Cluster Head Election and Multi Hop Using Fuzzy Logic for Wireless Sensor Network

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Abstract:*A wireless sensor network (WSN) consists of such spatially distributed autonomous sensors (a device that is generally able to perform its task without being connected to the interrogation unit) to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location.Wireless sensor networks (WSNs) are some of the fastest developing technologies and have many military and commercial applications. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network.*
In this paper cluster head election is done using fuzzy logic and then on the selected cluster head multi hop technique is adopted to send the data to the base station. The simulation done using MAT Lab clearly shows that using multi hop improves the speed and decreases the consumption of battery power as compared to LEACH OR CHEF mechanism.

Keywords *— Cluster head, Fuzzy Logic, Multi Hop, Wireless Sensor Networks.*

I. INTRODUCTION

With the advancement in Micro Electronics Mechanical System (MEMS) Technology, Chemical science which powers the battery with prolonged life and VLSI which leads to micro digital circuitry the feasibility of making the world wireless seems to be possible. Sensor networks can be used not only for detection, reconnaissance, tracking, and targeting of enemy forces, but also for monitoring and effectively managing friendly forces. In addition, commercial applications such as traffic monitoring, environmental measurements and physical parameters can be easily implemented using wireless sensor network [8].

The battery life is one of the main constraints in implementing WSN. A sensor network consists of a large number of micro sensor nodes, each with limited power, and communication and processing ability Once the network is deployed it is not feasible to replace the battery, so while designing the WSN the main feature that has to be taken into consideration is the battery consumption and the second factor is the speed with which the information has to be transferred from the nodes to the base station.

The energy consumption can be reduced by using only few of the nodes to communicate with the base station. These few nodes are called cluster head. The data is aggregated in these cluster head before transmitting to the base station [2]. Efficiency of network is dependent on election of cluster head and parameters taken to elect these cluster heads. Fuzzy logic is used to elect the cluster head with factors like residual energy, centrality and concentration which has shown improve simulation results than random election of cluster head [1].
In this paper the fuzzy logic is implemented to elect the cluster head and added to that the data is sent to the base station using multi hop method. Fuzzy logic is used as it helps in making real time evaluations. Simulations are done using Mat Lab to show the results obtained after using the approach have improved too many folds.
Cluster head election and multi hopping using fuzzy logic (CHEMF) is the approach used by the authors in this paper. We compare our approach to a previously proposed popular cluster-head selection technique called LEACH (Low Energy Adaptive Clustering Hierarchy).In Leach cluster head is elected randomly while in CHEF cluster head election using fuzzy, fuzzy logic is used for the above purpose.
In section 2 we will discuss what method we are adopting for cluster head election and how multi hopping of elected cluster head will be done. In section 3 we will discuss the tools and technologies used for improvement. In section 4 we will compare the result of the LEACH, CHEF & CHEMF & in section 5 we will conclude the paper.

II.RELATED WORK

Simple idea of a WSN can be easily understood by looking at architecture of WSN in figure 1.Nodes send data to respective cluster head and then the aggregated data is send to the base station.

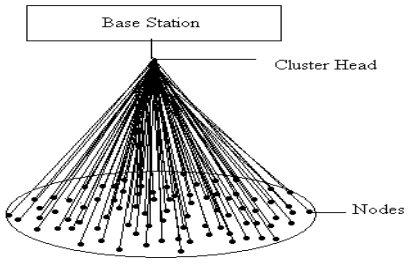

Figure 1 WSN architecture

Further what we have done is that data is not directly send to the base station but send through hop as can be seen in figure 2.

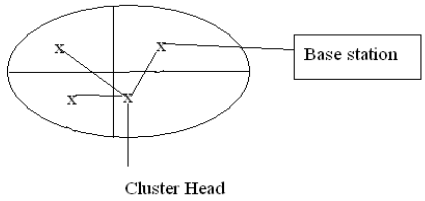

Figure 2 Multi Hop architecture

In multi hop design architecture, data is first collected at the cluster-head and then fused and forwarded to the next cluster layer toward the final destination.

