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A Fuzzy Based Approach of Energy Efficient Hierarchical Clustering Method in Wireless Sensor Networks

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Abstract: ***Hierarchical Clustering is a procedure of cluster analysis which aims to construct a hierarchy of clusters. There are two kinds of hierarchical clustering i.e. Agglomerative, which is a bottom – up approach, where all the observations start in its own cluster, and pairs of clusters are merged moving up the hierarchy, and the other one is divisive, which is a top - down approach, where each observation starts in one cluster, and splits up recursively while moving down the hierarchy. The main problem is Shortage of Network Lifetime, Presence of less Residual Energy, Cost of building the clusters and the issue of Dead Nodes, which occur very frequently. In the earlier work, only three parameters were considered i.e. Proximity, Node density and Battery level to Base station for the Effective utilization of the Cluster by Fuzzy inference Engine. They optimized the clustering process, Cluster Head Election and decreased the number of dead nodes. A lot of work has been done in Fuzzy based System Simulation for Cluster - Head Selection in Wireless Sensor Networks and Fuzzy System Based Cluster Selection (FSCS) Technique has been proposed by taking two Fuzzy logic controllers, and by using parameters i.e. DCC, Remaining Battery Power, Feedback sensor speed, Degree of Neighbor Nodes, Sensor speed, and Probability of Cluster Head Selection for the Effective utilization of the Cluster and decreased the Probability of the nodes, Controlled RPS, and increased the Controlled Feedback Speed. The objective is to cluster the nodes in a hierarchical way, by taking as many parameters as we can in order to decrease the number of dead nodes, save of cost of creating new clusters, increase the necessary residual energy, and enhance the network lifetime. The methodology applied is to select a cluster among the network randomly and calculate their weight functions. Cluster head Election is done on the basis of weight functions and weight function of the next hop is calculated. Among all the nodes, the optimized Next hop is calculated and Hierarchical Routing is performed using Fuzzy Inference Engine. The threshold time is computed for the cluster head, if it is achieved then again the cluster head election will take place in the same cluster. By applying this method, the residual energy and network lifetime can be increased, whereas the cost of creating the clusters and number of dead nodes can be decreased.***

Keywords: Hierarchical Clustering; Residual Energy; Network Lifetime, Battery level, Fuzzy Inference Engine, Cluster Head Election, Next hop

1. Introduction

Wireless Sensor Network is a recently emerging technology which consists of a large number of distributed sensor devices those are used to collect data from the environment. The sensor devices have less power in terms of both energy and processing and also have low storing memory capacity. WSN is a spatially distributed sensors to check the physical conditions such as temperature, pressure, sound etc. The Networks are usually Bi-directional order which enables the sensor activity. [Akyildiz F. and Kasimoglu I.H.2004] .WSNs have broad application foreground in industrial control, military, environmental monitoring and other fields. These devices are to collect information from physical environment like in volcanic eruptions, tsunami and earthquake monitoring, and similar disaster management uses, wildlife habitat monitoring, in battle field for tactical response team, weather monitoring, structural integrity monitoring, entertainment, logistics, transportation etc.

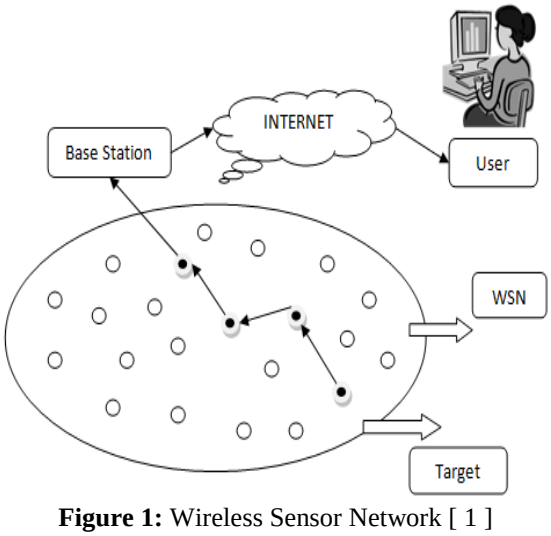

Figure 1: Wireless Sensor Network [1]

