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A Clustering Algorithm for WSN to Optimize the Network Lifetime Using Type-2 Fuzzy Logic Model

D V Pushpalatha
Dept. of EEE
GRIET
Hyderabad, India
E-mail: dvplatha@gmail.com

Padmalaya Nayak
Dept. of IT
GRIET
Hyderabad, India
E-mail: padmalaya@griet.ac.in

Abstract — **In past few years the use of Wireless Sensor Networks (WSNs) are increasing tremendously in different applications such as disaster management, security surveillance, border protection, combat field reconnaissance etc. Sensors are expected to deploy remotely in huge numbers and coordinate with each other where human attendant is not practically feasible. These tiny sensor nodes are operated by battery power and the battery operated sensor node cannot be recharged or replaced very easily. So, minimization of energy consumption to prolong the network life is an important issue. To resolve this issue, sensor nodes are sometimes combined to form a group and each group is known as a cluster. In each cluster, a leader node is elected which is called as the cluster head (CH). When any event is detected, each node senses the environment and sends to the respective cluster heads. Then cluster heads send the information to the base station (BS). So, appropriate cluster head election can reduce considerable amount of energy consumption. In this paper, we propose a cluster head election algorithm using Type-2 Fuzzy Logic, by considering some fuzzy descriptors such as remaining battery power, distance to base station, and concentration, which is expected to minimize energy consumption and extends the network lifetime.**

Keywords - WSN, Fuzzy Logic Type-2, Mamdani's Method

I. INTRODUCTION

The huge applications of WSN bring many challenges as these tiny sensor nodes are battery operated and deployed randomly and deterministically in hazardous places where human monitoring is highly risky. There are many typical issues like power constraints, limited computing capacity, open environment and wireless connectivity makes the sensor nodes faulty many times. Once the network is established, nodes keep on sensing the environment and the battery power goes off in due course of time. Whenever any events occur, the sensor nodes sense the environment and send the information to the other nodes or the base station. Then the base station aggregates the data and takes a higher level decision. So data duplication is a major problem in WSN. To avoid this data duplication and to make the network most energy efficient, data aggregation and sensor fusion have been reported in the literature [1]. Many routing protocols with many innovative techniques have been proposed in the literature to proof the network efficiency [14]. Clustering is one of these efficient techniques, where sensor nodes are categorized into different groups and each group is called as a Cluster. But the election of a leader node which is called cluster head is an important issue that contributes a lot to minimize the energy consumption. Only cluster head is permitted to send the information to BS. Figure 1 shows the general system model for clustered based WSN.

Low Energy Adaptive Clustering Hierarchy (LEACH) [1, 2] is the first ever clustering routing protocol which is proven to be energy efficient over flat routing protocol. In LEACH, the CH is elected on rotation basis in a probabilistic manner and attempt for balancing the load at each sensor node. The probabilistic value in LEACH elects an unstable no of cluster heads is each round. The cluster head may be elected near to the boundary of the network or more than one number of CHs is elected in each round that makes energy distribution improper. LEACH-C is another centralized routing protocol [2] elects the CH by collecting location information of each sensor node through the BS. As it is a centralized approach, better number of clusters is formed and CHs are distributed evenly among the clusters. In this approach, even if the network lifetime is increased, it increases the network overhead. In the proposed model, we try to improve the performance of LEACH in view of electing an appropriate CH by applying suitable Type-2 fuzzy Logic descriptors.

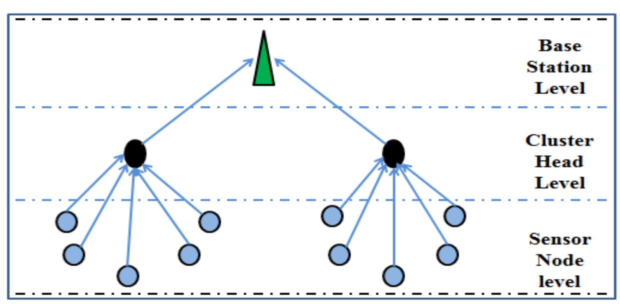

Figure 1: General System Model for clustered WSN

The following sections discuss the protocol in detail. The rest of the paper is organized as follows. Section II discusses about the related work in this area. Section III presents the Radio Model of WSN. Section IV presents the

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Fuzzy Inference Modules and the proposed algorithm. Section V presents the results and discussion followed by further research work and the conclusive remark.