In this case, the data from each sensor travels shorter distances, reducing the total latency in the network.

The assumption taken into consideration is same as in paper of CHEF [1] and in addition to that we have assumed a distance as critical. If the elected cluster head is at a distance more than critical distance than the data will be send through hop.

For selection of cluster head in LEACH [2] a minimum level of energy was decided and that energy was called threshold energy T(n).If the energy of the elected node is greater than that threshold energy than only it can be chosen as a cluster head in that round of transmission of data.

$T(n)=p/1-p*(r \bmod(1/p))$ if $n \varepsilon G$

$T(n)= 0$ otherwise 1

Where, P is the cluster-head probability, r the number of the current round and G the set of nodes that have not been cluster-heads in the last 1/P rounds.

The node that was elected as cluster head was based mere on the criteria of internal energy of that node without even taking into consideration the network. Many a time's two nodes which were in vicinity of each other were chosen as cluster head which indeed leads to more problems. second problem was that the elected cluster head were at the edges of the network for which each nod has to waste more energy for transmission of data. The value of cluster heads were not fixed they can be changed in each round. Last but not least cluster transmitting energy to the base station itself in many of the cases leads to wastage of energy and slow down the system to great extent.

LEACH-C [3] uses a centralized algorithm and provides another approach to form clusters as well as selecting the cluster-heads using the simulated annealing technique.

In [4] each node calculates its distance to the area centroid which will recommend nodes close to the area centroid and not the nodes that is central to a particular cluster, cluster centroid. Thus it leads to overall high energy consumption in the network for other nodes to transmit data through the selected node.

III.MODEL OF CHEMF

The cluster head in each round and in each segment is dependent on all three fuzzy variables taken into consideration. The hoping is done on these cluster head using minimum distance formula of transportation to transmit the data to the base station.

In our work we have tried to improve the placement constraint of the base station. The base station can be placed any where, it can even be outside the network area. The base station is taken with extra power and much more memory for long lasting network. Since we are using the sensor nodes as static or with very little mobility so it is easy to store locations of all the nodes in the base station. It becomes very easy for the base station to find the path for multi hoping at the later stage when the base station has to collect the data from cluster heads. The data in all the segments is send to the base station where the data aggregation is done. The aggregated data is even compressed before transmission of it to the base station. The cluster-head collects n number of k bit messages from n nodes that joins it and compresses it to cn k bit messages with $c \leq 1$ as the compression Coefficient. Total transmission to the base station is divided in following four steps:

Step1: Data from each node in each segment is send to the elected cluster heads.

Step2: Aggregation of data received from all the nodes in elected cluster heads and then compression of data before transmission to the base station [7].

Step3: deciding which cluster head will be transmitting directly and which will be transmitting through multi hop.

Step4: finding the shortest distance for transmission of data from cluster heads to the base station.

The radio model we have used is similar to [1a] with E (election) = 50 nJ/bit as the energy dissipated by the radio to run the transmitter or receiver circuitry and *amp* E(diss) = 100 pJ/bit/m2 as the energy dissipation of the transmission amplifier.

The energy expended during transmission and reception for a k bit message to a distance d between transmitter and receiver node is given by:

$$E(Trans)(k,d) = E(election)* k + ampE(diss)*k*d^{\lambda} \quad (2)$$

$$E (Receive) (k) = Eelec * k \quad (3)$$

Where, λ is the path loss exponent and $\lambda \geq 2$.

A. Fuzzy selection scheme: Mamdani method [9] of fuzzy logic is used for election of cluster head in our technique. The implementation of cluster head is based on following steps as used in paper of CHEF [1]

• Fuzzification of the input variables energy, concentration and centrality - taking the crisp inputs from each of these

and determining the degree to which these inputs belong to each of the appropriate fuzzy sets.