The WSN is built by nodes in which these nodes are connected by one another. Each node has some several parts - radio transceiver with an internal antenna or connection to an external antenna microcontroller, electronic circuit and an energy source, i.e. a battery. Sensor Nodes might vary in size due to dust particles, even though the working nodes of small dimensions are to be created. The cost of sensor nodes is variable, which ranges around hundreds of dollars, depending on the complexity of the nodes. Size and cost constraints on the nodes result in the corresponding

limitations on resources such as energy, memory, calculative speed and communications bandwidth. The topology of the WSN varies from a star network to advanced multi-hop wireless mesh network. The propagation technique between all the hops of the network are usually routing or flooding.

Recently, there are lot of research efforts towards the optimization of standard communication paradigms for those networks. Initially, these nodes had very less computation capacity and storage space and their only use was to transfer scalar data to the base station (sink). However, recently available sensor nodes have higher computation capability, higher storage space and better power solutions with respect to their predecessors and their primary usage area shifts from passive-indoor to active-outdoor applications [Singh R., Gupta I. and Daniel A.K. 2014].

The use of wireless sensor networks is substantiating day by day and at the same time it faces the problem of energy constraints in terms of limited battery lifetime. As each node depends on energy for its actions, this has become a major concern in wireless sensor networks. The collapse of one node can interrupt the entire process. Every sensing node can be in active (for receiving and transmission actions), idle mode and sleep modes. In active mode nodes consume energy when receiving or dispatching data. In idle mode, the nodes engross almost the same amount of energy as in active mode, while in resting mode, the nodes shutdown the radio to save the energy.

Clustering routing protocol is a hot issue of research because of the convenient topology management and high energy utilization. The earlier stages of research involved large demerit in the capacity of node, also time needed for network processing is also high on wireless distributed systems. LEACH is one of the classic clustering routing algorithms in WSNs. The selection of CH is based on random number, and the clustering probability is defined as a certain value. In cluster based WSN, the whole network is divided into individual clusters [Balasubramaniyan R. 2013]. Each node communicates with its CH that transmits the aggregated data along multiple paths to others CHs serving as gateways for data transmission until the Base Station (BS). That is called a multi hop hierarchical communication.

Many current WSN solutions are developed with simplifying assumptions about wireless communication and the environment, although the realities of wireless communication and environmental sensing are recognizable. Many of these solutions work very well in simulation. It is either unknown how the solutions work in the real world or they can be shown to work poorly in practice. We note that, in general, there is an excellent understanding of both the theoretical and practical issues related to wireless communication. For example, it is familiar how the signal strength drops afar. Effects of signal reflection, scattering and fading are understood. However, when building a true WSN, many specific device, application, and cost issues also affect the communication properties of the system. Radio communication in the form of AM or FM broadcast from towers performs quite differently than short range, low power wireless found in self-organizing WSNs.

2. Problem Identification

The Problem which has been identified in earlier work is Network Lifetime, Residual Energy , Cost Saving and the issue of Dead Nodes. Main aim of the work is to increase the Network Lifetime, residual energy, save the cost of constructing new clusters, and to decrease the number of dead nodes.

Clustering in Wireless sensor Networks is surely one of the most compelling challenge. LEACH is a popular routing protocol for Wireless Sensor Networks (WSN). The LEACH algorithm is divided into rounds. Each round contains a set-up stage, where every sensor node chooses a random number between 0 and 1 to decide whether it will become a cluster-head or not. It assumes that all nodes can transmit with enough power to reach the BS. The nodes always have data to transmit and all nodes start with the same level of energy and CHs drain approximately the same level of energy from each cluster member node. This approach is energy consuming.