II. BACKGROUND DISCUSSION

In clustering based protocol, each cluster head is responsible to send the information to the base station. In this section, most of the famous clustered based routing protocols are discussed. We have divided them in two categories. In first category, few protocols where cluster heads are elected in a probabilistic manner are discussed and in the second category, some of the fuzzy logic (Type-1) clustering based protocols are discussed.

A. Hierarchical Routing Protocols based on clustering

1) LEACH

LEACH [1,2] is a famous hierarchical routing protocol where CH is elected on rotation basis based on a probabilistic model and each sensor node gets equal opportunity to be a CH. LEACH protocol operates in two phases: set up phase and steady state phase. Clusters are formed in the set up phase and actual data is transmitted in the set up phase. Each node chooses a random number between 0 and 1 to be the CH. If the number is less than the threshold value *T* (*n*), the node gets the chance to be the cluster head for the current round. The threshold value *T* (*n*) is defined in equation (1).

$$T(n) = \begin{cases} \dfrac{p}{1 - p * \left(r \bmod \dfrac{1}{p}\right)}, & if\ n \in G \\ 0, & otherwise \end{cases} \qquad (1)$$

where *r* is the round which already ended, *p* is the probability of the nodes to be the CH, *G* is a set of nodes which have never been cluster head in the last *1/p* rounds.

Although in LEACH, load is equally distributed on each cluster head, still there are some drawbacks which are discussed here. As LEACH uses probabilistic model, there is a chance that two cluster heads are elected with close proximity which tends to exhaust over all energy in the network. More CPU cycles are consumed due to the selection of random number in each round. If the elected node is closed to the boundary of the network, other nodes could dissipate more energy to transmit the message to CH.

2) LEACH –C

LEACH-C [2] uses a centralized algorithm to elect the CH. This centralized algorithm is used by the BS to know the location information and energy of individual node. Better clusters are formed by BS by disturbing Cluster Head nodes throughout the network. The main drawback of LEACH-C is that the position of all the nodes must be known to BS. In [3-8], many clustering protocols have been discussed.

B. Fuzzy Logic (Type-1) based Clustering Protocol

Fuzzy Logic Model handles uncertainties and real time problems in a better way compared to probabilistic model. Many researchers have put the effort how Fuzzy Logic (FL) can be utilized to elect the efficient CH so that substantial life time can be achieved. Here, some of the well-known FL Type-1 based clustering algorithms have been discussed.

1) CHEF

In CHEF [4] CH is elected by using two parameters such as proximity distance and energy. This approach elects CH node with high energy and locally optimal node. Simulation result shows that the CHEF performs 22.7% better than LEACH. In [3], the author has considered three fuzzy parameters such as energy, concentration, and centrality to calculate the chance to be the CH and that can improve the network life time. But the main drawbacks with this protocol are that all the nodes are not equipped with GPS receivers and the nodes without GPS cannot provide location information. In F-MCHEL [7], CH is elected by utilizing fuzzy rules based on energy and proximity of distance. The node which is having maximum residual energy among the cluster heads is elected as a Master Cluster Head (MCH) and sends the aggregated data to the base station. F-MCHEL is an improvement of CHEF. It is more stable compared to LEACH and CHEF.. In [9-12] many protocols have been discussed based on fuzzy techniques. In [15], a protocol has been proposed by considering three fuzzy parameters such as remaining battery power, mobility, and distance to base station to elect a SCH. but the major drawbacks of this protocol is that the lifetime of the network remains constant irrespective of mobility variation.

III. ENERGY MODEL ANALYSIS

The radio model referred from [6] is shown in Figure 2. During transmission and reception, the amount of energy consumption from the transmitter to the receiver for *l* bits to a distance *d* is given in equation 2.

$$E_{TX}(l,d) = E_{TX-elec}(l) + E_{TX-amp}(l,d)$$
$$= \begin{cases} l * E_{elec} + l * \varepsilon_{fs} * d^2 \ if\ d < d_0 \\ l * E_{elec} + l * \varepsilon_{mp} * d^4 \ if\ d \geq d_0 \end{cases} \qquad (2)$$

- E_{elec} represents the energy dissipated per bit to run the transmitter or the receiver circuit. The amount of energy consumption depends on some parameters such as digital coding, modulation, filtering and spreading of the signal.
- ε_{fs} & ε_{mp} are the characteristics of the transmitter amplifier where ε_{fs} is used for free space and ε_{mp} for multipath.

