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Original Article

Energy Efficient Fuzzy Clustering Algorithm in Wireless Sensor Networks

Mahboobeh Eshaghi Gorji

Department of Engineering and Research Branch, Mazandaran Branch, Islamic Azad University, Mazandaran, Iran

*Corresponding Author E-mail: mahboobeh.eshaghi@gmail.com

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ABSTRACT

Wireless sensor network consist of many sensor nodesthat deploy in area unattended, these nodes sense area's eventsand send data to sink, an important property of these nodes is energy constraint, and so considering energy efficiency in theproposed protocols in this area is unavoidable. One of the mostpractical solutions is clustering, that means, instead of sendingraw data by nodes individually, after Cluster head election,nodes form clusters and send their data to cluster head, then cluster head send processed data to sink, and this consume lessenergy. LEACH is one prominent clustering protocol in wsn thatuses probability theory without considering location and energy. In this work we propose a new clustering protocol that solvessome LEACH problems in clustering. Our proposed algorithmimproves the performance and increase the network lifetime.This work uses fuzzy logic theory in two parts in algorithm: 1)CH election and 2) cluster membership. We simulate proposedalgorithm in MATLAB, based on results we can conclude thatour proposed algorithm works better than LEACH.

Keywords: Wireless, Network, Energy efficient.

Introduction

This document is a template. An electronic copy can bedownloaded from the conference website. For questions onpaper guidelines, please contact the conference publicationscommittee as indicated on the conference website.Information about final paper submission is available from theconference website. A wireless sensor network consists of alarge number of sensor nodes. These nodes can control over avast area effectively, collect information from theirenvironment and transmit them to a central point that makesdecision. Each node is equipped with a number of sensors(such as sound sensors, temperature sensors, infra-red sensors,tremor sensors or other kinds of sensors), a small processor, aradio sender/ receiver and a power resource. The nodes of thisnetwork can be fixed on the ground, on air, in water, onhuman body and/or on vehicles. The sensor nodescontributing each other try to

gather environment informationand send them to the sink (SANTI, 2005). Sensor network can be used in military securityapplications, controlling and monitoring the traffic, industrialautomation, controlling the procedures and machinery,environmental monitoring, biological and medicalapplications, reconstruction engineering like maintaining andcontrolling bridges, structures and expressways (Thuraisingham, 2004) Sensor nodes have limited computation capability, limitedpower and small memory size. The energy is the majorconstraint in WSNs, So, in designing these networks, we mustconsider these factors. As said in recent paragraph, sensornodes must send data to sink, and by considering that thetransmission has most energy consumption in compare withother functions in WSNs, so, to achieve energy efficiency,often in these networks, we use algorithms that reduce thevolume of the transmissions. One kind of the famousalgorithms to reach this goal is clustering. In theclustering algorithms, sensor nodes divide into clusters. Ineach cluster, one node is selected as the head of the clusterand is called the cluster head. The Cluster head collects datafrom nodes in the cluster and aggregates the data and send theaggregated data to the base station. In this way, only thecluster head communicates with the base station that causesthe overall data transmission be reduced . Till now,several clustering protocols have been proposed for wirelesssensor networks ,one of them is LEACH [11] which is alocalized clustering method based on the probability model.All sensor nodes evenly elect themselves as a cluster headbased on the probability model to distribute the energyconsumption.

Recently, in a cluster head election method usingfuzzy logic is introduced to overcome the defects of LEACH.They probed that the network lifetime can be efficientlyprolonged by using three fuzzy variables (energy, localdistance). This mechanism has some demerits: 1) in CHelection, sum of the distance from cluster members to CHcandidate is used as a parameter, in election, some nodes thathave equal energy, the node by lower summation is selectedas CH, but this cause more energy consumption 2) in CHelection, the algorithm uses probability, this causes that if anode has high energy, but because of random property ofalgorithm, this node isn't selected as CH.We propose a fuzzy algorithm to maximize networklifetime by using similar parameters in [10] and differentfuzzy rules in 1) CH election and also 2) cluster membership.This will prolong the network lifetime. In the rest, in section 2the proposed algorithm is explained and in section 3, thisalgorithm is evaluated and compared with similar works inthis field. Finally, we will summarize our work and results.