Among all the nodes of the Cluster, there is a node which is chosen as a means of transmitting data to and fro between the clusters, which is known as Cluster – Head. This Process of Cluster head Election is carried out by calculating the residual energy of the nodes in the given cluster and the cluster having highest residual energy is chosen as Cluster Head. The main problem was only the clusters with high residual energy were considered for the Cluster head Election, due to which the energy of the remaining nodes were not taken into count.

In the Earlier works, the Cluster Head Election was done using only three parameters i.e. Residual Energy, Node Density, and Proximity of the Base station, but the proposed method includes three extra parameters i.e.

- Density of Present Cluster head
- Distance between Base station and Sink
- Distance between Present Cluster Head and Next hop

There are many fundamental problems that WSNs researches have to address in order to ensure a reasonable degree of cost and system quality. These problems include sensor node clustering, Cluster Head (CH) selection and energy dissipation. There are many research works that deal with these challenges. The cluster based algorithms could be used for partitioning the sensor nodes into subgroups for task subdivision or energy management. Cluster formation is one of the most important problems in WSN applications and can drastically affect the network's communication energy dissipation. Clustering is performed by assigning each sensor node to a specific CH. All communication to (from) each sensor node is carried out through its corresponding CH node. Obviously one would like to have each sensor to communicate with the closest CH node to conserve its energy; however CH nodes can usually handle a specific number of communication channels. Thus, there are maximum sensors that each CH node can handle. This does not allow the sensor to communicate to its nearest CH node, because the CH node might have already reached its service capacity. CHs can fuse data from sensors to minimize the

amount of data to be sent to the sink. When network size increases, clusters can also be organized hierarchically.

3. Related Work

Mani M. and Sharma A.K. (2014) has worked on the Modified approach for Routing and Clustering in Sensor Network using Fuzzy Logic Control and proposed the Fuzzy Logic Control Based Stable Election Protocol (FLC – SEPE) and took three parameters i.e. Battery level, Node density and Proximity to Base station for the Effective utilization of the Cluster by Fuzzy inference Engine. They optimized the clustering process, Cluster Head Election and decreased the number of dead nodes.

Barolli L. et all (2012)has worked on the Fuzzy based System Simulation for Cluster- Head Selection and sensor speed Control in Wireless Sensor Networks and proposed Fuzzy System Based Cluster Selection (FSCS) Technique and by taking two Fuzzy logic controllers, and by using parameters i.e. Remaining Battery Power, DCC, Degree of Neighbour Nodes, Feedback sensor speed, Sensor speed, and Probability of Cluster Head Selection for the Effective utilization of the Cluster and decreased the Probability of the nodes, Controlled RPS, and increased the Controlled Feedback Speed.

Sert S.A. et all (2014) has worked on the Efficient Fuzzy Fusion based Framework for surveillance applications in Wireless sensor Networks and proposed Hierarchical Fusion, and Clock Synchronisation and targeted applications based on efficient framework in a hierarchical and corroborative way. They were successful in reducing the energy consumption and increased the accuracy of the framework.

Singh R., Gupta I., and Daniel A.K (2014) has worked on the position based Energy – Efficient Clustering protocol under Noisy Environment for Sensor Networks using Fuzzy logic Technique and proposed Cluster Formation using Binary tree concept in which they considered three parameters i.e. Noise Factor, Distance and Residual Energy as Input Functions and simulated the results using Matlab in which they increased the packet delivery ratio , decreased the link failure , lowered the error rate and increased the throughput performance.

Ke L., Bing F. and Yi S. (2012) has worked on the uneven clustering algorithm based on fuzzy theory for wireless sensor networks and proposed the Fuzzy theory Uneven Clustering Algorithm (FTCA), and considered the node location and Residual Energy during CH election, divided the network into uneven clusters, and simulated using MATLAB. They came with the result that Fuzzy theory Uneven Clustering Algorithm (FTCA) overcomes the limitation of single evaluation indicator, reduced the energy consumption, prolonged the network lifetime.

