Cluster Formation Based on Fuzzy Logic in Wireless Sensor Network

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Abstract—*Wireless sensor nodes are resource constrained and have limited amount of energy. Therefore, designing protocols that conserve energy is an important area of research. Researchers have investigated architectures and topologies that allow energy efficient operation of WSNs. One of the popular techniques in this regard is clustering. A typical clustering protocol contains two main steps: cluster head election and cluster formation. This thesis is aimed at investigation of the cluster formation process. We propose a Fuzzy Logic based approach that uses three descriptors namely: energy level, distance between cluster-head and base station, and distance between the cluster-head and the sensor's node. We compare our proposed model, CFFL (Cluster Formation based on fuzzy logic), with the most popular model, LEACH (Low Energy Adaptive Clustering Hierarchy), which was proposed previously to prolong network lifetime. The CFFL approach is shown to prolong network lifetime. In addition, it is shown that sensor node energy is consumed in a more uniform This protocol is based on the election of cluster head by the balance of the probabilities of the remaining energy for each node. In this paper, we propose to improve SEP by fuzzy logic. We show by simulation in MATLAB that the proposed method increases the stability period and decreases the instability of the sensor network compared with LEACH, LEACH-FL and SEP taking into account the energy level and the distance to the base station. We conclude by studying the parameters of heterogeneity as the protocol proposed (CFFL) provides a longer interval of stability for large values of additional energy brought by the more powerful nodes (advanced).*

Keywords:- wireless sensor networks, Energy-efficiency, Leach, sensor network; fuzzy logic; network lifetime

I. INTRODUCTION

Wireless Sensor Networks (WSNs) consist of many battery-powered sensor nodes that detect their physical surroundings and send them to a sink node. Since the battery resource directly affects the operation time of sensors, it is very important in prolonging the lifetime of a WSN to design energy-efficient protocols. Thus, many studies in WSNs have been focused on delivering the sensed data to the destination energy-efficiently. Routing in WSNs means that the information from sensor nodes (SNs) is forwarded to the base station (BS) regularly or on demand.

It is classified as flat and hierarchical routing. Clustering approach can be regarded as one of hierarchical routing techniques. As reported in many research works, clustering schemes have great advantage for energy saving in WSNs . The clustering associated with data aggregation improve the network performance by decreasing the amount of data to be delivered and the number of hops from sensors to the BS. In such a networks, however, more energy is consumed in the cluster head nodes because more computing and communication load is assigned to the cluster heads. This results in the non-uniformity of energy consumption among nodes, making some nodes die earlier than others.

A. Architecture of Wireless Sensor Network

Wireless sensor network consists of large number of sensor nodes. These nodes are low-cost, low-power and multifunctional and always consists of sensing, data processing and communication components. In a wireless sensor network application, these nodes are usually random deployed over the monitored area. They can measure the ambient conditions, process the measurements, and communication with other sensor nodes surrounding them to exchange their measurements and other information via radio or optic. The networked sensor nodes can improve the sensing accuracy. There are multiple sensor nodes surrounding the phenomenon when an event occurs. So the physical phenomenon is sensed by several sensor nodes. These sensing data from each node can be aggregated to get a multi-dimensional and more precision view of the event. The networked sensor nodes can also make the monitor task unattended. When the sensors nodes deployed in the monitoring area, they can form a self-organized network. So when a sensor node sensed a data, it could communication with other nodes to find a route that can send their measurements to the sink node. The sink node is a special node that is more powerful than other node in the network, and it can send the data which is from other nodes to the user. Also user can access the sink node to get the situation of the monitoring area. So the wireless sensor network can perform many unattended applications, such as the forest fire detection.