PROPOSED ALGORITHM

As mentioned earlier, in LEACH, because of applying probability in CH election, it might select CHs which aren't optimal, and beside this, CHEF is oblivious about density, and this causes inter cluster domain transmissions perform in longer distances. We consider these factors and propose our fuzzy clustering algorithm. In proposed algorithm, by considering distance and energy parameters, we use fuzzy logic in CH election and also in forming clusters by focusing on energy efficiency. In this work we use energy and number of neighbours parameters to select CH candidate, and also, in cluster

membership part, we use CH's energy and distance to CH as parameter, a key difference between our algorithm and other clustering algorithms is cluster expiration, in other works, cluster head selection performs periodically, but in our work, when CH achieves some conditions, its cluster expires and only in this part, clustering perform, this reduces overhead of doing clustering and also, by doing this locally, clustering consumes less energy. In figure 1, pseudo code of our algorithm is presented**:**

```
Send_MSG_To_BS;
Cluster Head_Election();
Levelling ();
Cluster Create();
Receive_MSG_From_BS;
While (Network Life Time)
TDMA();
Data Transmission();
IF The Cluster Head Haven't Enough
Energy && there is a Cluster Member with
More Energy from Cluster Head
Cluster Expired();
New Cluster Head Election();
New Cluster Create();
New Levelling ();
End IF
END While
```

Figure 1. Pseudo code of our algorithm

At the beginning, sink selects CH candidates based onenergy and neighbours number parameter, and then removethe CHs which are in each other range, then in levelling, CHsform spanning tree to do transmission in multi hop manner. Incluster create, nodes select their CHs and form clusters.In continue, CHs setup TDMA scheduling , by applyingTDMA to cluster members, each node send data in its timeslot, this prevent collision and then to provide energyefficiency, go to sleep mode until next slot, and this causenodes consume less energy.In data transmission, cluster members send data to theirCHs and CHs after aggregation send aggregated data to sink.In if statement, if a CH's energy reaches less that a threshold,which CH cannot work more than a few rounds and also, thereis a cluster member with higher energy, this cluster expiresand cluster headselections perform.

To apply fuzzy in our algorithm, we use Mamdani system,in new cluster head election, we use energy and sum ofneighbours distance as fuzzy variables, the membershipfunction and rule base are presented in fig. 2 and table I.

Table I. Rule Base of Cluster Head Election

Energy	Local Dist	Weight1
Low	Far	Very Low
Low	Medium	Low
Low	Close	Rather Low
Medium	Far	Med Low
Medium	Medium	Med
Medium	Close	Med High
High	Far	Rather High
High	Medium	High
High	Close	Very High