Vijaya C.S. and Alagarsamy K. (2014) has worked on the Analytical Survey on Ant and Fuzzy Clustering Based data Aggregation Techniques in Wireless sensor Networks and did the Parametric Evaluation on Fuzzy Clustering on the Basis of Network Lifetime, Packet Delivery ratio Latency, and Energy Consumption . They surveyed that Energy Consumed and the Computational Cost has been reduced, Scalability has been increased, and Node Breakdown is decreased upto a large extent.

Balasubramaniyan R. and Chandrasekharan M. (2013) has worked on A New Fuzzy Based Clustering Algorithm for Wireless Mobile Ad Hoc Sensor Networks and proposed the Fuzzy Relevance Based Cluster Head Selection Algorithm by taking the parameters as Network Size, Number of nodes, Speed, Pause Time, Packet Size, Transmission Range, Simulation Time, and Hello Packet Interval into consideration and simulated using NS-2 Simulator. They successfully reduced the overhead due to the flat structure by easy resources of management, bandwidth allocation, more efficient than previously run protocol.

Amri S. Kaddachi M.L. and Trad A.B.(2003) worked on the energy- efficient multi-top Hierarchical Routing protocol using Fuzzy Logic (EMHR-FL) for wireless sensor networks by taking four parameters, Residual – Energy of cluster head, distance between cluster head and base station, the distance between the two cluster heads and density of cluster head. They calculated the cost in the output by using Mandani Inference engine. They tried to minimize the network lifetime, increase the residual energy and compared the result with Leach Protocols.

Bansal K. and Sharma B. K. (2014) worked on the Energy Efficient Heterogeneous clustering Protocol for wireless sensor networks using fuzzy logic with different base station locations. They took two parameters i.e. Predicted Residual Energy (PRE) and Distance to Base station (DBS) and simulated using Mandani Inference Engine by using FEEHCP Protocol. They took 100 sensor nodes within the dimension of network 100 x 100 m. It improved the stability period more than 100% and decreased the early node death problem.

Gajar S. Sarkar M. and Dasgupta K. have worked on the Cluster Head selection protocol using Fuzzy logic for Wireless sensor networks. They took three parameters i.e. Residual Energy, Distance between neighbour nodes and distance of node from base station and simulated using Fuzzy inference system which resulted in decrease of energy wastage, increase of reliability, decrease of energy consumption and increase of network lifetime.

Romoozi M., Ebrahim Pour-Komleh H. has worked on the positioning method in wireless sensor networks using genetic algorithms and considered two parameters i.e. the number of nodes and initial energy. They compared the algorithm with each protocol and got the result as increase in network lifetime, decrease in communication energy and proper positioning of the nodes in the closest possible distance. The algorithm used is K-means.

Gupta I., Riordan D., Srinivas S. worked on the cluster head election using Fuzzy logic for wireless sensor networks. They considered four input variables as energy, concentration, centrality and chance and simulated with the help of Fuzzy inference system. They were very successful

in increasing the network lifetime and election of cluster head in a better way when compared to each protocol.

Godbole V. has worked on the performance analysis of clustering protocol using Fuzzy Logic for wireless sensor networks. He took into consideration three parameters i.e. Distance between cluster head and base mode, residual energy and competition radius and simulated with the help of Fuzzy inference system. He proposed FCA i.e. Fuzzy Clustering Algorithm and was successful in making the algorithm better than that of each protocol. As a result he found that FCA was a stable and energy saving clustering algorithm.

Abedini S. M., Karimi A. worked on the increasing of life time of heterogeneous sensor network by using genetic Fuzzy clustering. They used three parameters i.e. Energy of node, Node density and Node Centrality and simulated the result using NS2 simulator. They proposed genetic algorithm which was successful in increasing the network lifetime and increasing of number of messages received to the base station. It was proved better than leach, GFS and EEC algorithms as it elongated the death time of the network.