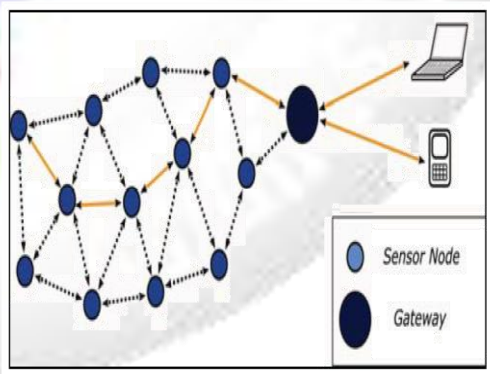

Fig. 1: Architecture of wireless sensor network

B. Energy model used

The radio hardware dissipation model assumed in LEACH is a simple radio model where the transmitter dissipate energy to run the radio electronics and the power amplifier, and th e receiver dissipates energy to run the radio electronics, as shown in fig2

Currently, there is a great deal of research in the area of low-energy radios. Different assumptions about the radio characteristics, including energy dissipation in the transmit and receive modes, will change the advantages of different protocols. In our work, we assume a simple model.

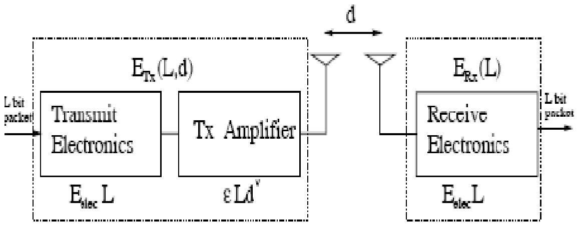

Fig. 2: radio energy model

II. EXISTING CLUSTER FORMATION PROTOCOL

The main drawback of Leach is that it uses an inadequate equation for CH election, which prevents it from providing an optimal cluster formation. Hence, each node has a different view of the network in every round and during the CH election each node computes different parameters to choose its CHs. It should be emphasized that Leach elect many CHs, but does not deal with a real situation in the network and as a result, it will have high energy cost, fast network partitioning and an inefficient load balancing.

There are other proposals that apply Fuzzy logic to help the process to elect CHs. We proposed a powerful reduction algorithm for sensor networks based on fuzzy logic and a number of neighbour nodes. It uses four input parameters for FLC (Fuzzy Logic Control) to make the CH selection, i.e. cluster- centric distance, the remaining energy, and the degree and number of the neighbour nodes. The Energy-Efficient Cluster-Head Selection proposes a solution based on fuzzy logic for CH selection. The selection of the CHs is based on the number of neighbour nodes and remaining energy, which are the input for the fuzzy system. The output is the degree of probability that each node will become a CH. The node with a higher degree of probability has a greater chance of becoming a CH.

In WSN network, a few nodes become cluster head which causes the energetic heterogeneity of the network, therefore the behavior of the sensor network becomes very unstable as soon as the life of the first node is elapsed. SEP has proposed the extension of time to network stability before the death of the first node and the reduction of unstable time before the death of the last node. This protocol is based on the election of cluster head by the balance of the probabilities of the remaining energy for each node. In this thesis , we propose to improve SEP by fuzzy logic (SEP-FL). We show by simulation in MATLAB that the proposed method increases the stability period and decreases the instability of the sensor network compared with LEACH, LEACH-FL and SEP taking into account the energy level and the distance to the base station. We conclude by studying the parameters of heterogeneity as the protocol proposed (SEP-FL) provides a longer interval of stability for large values of additional energy brought by the more powerful nodes (advanced).

From the analysis of the Litterateur Survey it is evident that uniform clustering distribution, load balancing and a fair distribution of resources are needed to increase reliability, reduce network resource usage and save energy

III. PROPOSED WORK

A. Cluster Selection

As mentioned earlier, in hierarchical architectures, the nodes are divided into clusters and a set of nodes is periodically elected as a CH. CHs are used for more complex tasks, such as: the management of each cluster, collecting data from non-CHs, data aggregation, and sending the collected data to the BS. In this context, it is important to use multiple metrics for CH election to provide an energy-efficient and load balance model. Furthermore, the cluster formation process can lead to poor energy use, if the CHs that are elected are only based on a single metric. In this context, CFFL proposes an equation, which is used by nodes to enable them to become a CH.

During the initialization of the network, BS broadcasts a startup message, which enables the node to compute the distance to BS. The distance is computed by means of Received Signal Strength Indicator (RSSI). Following this, the nodes are able to adjust the transmission power according to distance, which reduces the energy consumption since higher transmission power consumes more energy.