• Rule evaluation - taking the fuzzified inputs, and applying them to the antecedents of the fuzzy rules. It is then applied to the consequent membership function (Table 1).

• Aggregation of the rule outputs - the process of unification of the outputs of all rules.

• Defuzzification - the input for the defuzzification process is the aggregate output fuzzy set chance and the output is a single crisp number.

We will be using centre of gravity method for finding the membership function as used by CHEF [1]. The aggregated points are fuzzified using centre of gravity function. The membership function is calculated using the formula as used by CHEF [1].

COG = $(\sum \mu_A(x)*x)/ \sum \mu_A(x)$

Where, **$\mu_A(x)$** is the membership function of set A.

B. Multi hop model: After the cluster head are elected the data has to be sent to the base station. The data can be either send directly to the base station as in LEACH [2] /CHEF [1] or by multi hop approach designed by us in this paper. In this we have decided a minimum distance called as critical distance denoted by D_C. If the distance of elected cluster head is less than D_C than the cluster head communicates directly with the base station else it has to adopt multi hop D_C is dependent on the dimension of the system as well as power available to the base station and sensor nodes initially [10].

D_C=0.15 units if we take dimension of the network as 1*1 unit^2. As cluster head in each round changes so minimum distance calculation also changes in each round. Transportation method is used to find the appropriate path. The algorithm is stored in the base station and it's the duty of the base station to find the path which has minimum distance [10].

C. Methodology adopted: While electing cluster heads we have applied Fuzzy taking into following variable under consideration.

Residual energy: as the energy available with each node at the starting of the round and the energy left at the end of the round.

Node density: as the number of nodes in close vicinity of each node.

Node centrality: as the sum of distance of the nodes from all the nodes.

Path chosen: as the path decided by the base station to receive the data from the cluster heads.

Method of Calculation of each parameter is such that it is not dependent on the base station as in case of CHEF [1]. In CHEF all three parameters responsible for election of cluster head was dependent on base station which leads to restriction of placing the base station in the centre of the network. In our work this has been totally removed.

Residual energy can be very easily calculated by storing previous energy and then reducing the energy consumed in transmission.

Node density is calculated by knowing the coordinates of each node as they are considered to be static.

Node centrality is calculated by adding the distance of each node from all other nodes and then the node with minimum distance has the maximum centrality.

The linguistic variables used to represent the residual energy and node density, are divided into three levels: low, medium and high, respectively, and there are three levels to represent the node centrality: near, average and far, respectively. The outcome to represent the node cluster-head election chance was divided into seven levels: very low, low, lightly low, medium, lightly high, high, and highly high.

The fuzzy rule base currently includes rules like the following:

if the residual energy is high and the node density is high and the centrality is near then the node's cluster-head election chance is highly high. Thus we used 3^3 = 27 rules for the fuzzy rule base.

We used triangle membership functions to represent the fuzzy sets medium and average trapezoid membership functions to represent low, high, near and far fuzzy sets. The membership functions developed and their corresponding linguistic states are represented in Table1 and Figures 3 through 6.

Sr. no	Residual Energy	Node Conc.	Node Centrality	chances
1	Low	Low	Near	low
2.	Low	Low	Average	Low
3.	Low	Low	Far	Very low
4.	Low	Medium	Near	Lightly low
5.	Low	Medium	Average	Low
6.	Low	Medium	Far	Very low
7.	Low	High	Near	Medium
8.	Low	High	Average	Low
9.	Low	High	Far	Very low
10	Medium	Low	Near	Medium
11	Medium	Low	Average	Low
12	Medium	Low	Far	Very low
13	Medium	Medium	Near	High
14	Medium	Medium	Average	Lightly high
15	Medium	Medium	Far	Low
16	Medium	High	Near	High
17	Medium	High	Average	Lightly high
18	Medium	High	Far	Low
19	High	Low	Near	Lightly high
20	High	Low	Average	Low
21	High	Low	Far	Very low
22	High	Medium	Near	Lightly High
23	High	Medium	Average	High
24	High	Medium	Far	Lightly high
25	High	High	Near	Highly high