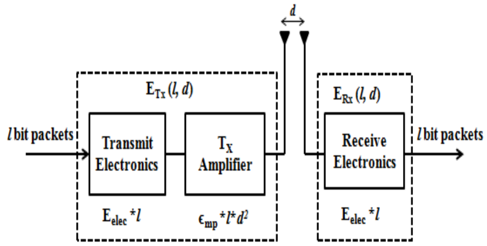


Figure 2: Radio Model

As the distance between transmitter and receiver is less than the threshold value d_0, the free space model (d^2 power loss) is used. Otherwise, the multipath fading channel model (d^4 power loss) is used. Power control can be used to invert this loss by appropriately adjusting the power amplifier. The equation 3 shows the amount of energy consumption to receive l bit of data while equation 4 represents the threshold value which is the ratio of ε_{fs} & ε_{mp}.

$$E_{Rx}(l) = Elec * l \tag{3}$$

$$d_0 = \sqrt{\varepsilon_{fs}/\varepsilon_{mp}} \tag{4}$$

IV. PROPOSED MODEL

Fuzzy Logic is used to handle uncertainties of real time applications more accurately than the probabilistic model. In [18] FL Type-1 is used to handle the uncertainty to elect SCH. But in this proposed model, Type-2 Fuzzy logic is used to elect the CH. The major benefit of using Type-2 fuzzy sets is that it can handle uncertainty and imprecision in a better way compared to Fuzzy Type-1. Further it can reduce the overheads of collecting and calculating energy and location information of each node. Most of the FL based clustering algorithms discussed in the literature is based on Type-1. So, in this paper we try to attempt to use Fuzzy Logic Type -2 where it can tackle uncertainties in a particular range.

A. System Assumption

In the proposed model, sensor nodes are considered to be deployed randomly to monitor the environment continuously.

1) All the sensor nodes are considered to be static including the base station
2) Homogeneous networks have been considered such that all the sensor nodes have initial equal energy.
3) The distance between the base station and the sensor node can be computed based on received signal strength indicator (RSSI).

B. System Model

In the proposed model, the CH is elected based on Type-2 Fuzzy Logic. Many research results are available based on Type 1 Fuzzy Logic. As of now, there is a lack of research result with Type-2 Fuzzy Logic. The difference between Type-2 and Type-1 is that Type-2 Fuzzy Logic Model is more accurate to handle the uncertainty when compared to Fuzzy Logic Type 1 model. The basic reference model for Type-2 is given in Section C. In basic LEACH [2], the cluster formation algorithm was defined to ensure that the no. of cluster per round is k, a system parameter. The optimal value of k *(k optimal)* in LEACH can be determined analytically by computation and communication energy model. For instance, if there are N nodes distributed randomly over M×M region, and k clusters are assumed, then there are N/k nodes per cluster (one CH and (N/k)-1) Non Cluster head nodes. Each CH dissipates energy by receiving the signal, aggregates it and sends the average signal to BS. The proposed model is depicted in Figure 3.

The Proposed Algorithm

/ for every round */*
1. Select CH based on *Fuzzy Logic Type-2* if-then rules from the sensor nodes
2. In each round, select $k_{optimal}$ CHs

/ for $k_{optimal}$ CHs */*
3. All CHs sends the aggregated data to BS

/ end of for */*
4. BS collects the information from CH

/ end of rounds */*

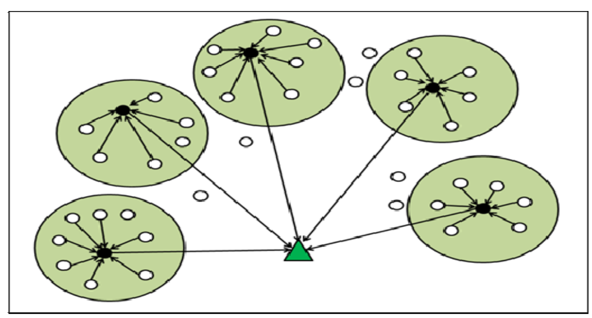


Figure 3 Proposed Model using Type-2 Fuzzy Logic Model

C. Fuzzy Logic Model

The Fuzzy logic Type-1 model consists of four modules: a fuzzifier, fuzzy inference engine, fuzzy rules and a defuzzifier. The block diagram of the Fuzzy Inference System is shown in Figure.4. There are four steps required to complete the process. It is assumed that sensor nodes send the data after detecting an interesting event. CH collects these data, aggregates it and send to the base station. Type-1 Fuzzy logic is used to handle uncertainties to some extent, because type-1 fuzzy sets are certain. Type-2 FLS when compared to Type-1 FLS, are very useful in situations where a membership function cannot be determined exactly, and measurement uncertainties like the data affected by noise are also present in the system [19].