B. Cluster Formation

During this sub-phase, non-CHs select the best CH by considering a multiple metrics, i.e. residual energy and a distance from non-CH to CH. Then, non-CHs compute a probability value to each CH candidate using TS. The non-CH chooses the CH with a higher probability value and sends a join message to CH.

The use of fuzzy logic is appropriate, whenever it is not possible to employ a mathematical model for the system. Additionally, fuzzy can reduce the complexity of the model, computational effort and memory. In this context, TS is able to provide higher computational efficiency and better Gain-scheduling controllers than Mamdani fuzzy system, which is expected for resource constrained WSN. TS receive context information from nodes as input and converts into fuzzy linguistic variable input. The defuzzifier process produce a crip output from the fuzzy set and rules that is the output of the inference engine. TS is formed of four modules: rules, inference engine, fuzzifier and defuzzifier.

Fuzzy logic provides a rigorous algebra for dealing with inaccurate information. The linguistic input variables of the system are the remaining energy, expressed in percentages and the distance between non-CH and CH (expressed in meters), which these linguistic input have been determined based on the simulation result,. The specifications related for the input and output functions of the system and their respective Linguistic Values (LV) are as follows:

– Residual energy: u=[0,100]: LV = low, average, high;
– Distance: u=[0,100]: LV = small, average, big;
– Probability: u=(0,1]: LV = very high, high, moderately high, fairly high, average, fairly low, moderately low, low, very low. Shown in table 1

A suitable means of determining the appropriate membership functions and meaningful fuzzy operations in the context of each particular application is crucial to make the fuzzy set theory useful in practical terms . For the representation of the linguistic states (low, high, small and large) of the input variables, the degrees of membership to these sets must remain constant for certain values of the universe of discourse.

Energy level	Distance to the BS	Chance to become CH
low	Far	Very weak
low	Medium	Weak
low	Close	Little weak
medium	Far	Little medium
medium	Medium	medium
medium	Close	High medium
high	Far	Little strong
High	Medium	Strong
high	close	Very strong

Table 1.

C. *Proposed fuzzy based clustering*

1) *Initial Round*

1. BS selects CHs randomly and broadcast the CH _MSG (CH message)
2. Cluster formation and data transfer take place
3. Each node calculates the residual energy and node centrality and sends them to BS through CH
4. End

IV. General Rounds

1. fuzzy cost ← calculated by BS using node centrality and residual energy
2. BS selects CHs based on the value of fuzzy cost and broadcast the CH_MSG
3. Cluster formation and data transfer take place
4. Each node calculates the residual energy and node centrality and sends the values to BS through CH
5. End

V. Algorithm for Cluster Formation

```
  Start up
1:if BS then
2:   Broadcast startupMessage(id)
3:end if
   On receiving a startupMessage
4:µ<-rand(0,1)
5:probability<-equation2
6:ifµ<probability then
7:     Becandidate<-TRUE
8: end if
9:  if beCandidate=TRUE then
10:      Broadcast chMessage(ID,residual Energy)
11:end if
    On receiving a ch Message
12:if   !becandidate then
13       c.rssi<-estimateDistance(chMessage)
14:      c.residualEnergy<-chMessage. residual Energy
15:      c.id<-chMessage.id
16       ADD c  tocandidateCluster Head set S
17:end if
    Join A Cluster Head Candidate
18: if  !becandidate then
19:      CH=fuzzySystem(s,residualEnergy,RSSI)
20:      Broadcast joinMessage(CH[0].ID,id)
21:end if
```