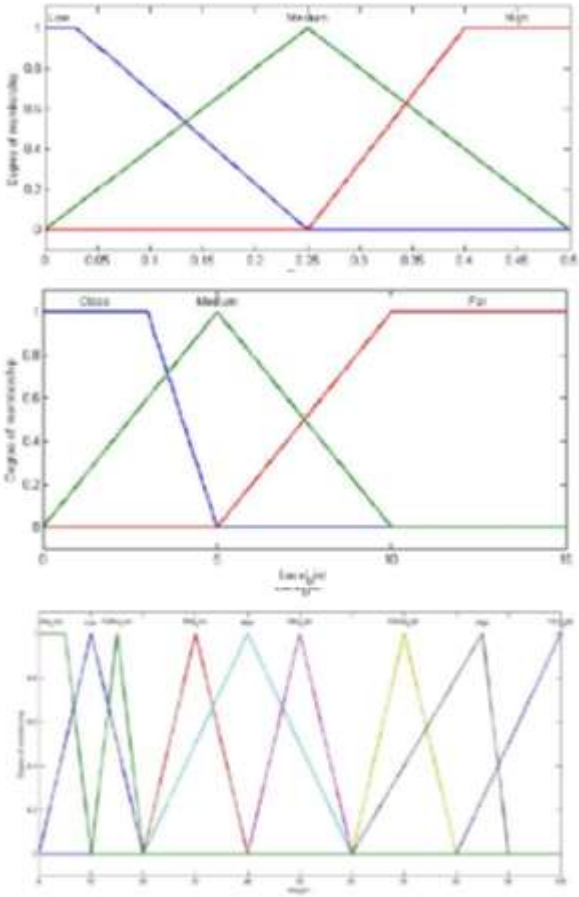

Fig. 2 Fuzzy variable of cluster head election

And in, in new cluster create, energy and distance are fuzzyvariables, the membership function and rule base arepresented in figure 3 and table II.

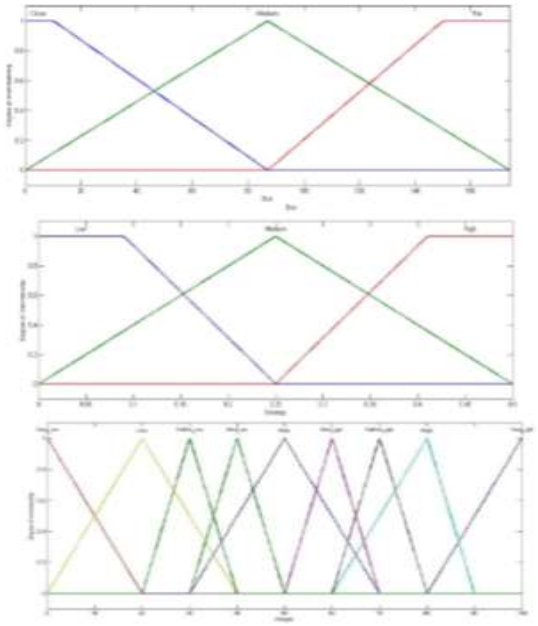

Fig. 3 Fuzzy variable of cluster create

Table II. Rule Base of Cluster Create

Dist	Energy	Weight2
Close	Low	Very Low
Close	Medium	Low
Close	High	Rather Low
Medium	Low	Med Low
Medium	Medium	Med
Medium	High	Med High
Far	Low	Rather High
Far	Medium	High
Far	High	Very High

Performance Evaluation

All In this section we present simulation results. Toevaluate the efficiency of the proposed algorithm, we simulatethe algorithm and LEACH in MATLAB. Thesimulation areais considered a 300*300 square area that 200-400 nodes aredeployed in this area randomly. The initial energy of all nodesis equal 0.5J. Thecommunication range of all nodes is set to85 meter and the range to communicateCHs is 150 meter. We use the communication model used in. Equation (1)represents the amountof energy consumption in transmitting apacket with k bits over distance d. Eelecis the amount ofenergy consumption to run the transmitter or receiver circuitry.Efsand Emp is the amount of energy dissipated in the RFamplifier according to thedistance d0 which can be obtainedfrom Equation (2).

$$E_{tx} = \begin{cases} (K*(Eelecd + Efs*d^2), if\ d \le d0 \\ K*(Eelec + Emp*d^4), if\ d > d0 \end{cases} \quad (1)$$

$$d_0 = \sqrt{\frac{Efs}{Emp}} \quad (2)$$

The amount of energy consumption in receiving a packetwith k bits can be calculated as follow:

$$E_{rx} = K * Eelec$$

The amount of energy consumption for aggregatingreceived packets from sensor nodes in cluster heads with kbits can be calculated like follow

$$E_{rx} = K * E_{DA}$$

The variable k is sum of sensors sensed data and clusterhead sensed data. EDA is the per bit energy consumption toaggregating in cluster head.In fig. 4, wecompare network life time in three algorithmswith 200-600 nodes. In this work we suppose the network lifetime is until that 37.5 percent of nodes finish their energy. Fig4 shows results of 10 simulation scenarios. In average for 400nodes, thenetwork lifetime of LEACH is 68.4 and thenetwork lifetime of none fuzzy proposed is 349.8 and fuzzyproposed is 574.7. Fuzzy proposed algorithm is moreefficient than LEACH and none fuzzy proposed. This isbecause the fuzzyalgorithm considers the energy and sumneighbors distance in cluster head election and energy anddistance in cluster create.

