (*Efis)*	10nJ/bit
Multipath Energy Loss (*Emp)*	0.0013Pico joule per m^3

Adaptive Energy (*EDA)*	5nJ/bit
Optimal probability (*P*)	0.1
Threshold distance (*Do)*	70 m
Maximum number of rounds (rmax)	9000

For given network we have considered network parameters mentioned in the Table 2 for a given heterogeneous network. "*m*" and "*a*" parameters are used to represent the level of heterogeneous network, "*m"*refers to the nodes having higher energy as compared to normal nodes and are known as advance nodes. The factor by which these nodes have higher energy is represented by "*a"*. In this case m=0.1 indicates the number of advance nodes have energy a=2 times more energy than that of the normal nodes.

Simulation Results

Input Member function Plots

Residual energy memberfunction

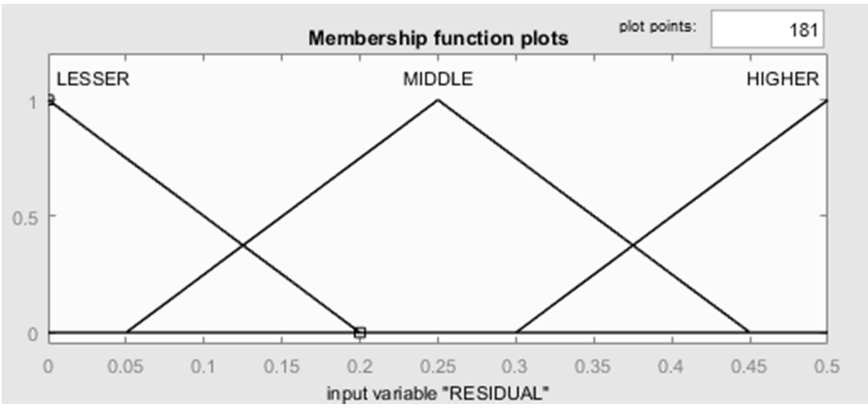

Fig. 1 Plots indicating residual energy member function

Fig. 1 represents Plot of residual energy, the plot represents the three level of values representing LESSERamount of residual energy available, MIDDLE level of energy available and HIGHER amount of available energy.

Throughput Memberfunction

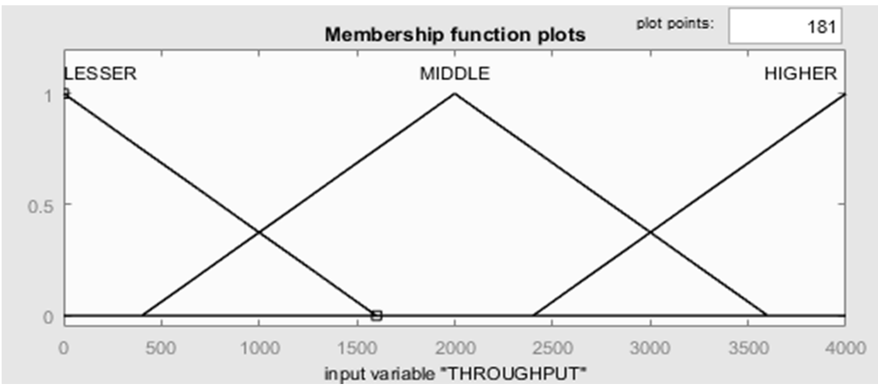

Fig. 2 Plot of Throughput member function

Fig. 2 represents the throughput memberfunction plot consisting of three levels representing LESSER amount of throughput that is less number of bits transmitted in each round, MIDDLE throughput representing mediocre amount of bits transmitted and HIGHER throughput representing high rate of bits transmitted.