A. *Cluster formation method used for heterogeneous network*

In every round, sensor node (advanced and normal) calculates the chance to become the cluster head using IF-THEN rules which are described in precedent section. After, it selects the maximum of these chances. If the maximum is less than the threshold T(s) (for advanced and for normal nodes) then the node becomes a cluster head and advertises this fact to other nodes around the cluster. the nodes that receive this message calculate the distance between the cluster head and itself and send a join–message to the closest one of the cluster head to form a cluster. Equations below define the T(s) of different type of nodes, where Padv, Pnrm, are the probabilities to become cluster head for advanced and normal nodes respectively and r is current round. The G' and G'' are the sets of advanced and normal nodes that not elected as cluster heads in last 1/Padvand 1/Pnrmrounds per epoch respectively

$$T(S_{adv}) = \begin{cases} \dfrac{P_{adv}}{1-P_{adv}\left(r \bmod \dfrac{1}{P_{adv}}\right)} & if\ S_{adv} \in G' \\ 0 & otherwise \end{cases}$$

$$T(S_{nrm}) = \begin{cases} \dfrac{P_{nrm}}{1-P_{nrm}\left(r \bmod \dfrac{1}{P_{nrm}}\right)} & if\ S_{nrm} \in G'' \\ 0 & otherwise \end{cases}$$

VI. Simulation ANALYSIS

Here, 50 nodes are placed randomly between (x=0, y=0) and (x=50, y=50). The location of BS is (50, 50). The simulation parameters are described in Table 2

PARAMETERS	VALUES
network size	$(50*50)m^2$
base station location	(50,50)m
emp	0.0013
number of nodes	50
initial energy	0.5J
data packet size	4000bits
probability to become ch	0.1

Simulation experiments were conducted to analyze the performance of CFFL Mat lab .The simulations were carried out and repeated 30 times with different number of seeds. The data analyzes use the 10 percentiles, in order to provide a confidence interval of 95%. The performance of CFFL was compared with LEACH and EECHS in terms of network lifetime, number of clusters, non-CH per clusters and PRR.

We evaluate CFFL under characteristics of rainforest areas, which have various effects on wireless communications, such as attenuation, scattering, and absorption. In this context, Tewari et al. [19] propose a propagation model that is based on an empirical model and consider the natural features of the forest region1. Thus, by using this propagation model, it is possible to evaluate CFFL in real-life conditions and improve the accuracy of the results.

In the hierarchical architecture, CHs are responsible for more complex tasks, e.g. they receive the collected data sent by non-CHS, aggregate the non-CHs packets into a single packet, and send it to the BS. At the same time, non-CHs can turn off the radio after transmitting their packets, reducing energy consumption and avoiding communication conflicts. In resuming, the routing protocols must have the best number of cluster per round, i.e. a number near to the selected probability, which defines the best number of the cluster so that it can reduce energy consumption, interference and the problem of disconnection.