The rules of Type-2 FLS are characterized by IF- THEN statements, where their antecedent or consequent sets are of type-2.

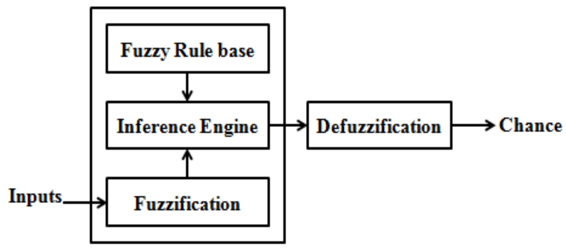


Figure 4. Block Diagram of Type-1 Fuzzy Inference system

To save some energy, the idea is to elect the CH based on Type-2 fuzzy descriptors such as Remaining Battery Power, distance to base station and Concentration. Typically, a Type-2 fuzzy set [20] is characterized by two type-1 fuzzy set membership functions, a superior and an inferior membership function. The footprint of uncertainty (FOU) is defined as the interval between these two Type-1 membership functions and is used to characterize a Type-2 fuzzy set. Similar to a Type-1 fuzzy logic system, Type-2 fuzzy logic system includes four components:

1. *Fuzzifier:* Translates inputs or crisp values to fuzzy values.
2. *Inference System:* Combines rules and gives an output of Type-2 fuzzy sets from an input.
3. *Type Defuzzifier/Reducer:* A Type-1 fuzzy set is generated by the Type reducer, which is then converted by the defuzzifier to a numeric output [21].
4. *Knowledge Base*: Contains a set of fuzzy rules, and a membership function set known as the database.

The block diagram of a Type-2 fuzzy inference system is shown in Figure 5.

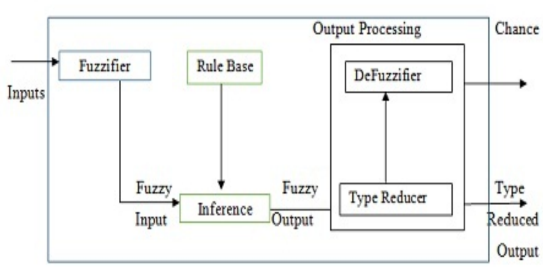


Figure 5. Block Diagram of Type-2 Fuzzy Inference system

1) Fuzzification Module: In our proposed protocol, Mamdani's Method Fuzzy Inference Technique is used to elect the CH as it is the most frequently used inference technique. The inference techniques and the fuzzy system used for our proposed model are given in Figure 6. We have considered three fuzzy input variables to elect the tentative Cluster Head.

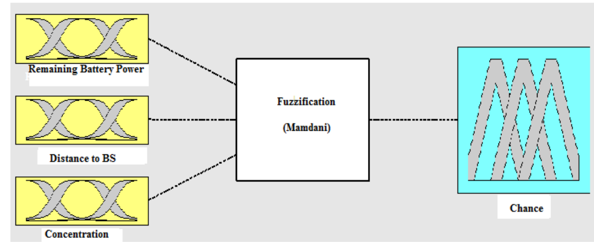


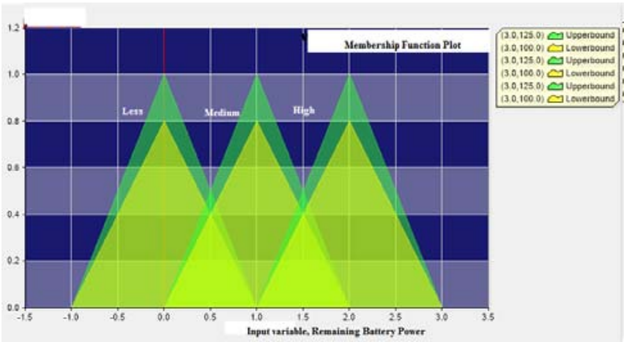
Figure 6. Fuzzy System for the proposed model

All the three input variables have three membership functions each. The fuzzy set that represents the first input variable i.e. remaining battery power is depicted in Figure 7 (a). The linguistic variables for the fuzzy set is less, medium and high. Triangular membership function which has high computation speed has been considered for less, medium and high. The second fuzzy input variable is the distance to the base station. The linguistic variables for the distance to BS are taken as close, adequate, and far. The fuzzy set for the distance to BS is depicted in Figure 7 (b). The third fuzzy input variable is the concentration that means how many nearby nodes around the leader node. The linguistic variables for concentration are considered as low, medium and high. The fuzzy set for concentration is shown in Figure 7(c). Table I shows the Membership functions of all the input variables. The degree of the membership function is shown by a numerical after each membership function.