Distance Memberfunction

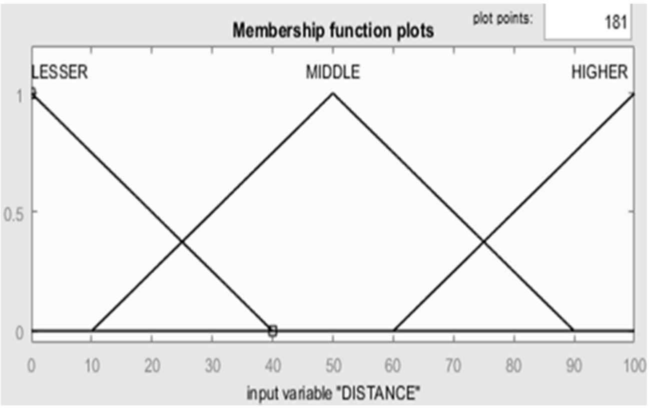

Fig. 3 Plot of Distance Member Function

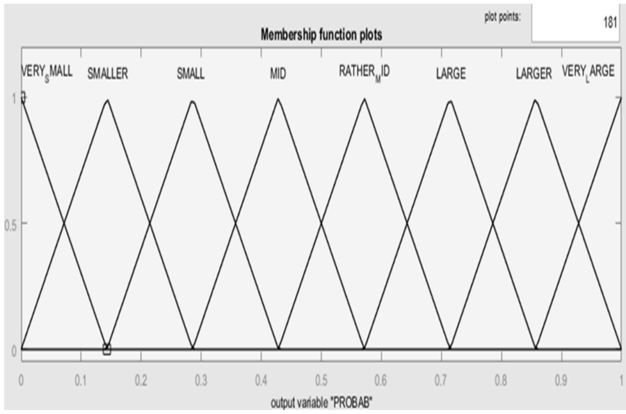

Fig. 4 Plot of PROBAB memberfunction

Fig 3 represents plot of distance from the sink consisting of three levels that is nodes are present atless distance or closer to the sink, at medium distance and far away from the sink.

Output FIS memberfunction

Fig. 4 The PROBAB represent the chances of a given node with given Residual energy, Throughput and Distance for becoming cluster heads.

Ruler viewer

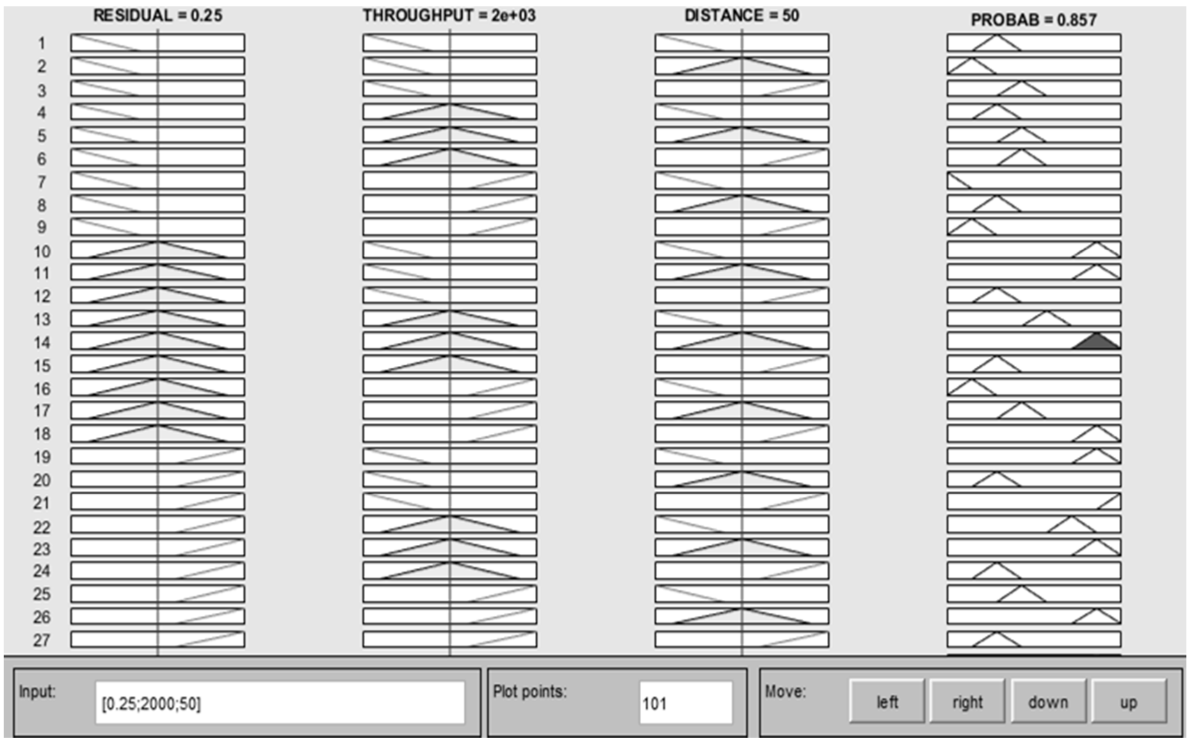

Fig. 5Fuzzified output for fuzzy inputs

Ruler view in Fig. 5represents the fuzzified output for given inputs, we can put the value for inputs at runtime and accordingly the output will move left and right depending on the input variables.

Conclusion

In this paper we presented a fuzzy logic based cluster head selection method with enhanced network life time, making use of residual energy, throughput and distance together as the FIS input variable. Depending on FIS output variable PROBAB the node which turns out to have a HIGHER probability will be selected as cluster head.The values for given inputs can be applied at run time and output can be obtained accordingly.

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