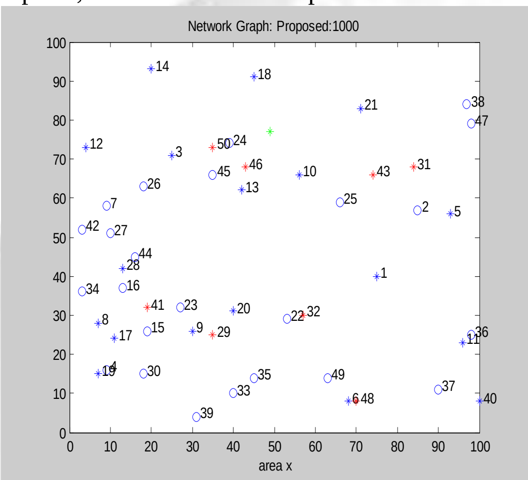

Fig 3 proposed network graph based on fuzzy logic

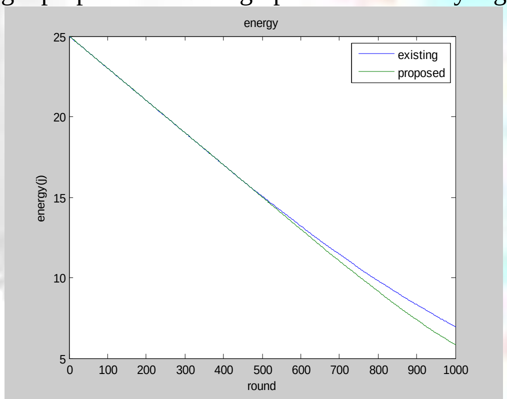

Fig. 4: Comparison of the proposed algorithm with existing based on energy

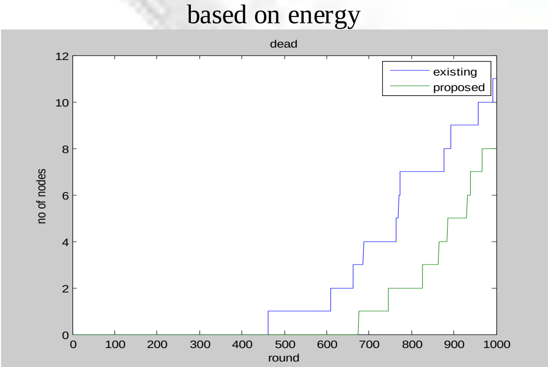

Fig. 5: comparison of first dead with existing technique(homogeneous network)

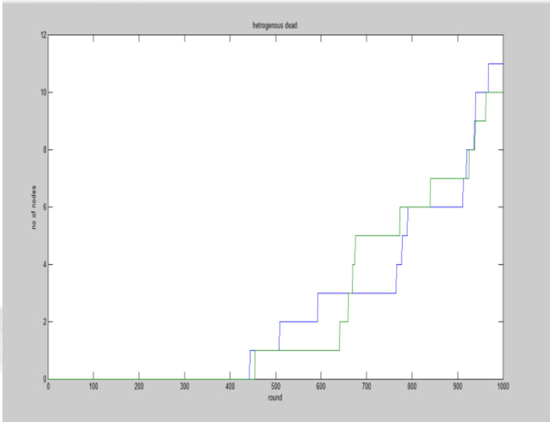

Fig. 6: comparison of first dead with existing technique (Heterogeneous network)

When the results are analyzed, it can be concluded that in general CFFL has a better number of clusters per round, i.e. a value near to 5, which is the defined probability. This is due to the fact that CFFLL proposes the residual energy as the principal variable in the CH election. In this way, it can establish the correct numbers of CH per round with regard to all the nodes that are alive.

VII. Conclusion

CFFL a Cluster-based approach for Energy-efficiency for WSNs. CFFL proposes two sub-phases for the setup phase, namely CH election and cluster formation. In the former of the CH, each node determines a new probability function to become a CH, based on its remaining energy and a stochastic equation. The cluster formation, the non-CHs select the most reliable CH based on residual energy, and the distance between them. This information is used as input to TS, which seeks to overcome any uncertainties and thus be able to estimate the correct CH. Simulations were carried out to show the impact and benefits of CFFL in terms network lifetime and FND. We found that CFFL increases the network lifetime in 18%, and FND in 14% compared to LEACH.

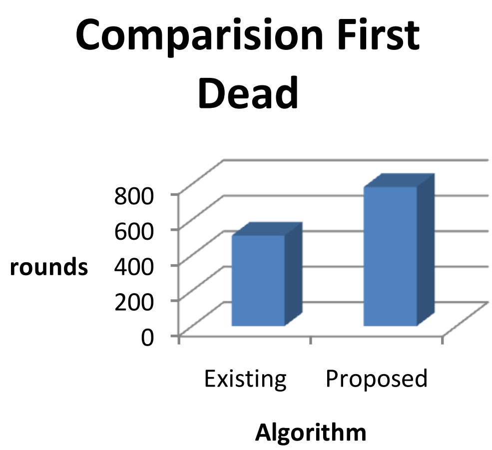

Fig. 7: comparison graph

VIII. Future Work

An energy efficient dynamic clustering protocol is proposed for WSN, which uses fuzzy logic to select the cluster heads. Here, the cluster head selection is centralized, but the data collection is distributed. Comparing to LEACH, this approach can prolong the sensor network lifetime and also can achieve the optimum number of clusters in every round. This algorithm is simple as well as it has less computational load. So, this algorithm can be efficiently used in larger WSN. For future work, the performance can also be compared with other well known protocols, such as LEACH-C (LEACH-Centralized) HEED (Hybrid Energy Efficient Distributed). Moreover, further research will be continued to expand this algorithm to meet the requirements of QoS (Quality of Service) for WSN. The sensor nodes are stationary in this proposed algorithm; so another research can be done to apply this technique to the mobile sensor node

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