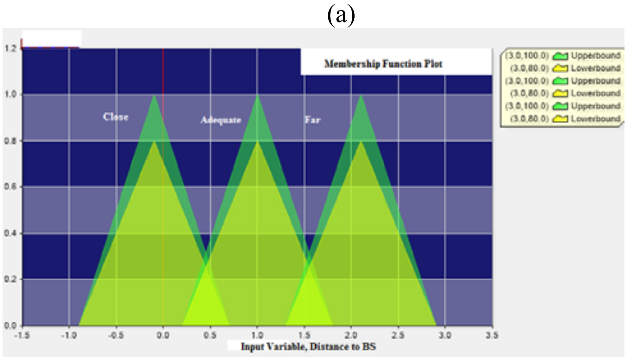
2) Rule Base and Inference Engine: In our system, we have used 27 rules in the fuzzy inference. The form of the rules is if X, Y, Z then C. X represent remaining battery power, Y represents distance to BS, Z represents the concentration, and C represents the chance. The output chance is composed of 7 membership functions Very poor, Poor, below average, average, above average, Strong, and Very Strong. The fuzzy set for chance is depicted in Figure 8. Table II shows the Membership functions for the output variable *chance.* The chance value to be the CH is calculated considering three input parameters such as remaining battery power, distance to BS and concentration by using Fuzzy rules. The fuzzy rules and value of chance is depicted in Table III.

TABLE I: MEMBERSHIP FUNCTION FOR INPUT VARIABLES

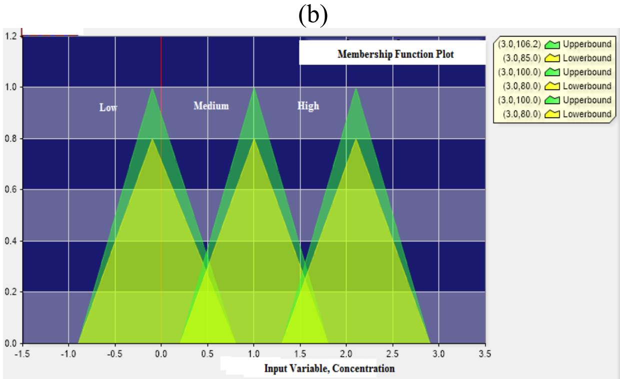
Membership Functions		
Remaining Battery Power	**Distance to BS**	**Concentration**
Less (0)	Close 0)	Low (0)
Medium (1)	Adequate (1)	medium (1)
High (2)	Far (2)	High (2)



(a)



(b)



(c)

Figure 7 Membership Function Plots (a) Remaining battery Power (b) Distance to BS (c) Concentration

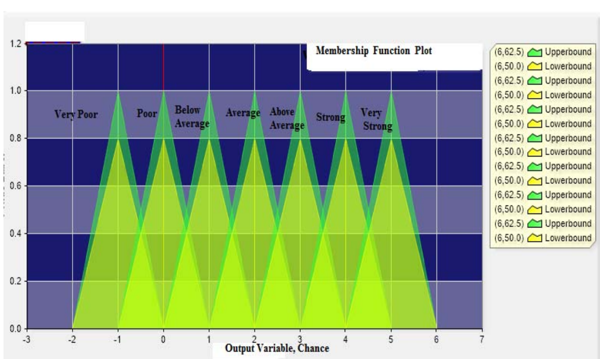


Figure 8 Fuzzy set for output variable Chance

TABLE II MEMBER SHIP FUNCTIONS FOR OUTPUT VARIABLE CHANCE

Membership Functions
Chance
Very poor (-1), Poor (0), Below Average (1), Average (2), Above average (3), strong(4), very strong(5)

The rules are derived from the formula which is given in equation (5).

$$Chance = \sum_{0}^{5} (RBP, Distance\ to\ base\ station, Concentration) \quad (5)$$