4. Methodology

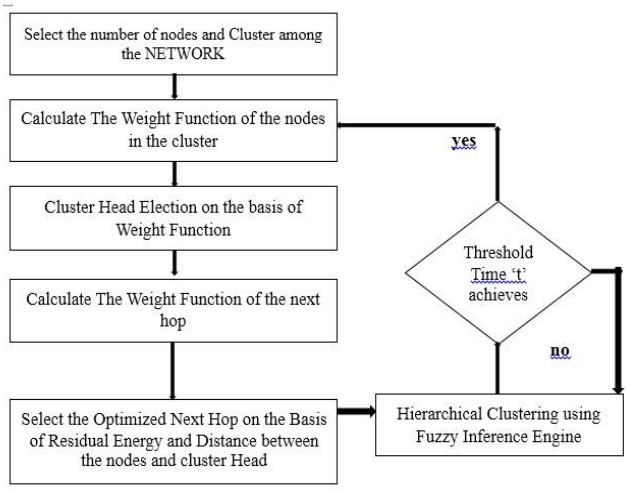

Fig. 4.1. Flowchart of the Proposed Methodology

Step 1:- Selection of Cluster:-

- Select the number of nodes, which will be known as Cluster Members and number of clusters , , in the field of 1000 X 1000 matrix.
- The Selection of the Cluster is just a Random process, as the nodes can be anywhere inside the cluster field.
- The x and y co-ordinate of the nodes of the node will be decided randomly in the matrix of 1000 x 1000.

Step 2:- Calculation of Weight Functions of Nodes in the cluster**:-**

- The Weight Function can be calculated as follows-
- **i** is the sensor , **CHi** is the cluster-head i and **CHj** is the clusterhead j
- SB is the base station;
- **j** is the jth neighbor of sensor i;
- The distance between node CH**i** and adjacent CH**j** is **d(i,j)** and the distance between CH**j** and Sink node is **d(j,S).**

The weighting function is constructed as described in equation as given below :-

```
di = (p2(1) - p1(1))^2 + (p2(2) - p1(2))^2;
dis = sqrt(di);
```

- We are taking the Following parameters in Consideration while calculating the Weight Function :-

1. Residual Energy of Cluster Transmitter **S[i]**
2. Distance Between CH Transmitter and its Adjacent Next Hop **[d(i,j)]**
3. Signal Strength

Step 3:- Cluster Head Election on the basis of Weight Function and Residual Energy

- The Node Having a maximum weight function Value will be the Cluster Head **(CH).**
- Calculate the distance between the Cluster Heads and the nodes as well as the available energy among the clusters.
- Initialise the value of Energy as 1 KJ or 1000 J.
- The Cluster Head will Act as Gateway between Base Station (BS) and Sink.
- It will be responsible for the co-ordination of the data among the nodes and route the data by calculating the Next hop from the another Cluster
- Cluster Head transfers the data to that CH, where the possibility of optimizing the Clustering is Maximum.

Step 4:- Calculate the Weight Function of the Next Hop and Energy Initialisation.

- The Weight Function of the Next Hop can can be calculated by considering all the Parameters from the Present Cluster Head , i.e.

1. Residual Energy of Cluster Transmitter **S[i]**
2. Distance Between CH Transmitter and its Adjacent Next Hop **[d(i,j)]**
3. Density of Next Hop **D(n)**

Step 5:- Selection of the Optimized Next Hop**.**

- The Next hop having the maximum Weight Function of the Next Hop will be considered as the Optimized Next Hop, Again the Cluster

Step 6:- Hierarchical Clustering Using Fuzzy Inference Engine

- The Next hop having the maximum Weight Function and Residual Energy of the Next Hop will be considered as the Optimized Next Hop, Again the Cluster will perform the Cluster Head Election process.