In figure 5, we compare number of alive nodes in threealgorithms with 300 nodes, number of alive nodes at 10simulation scenarios. In average, Number of alive nodes in thefuzzy proposed algorithm is more than none fuzzy andLEACH. Thisis because the fuzzy algorithm considers

theeffective parameter and uses the fuzzyif-then rules in decisionmaking.

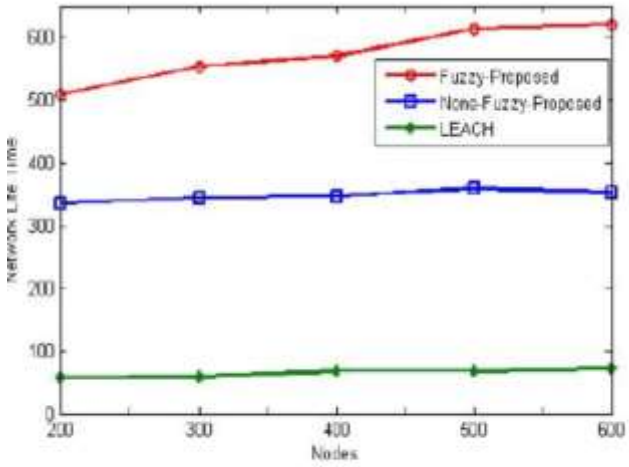

Fig. 4 Network life time

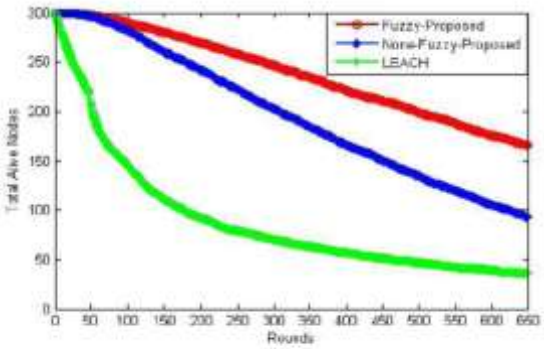

Fig. 5 Number of alive nodes

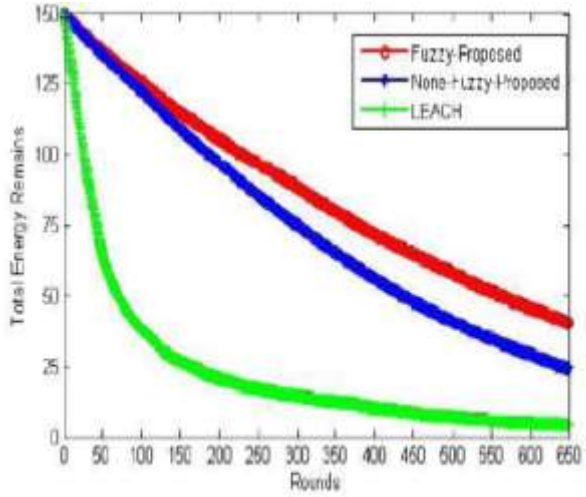

Fig. 6 Totoal energy remains

In figure 6 we compare total energy of the network with threealgorithm for 300 nodes at 10 simulation scenarios, we findthat fuzzy algorithm is more energyefficient than others.

Conclusion

In this paper we propose an energy efficient clusteringalgorithm that uses fuzzylogic, by using energy, distance andnum of neighbors as fuzzy variables to CH selection and alsoin cluster membership. As showed in simulation results, weimprove the performance and reduce energy consumption

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