TABLE III FUZZY RULES AND VALUE OF CHANCE

Remaining Battery Power	Distance to BS	Concentration	Chance
Less (0)	Far (0)	Low (0)	Very Poor (-1)
Less (0)	Far (0)	Medium (1)	Poor (0)
Less (0)	Far (0)	High(2)	Below Average (1)
Less (0)	Adequate (1)	Low (0)	Poor (0)
Less (0)	Adequate (1)	Medium (1)	Below Average (1)
Less (0)	Adequate (1)	High (2)	Average (2)
Less (0)	Near (2)	Low (0)	Below Average (1)
Less (0)	Near (2)	Medium (1)	Average (2)
Less (0)	Near (2)	High (2)	Above average (3)
Medium (1)	Far (0)	Low (0)	Poor (0)
Medium (1)	Far (0)	Medium (1)	Below Average (1)
Medium (1)	Far (0)	High (2)	Average (2)
Medium (1)	Adequate (1)	Low (0)	Below Average (1)
Medium (1)	Adequate (1)	Medium (1)	Average (2)
Medium (1)	Adequate (1)	High (2)	Above Average (3)
Medium (1)	Near (2)	Low (0)	Average (2)
Medium (1)	Near (2)	Medium (1)	Above average
Medium (1)	Near (2)	High(2)	Strong (4)
High (2)	Far (0)	Low (0)	Below average (1)
High (2)	Far (0)	Medium (1)	Average (2)
High (2)	Far (0)	High (2)	Above Average (3)
High (2)	Adequate (1)	Low (0)	Average (2)
High (2)	Adequate (1)	Medium (1)	Above average (3)
High (2)	Adequate (1)	High (2)	Strong (4)
High (2)	Near (2)	Low (0)	Above average (3)
High (2)	Near (2)	Medium (1)	Strong (4)
High (2)	Near (2)	High (2)	Very Strong (5)

V. RESULTS AND DISCUSSION

In this proposed protocol, the Cluster Head (CH) is elected based on Type-2 Fuzzy Logic Model. There are three fuzzy descriptors such as Remaining Battery power, Distance to base station and Concentration is used to elect the CH. We have applied Mamdani's if then else rule to find the chance to be the CH. The validity of the chance to be the CH of the proposed protocol has been verified through Fuzzy Inference rules using MATLAB. As we have considered three parameters, 3^3 (27) rules. The probability of chance to be the cluster head has been derived based on the formula which has given in equation 5. We are working on the simulation results through MATLAB and NS-2.

VI. FUTURE WORK

Our future work includes analyzing the performance parameters such as First Node Dies (FND), Half Node Alive (HNA), stability, and efficiency of the network by using both NS-2 Simulator. We can compare the performance parameters of our proposed protocol with LEACH and LEACH-C protocol. The intuitive result of our proposed protocol says that it can be more energy efficient than any other protocol.

VII. CONCLUSION

The summary of the paper concludes that an energy efficient clustering algorithm has been proposed for Wireless Sensor Network using Type-2 Fuzzy Logic. The three fuzzy descriptors (remaining battery power, distance to base station, and concentration) have been chosen to elect the Cluster Head (CH) and only CHs can deliver the message to the base station. The main idea is to use Fuzzy Logic Type 2 Model to elect the CH as it handles the uncertainty more accurately than Type 1 fuzzy logic model. Many research results are available based on Type 1 Fuzzy Logic Model not with Type-2 Fuzzy Logic Model. The validity of the proposed protocol has been verified through MATLAB Fuzzy Inference System tools (Mamdani's rule). Still some of the performance parameters can be measured through NS-2 Simulator. The work is under progress.

REFERENCES

[1]. W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, Energy-efficient Communication Protocol for Wireless Microsensor Networks., in IEEE Computer Society Proceedings of the Thirty Third Hawaii International Conference on System Sciences (HICSS '00), Washington, DC: IEEE, 2000, pp. 1-10.

[2]. W. R. Heinzelman, A. Chandrakasan and H. Balakrishnan,"An application-specific protocol architecture for wireless microsensor networks," in IEEE Transactions on Wireless Communications, 1(4), pp. 660 – 670, Oct. 2002.

[3]. I. Gupta, D. Riordan and S. Sampalli, "Cluster -head Election using Fuzzy Logic for Wireless Sensor Networks", Communication Networks and Services Research Conference, pp.255-260,May 2005.