Fuzzy Inference System

A Fuzzy system normally consists of four parts:

- Fuzzification module transforms the system inputs, known as crisp numbers, into fuzzy sets. This is done by applying fuzzification function.
- Knowledge base: It stores IF-THEN rules.
- Inference engine: It replicates the human reasoning process through fuzzy logic on the inputs and IF-THEN rules.
- Defuzzification module: It metamorphoses the fuzzy set obtained by the inference engine into a crisp value.

5. Results and Discussions

No of Nodes	No. of Clusters	Readings of Energy Consumed by Base Paper Method	Readings of Energy Consumed by Proposed Method
10	2	778	773
		775	770
		780	788
		760	753
		765	763
15	3	777	769
		773	762
		781	784
		753	750
		760	758
20	4	780	775
		775	774
		774	771
		768	765
		754	751
25	5	776	765
		784	789
		778	771
		765	774
		750	744
30	6	772	771
		776	766
		782	796
		781	754
		788	767

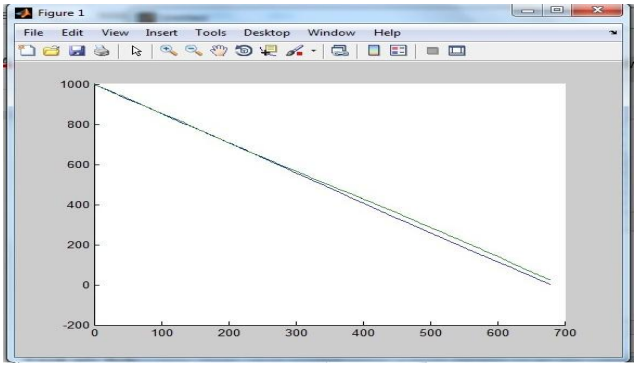

Figure: Energy Consumed in the Previous works

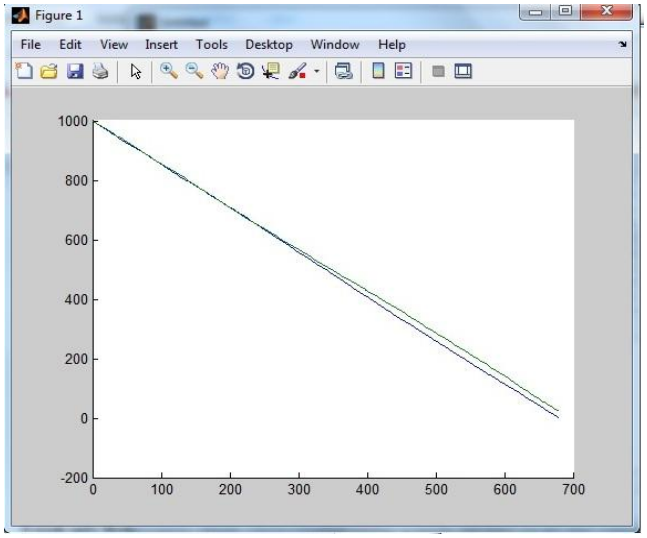

Figure: Energy Consumed in the Proposed Method

6. Conclusion and Future Work

The New Clustering Algorithm will receive and transmit data with much more efficiency than the conventional method of Hierarchical Clustering protocol. The Multiple Readings taken above prove that the Proposed Algorithm has more network lifetime than previous works. Since the Network Lifetime is Increased , hence the Residual Energy of the Cluster Head will be more than the previous works.

The Work is carried out with MATLAB as a Simulation tool, may be there are some possibilities of increasing of accuracy rate if it is carried out by NS – 2 Simulator.As a future work, we think that this solution can be enhanced with the study of other parameters i.e. the cost of link from CH to his adjacent and the buffer capacity at node. With this approach, it seems possible to avoid considerable energy loss and lengthy time processing. The Real Time Simulation system is expected to give better results in further Research.

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