26	High	High	Average	High
27	High	High	Far	low

Table 1 fuzzy rule

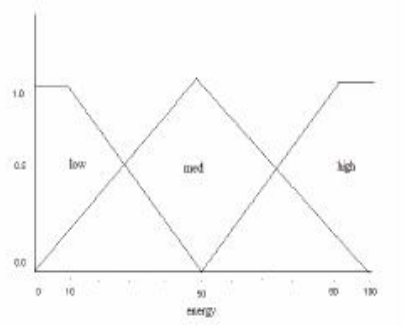

Figure 3 fuzzy residual energy set

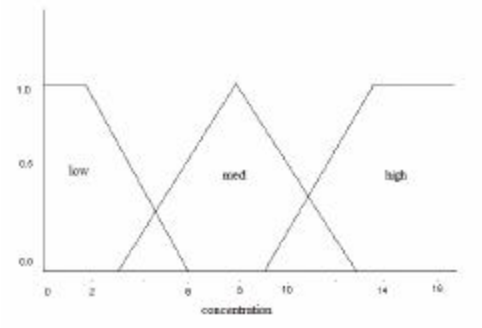

Figure 4 fuzzy node density set

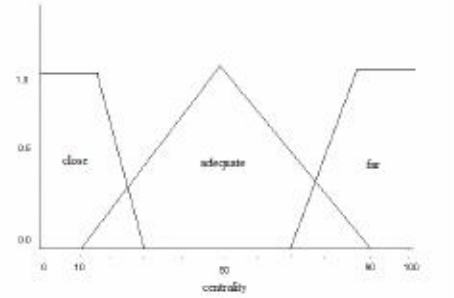

Figure 5 fuzzy node centrality

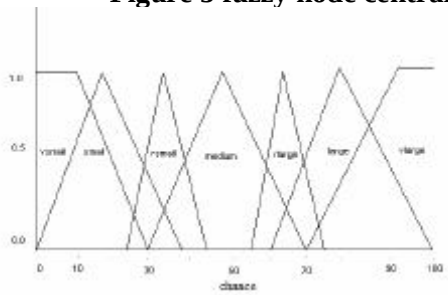

Figure 6 fuzzy chance set

Nodes with highly high chances of election after defuzzification are selected as cluster head in each segment. In case of tie that node will be chosen as cluster head which can reduce the distance of transmission to the base station. This is the work which base station will be doing while choosing the desired path. The data transmission method is same as in LEACH but it is through multi hop.

IV. SIMULATION RESULTS AND COMPARISONS

We have used MAT Lab to code the algorithm and found that the new approach has worked. The results in the following tables clearly show the difference in energy consumption and the number of nodes dead after a fixed number of iterations.

Technique used	After 10,000 iterations		After 30,000 iteration		After 50,000 iterations	
Parameters	% of Energy consumed at base station	Total number of nodes dead	% of Energy consumed at base station	Total number of nodes Dead	% of Energy consumed at base station	Total number of nodes dead
LEACH	25%	29	34 %	40	40%	47
CHEMF	19%	10	22 %	14	26%	17
CHEF	20%	16	28 %	22	33%	26

Table 2 Difference of three techniques

Above table clearly shows the difference in the three techniques. The results are obtained with fuzzy logic tool box in mat lab probably in real life we will have slight difference to the above.

V.CONCLUSION

We have discussed truly a new approach of using multi hoping and election of cluster head using fuzzy logic in WSNs. Our approach is most suitable whether the cluster head is in the network or outside the sensor network. The approach is suitable for all network small, medium and large.

We have tried to work on the reduction of energy and increasing speed of the system but system is reliable if and only if it is fault tolerant which is left as future work.

VI. REFERENCES

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