[4]. Jong-Myoung Kim, Seon-Ho Park, Young-Ju Han, TaiMyoung Chung, "CHEF: Cluster Head Election mechanism using Fuzzy logic in Wireless Sensor Networks" ICACT, PP. 654-659, Feb. 2008.

[5]. Abhijeet Alkesh, Ashutosh Kumar Singh, N.Purohit, "A moving base station strategy using fuzzy logic for life time enhancement in wireless sensor network", in proc. of International Conference on Communication Systems and Network Technologies, 2011, pp 198-202.

[6]. Hoda Taheri et.al. "An energy-aware distributed clustering protocol in wireless sensor networks using fuzzy logic", Ad hoc Networks 10 (2012), pp. 1469-1481.

[7]. Tripti Sharma, Brijesh Kumar, "F-MCHEL: Fuzzy Based Master Cluster Head Election Leach Protocol in Wireless Sensor Network", International Journal of Computer Science and Telecommunications, Volume 3, Issue 10, October 2012, pp. 8-13.

[8]. Z.W.Siew, C.F.Liau, A.Kiring, M.S. Arifianto, K.T.K. Teo, "Fuzzy Logic Based Cluster Head Election for Wireless Sensor Network", in Proc. of 3rd CUTSE International Conference, Malaysia, 2011, pp. 301-306.

[9]. Vibha Nehra, Raju Pal, Ajay K Sharma, "Fuzzy-based Leader Selection for Topology Controlled PEGASIS Protocol for Lifetime Enhancement in Wireless Sensor Network", International Journal of Computers & Technology, Volume 4, No. 3, March-April, 2013, pp.755-764.

[10]. Ge Ran, Huazhong Zhang, Shulan Gong, "Improving on LEACH Protocol of Wireless Sensor Networks Using Fuzzy Logic", Journal of Information & Computational Science 7, (3) (2010), pp. 767–775.

[11]. Hironori Ando, Leonard Barolli, Arjan Durresi, Fatos Xhafa, and Akio Koyama, "An Intelligent Fuzzy-based Cluster Head Selection System for WSNs and Its Performance Evaluation for D3N Parameter", 2010 International Conference on Broadband, Wireless Computing, Communication and Applications, 2010, pp. 648-653.

[12]. Zohre Arabi, "HERF: A Hybrid Energy Efficient Routing using a Fuzzy Method in Wireless Sensor Networks", International Conference on Intelligent and Advanced Systems (ICIAS), 2010, pp.1-6.

[13]. E.H. Mamdani, S. Assilian, "An experiment in linguistic synthesis with a fuzzy logic controller", International Journal of Man–Machine Studies 7 (1) (1975), pp. 1–13.

[14]. Kemal Akkaya, Mohamed Younis, "A survey on routing protocols for wireless sensor networks", Ad Hoc Networks 3 (2005), pp. 325–349.

[15]. Padmalaya Nayak, D. Anurag, V.V.N.A Bhargavi, " Fuzzy based method Super Cluster Head election for Wireless Sensor Network with Mobile Base Station (FM-SCHM)", in Proc. of 2nd International Conference on Advanced Computing Methodologies", GRIET, Hyderabad, 2013, pp. 422-427.

[16]. Y.Wang, F. Wu, and Y. Tseng, "Mobility Management Algorithms and Applications for Mobile Sensor Networks," Wireless Comm. Mobile Computing, Vol. 12, 2012, pp. 7-21.

[17]. M.J. Handy, M. Haase, and D. Timmermann, "Low energy adaptive clustering hierarchy with deterministic cluster-head selection," in Proc. of Int. Workshop Mobile Wireless Commun. Netw., 2002, pp. 368–372.

[18]. Padmalaya Nayak, D. Anurag " A Fuzzy Logic based clustering algorithm for WSN to extend the Network Lifetime" Accepted for Publication in IEEE SENSOR JOURNAL, DOI: 10.1109/JSEN.2015.2472970

[19]. O. Castillo, P. Melin, Soft Computing and Fractal Theory for Intelligent Manufacturing (Springer, Heidelberg, 2003)

[20]. O. Castillo, P. Melin, Type-2 Fuzzy Logic: Theory and Applications (Springer, Heidelberg,(2008)

[21]. N.N. Karnik, J.M. Mendel, An introduction to type-2 fuzzy logic systems, Technical Report, University of Southern California ,1998